South Australian evaluation of environmental outcomes under the Basin Plan | 2020

South Australian River Murray Water Resource Plan Area

SOUTH AUSTRALIA

Government of South Australia

Department for Environment and Water

Acknowledgement of partners

Many individuals and staff from South Australian government agencies, universities, and organisations including the Murray–Darling Basin Authority, South Australian Research and Development Institute, and the University of Adelaide, contributed data, information, reports, expert input, and reviews at all stages of this evaluation. This evaluation report is the product of a collaborative effort and the authors thank all contributors.

This work has relied on a number of monitoring programs for data and information, including The Living Murray, the Long-term Intervention Monitoring Program and The Riverine Recovery Program.

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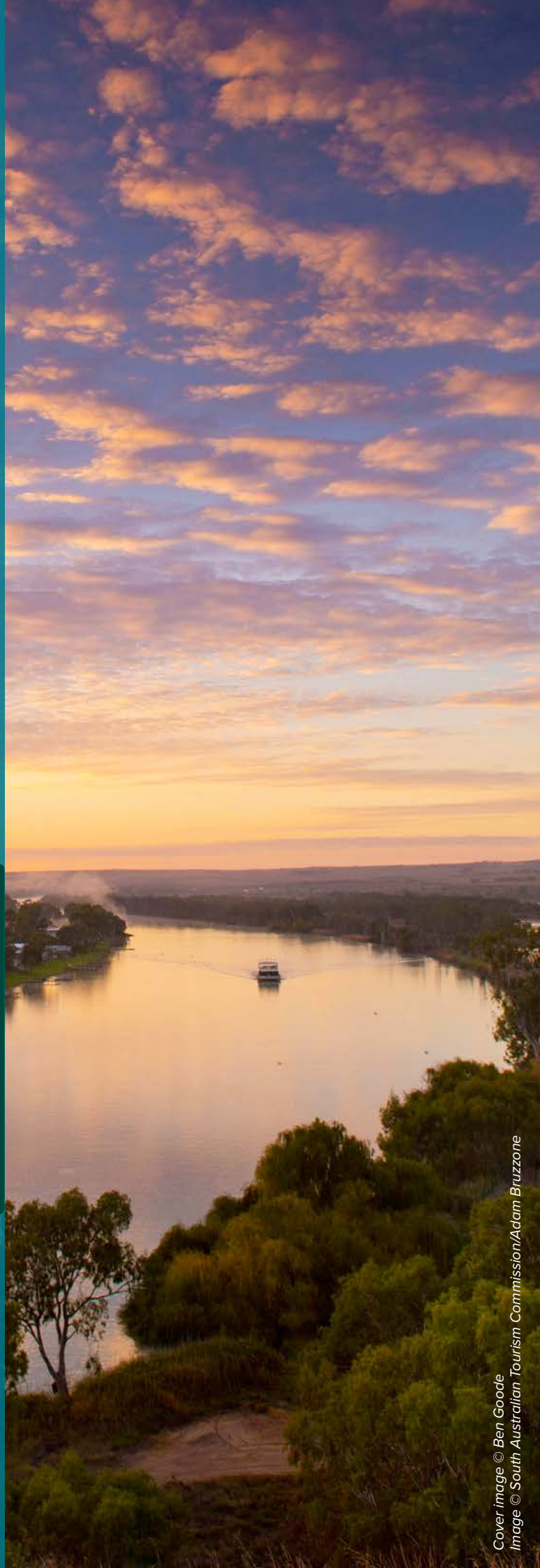
Acknowledgment of Country

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.



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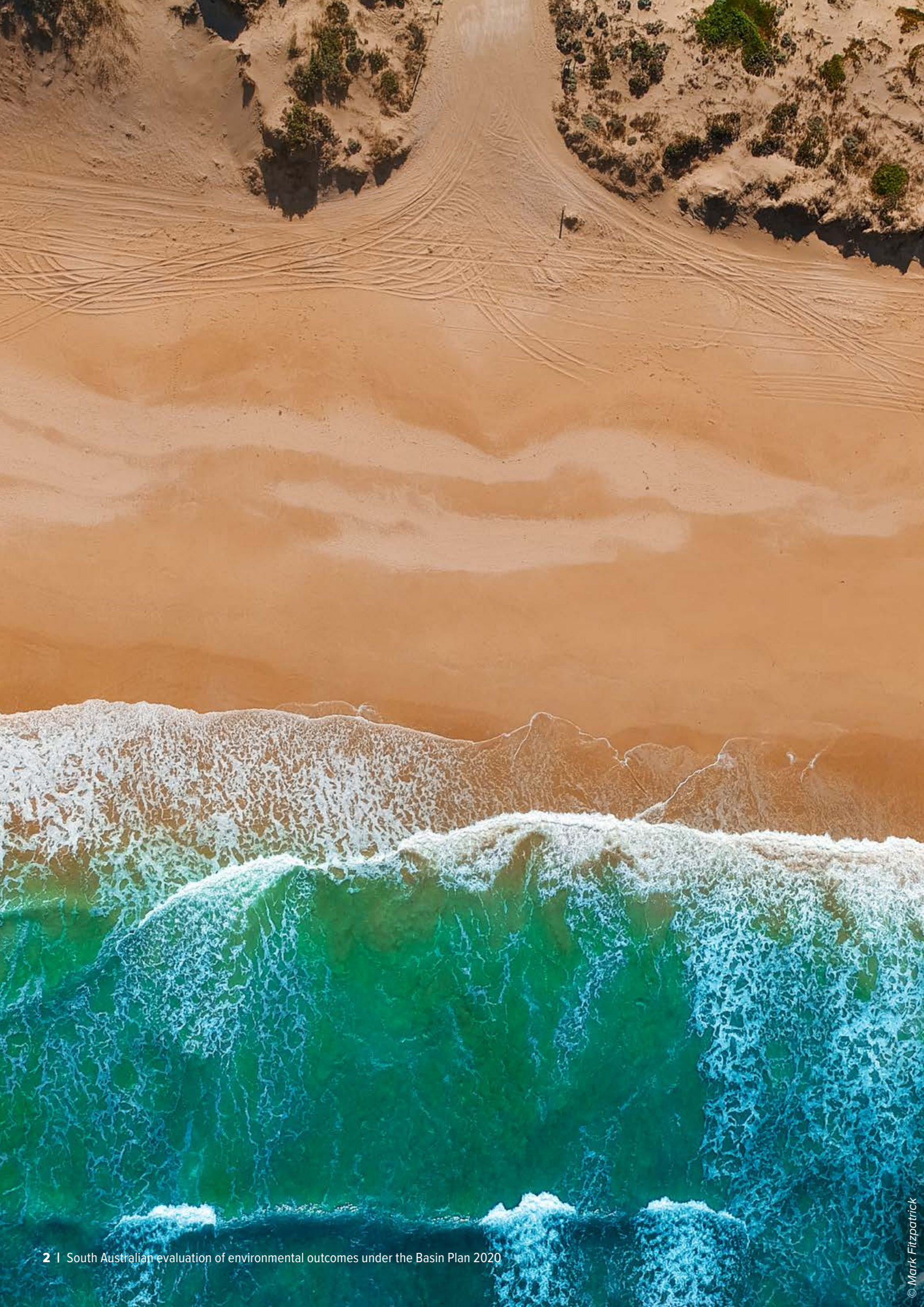

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Synopsis

The *South Australian evaluation of environmental outcomes under the Basin Plan: 2020 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 Murray-Darling Basin Plan.

The South Australian Government is committed to implementing the Basin Plan in full and ensuring that we have a sustainable, healthy, working river for future generations.

This evaluation draws together current evidence from the SA River Murray Water Resource Plan Area to provide a summary of progress made towards achievement of outcomes. It highlights key achievements and areas where further sustained effort is required.

This report comes at an important time in the implementation of the Basin Plan. It will support the continued work towards our full implementation of our Basin Plan obligations in 2024 and the upcoming review in 2026.

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

- Was this what we expected to see?
- 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 findings

This evaluation demonstrates that:

- The Basin Plan is working and water has been available for the environment during recent dry times. This has helped to improve the resilience of some critical habitats including the Lakes and Coorong and those parts of the floodplain that have been actively managed with infrastructure.
- Implementation of the Basin Plan to date has supported:
  - Improved connectivity between the Lakes, Coorong and Murray Mouth with 10 years of continuous flow and increased barrage flows, providing critical pathways for movement and recruitment of key diadromous fish species.
  - Improvements in black bream and greenback flounder populations in the Murray estuary and Coorong and small-mouthed hardyhead in the Coorong.
  - Overbank and spring-summer flows, and more localised fast-flowing habitats which may have supported the recruitment and dispersal of Murray cod and an increase in food resources for these fish.
  - Improvements in the abundances, distribution and breeding of Lakes waterbird communities.
  - Supported managed floodplain inundations which has contributed to improvement in river red gum and black box condition within inundated areas.
- Following the impacts of the Millennium Drought, we have seen some positive signs of recovery. We need to continue to build resilience to ensure our ecosystems can recover from future drought.
- We have seen positive outcomes for the areas where water has been delivered for the environment.
- To achieve broader scale outcomes, we need to increase the area that we can inundate and coordinate the delivery of water across the southern connected Basin.

This report summarises our assessment and evaluation in a simple and accessible format. It communicates outcomes achieved to date and what's still to be done.

This report begins with a chapter on the Basin Plan, followed by a summary for each Priority Environmental Asset in the South Australian River Murray Water Resource Plan area, which includes evaluation findings for key indicators in the form of expected outcome reports. This report is supported by two technical reports.

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

- Recovers the final 450 gigalitres (GL) which is critical to further improve environmental outcomes for South Australia's assets in addition to the floodplain benefits it will deliver in NSW and Victoria.
- Addresses physical and policy constraints to ensure that water for the environment can be delivered more effectively, while increasing protection for many landholders from higher natural flows.
- Protects water for the environment across the Murray-Darling Basin to ensure return flows from environmental watering events are available for downstream environmental outcomes.
- Improves the coordinated delivery of water for the environment across the Southern Connected Basin to improve system connectivity including through to the end of the system and out of the Murray Mouth.
- Encourages efficient and effective use of water for the environment through more innovative river operations.

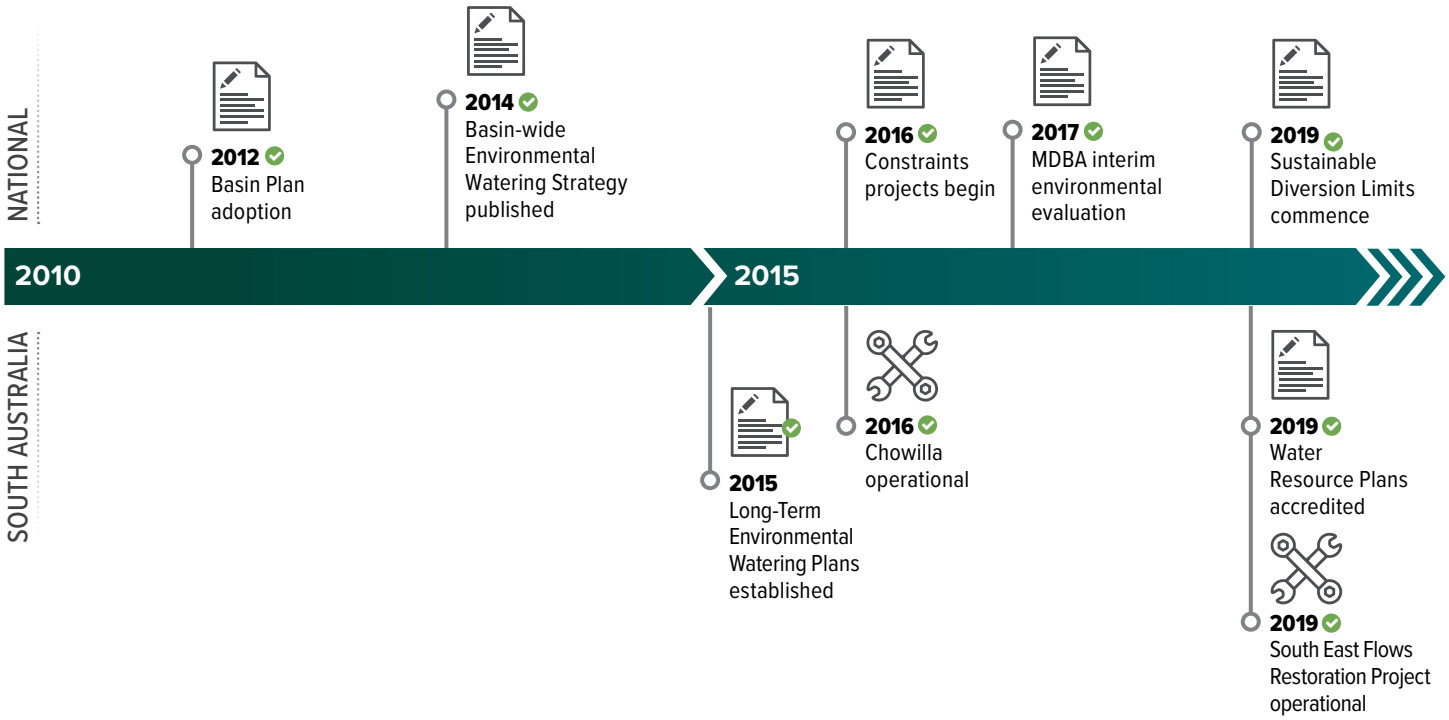
What is the Basin Plan?

The South Australian River Murray supports a vibrant, unique and highly valued environment, as well as providing significant social, economic and cultural benefits to regional communities.

In 2012, the Basin Plan was adopted by the Commonwealth Government with bi-partisan support. It provides an integrated and strategic framework for water reform, consistent with the requirements of the *Water Act 2007*.

The aim of the Basin Plan is to ensure the long-term health and sustainability of the Murray-Darling Basin. It does this by sharing water among all water users, including the environment, to leave enough for the rivers, lakes and wetlands and the plants and animals that depend on them.

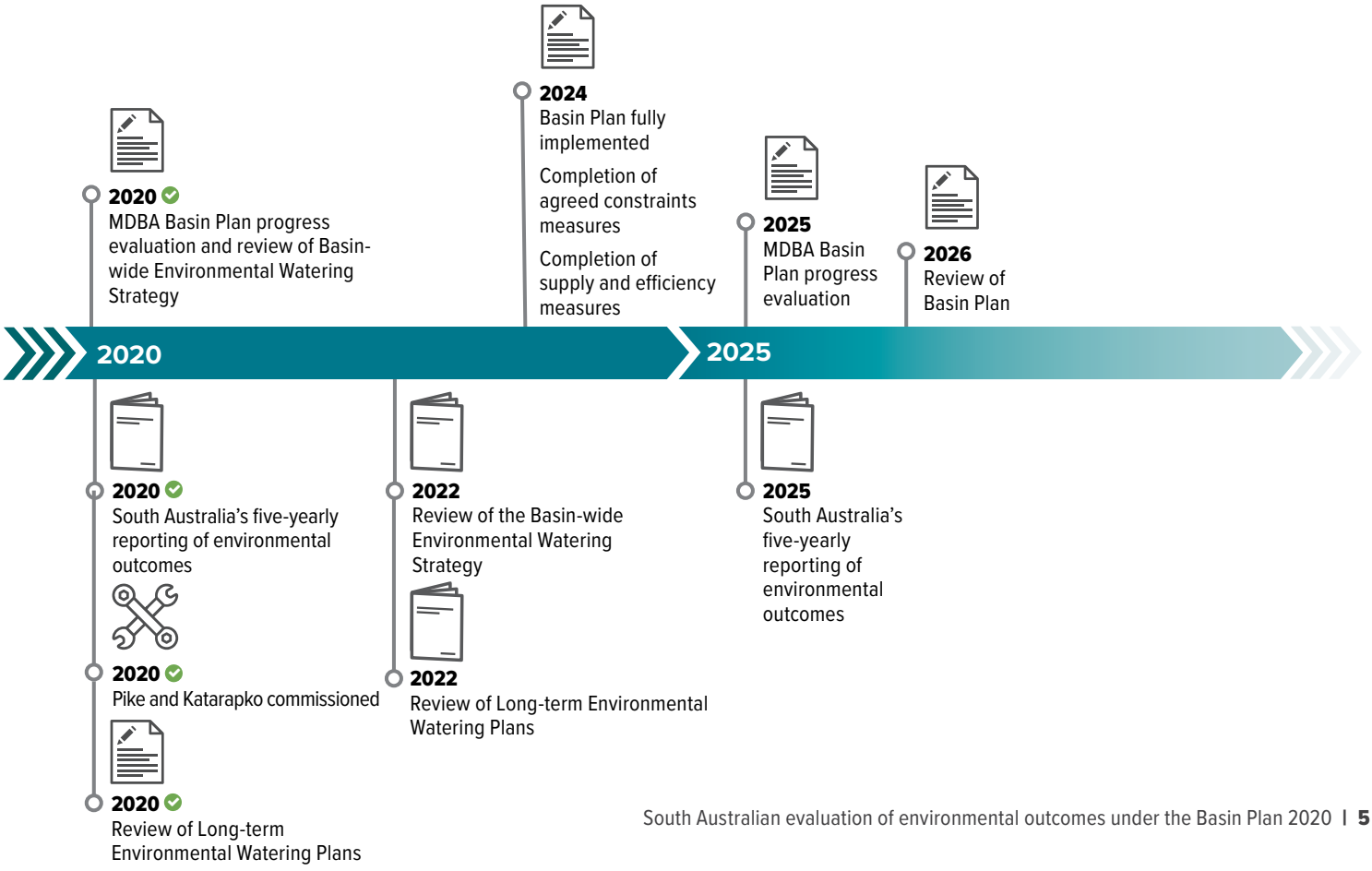
Implementation of the Basin Plan in South Australia



Implementation of the Basin Plan

South Australia has made significant progress towards full implementation of the Basin Plan including:

- Setting of new Sustainable Diversion Limits (SDL) for surface water and groundwater which came into effect from 1 July 2019.
- All three water resource plans submitted on time and accredited by the Commonwealth Minister.
- All Supply and Constraints projects notified under the SDL adjustment mechanism within South Australia are either complete or on schedule for completion by the June 2024 deadline.
- Investment in environmental infrastructure at Pike and Katarapko floodplains is currently in the commissioning stage, enabling ecological benefits to be realised.
- Efficiency Measures projects that contribute towards completion of the recovery of the final 450 GL of water for the environment.
- Meeting our `bridging the gap' water recovery target of 183.8 GL for the environment.
- Continuing to work with a range of partners and water holders to coordinate the effective delivery of water to our priority assets to achieve our short and long-term environmental outcomes in South Australia.



Environmental outcomes for South Australia

As part of the Basin Plan we are seeking to achieve environmental outcomes for:

Flows and ecosystem function

Vegetation

Fish

Birds

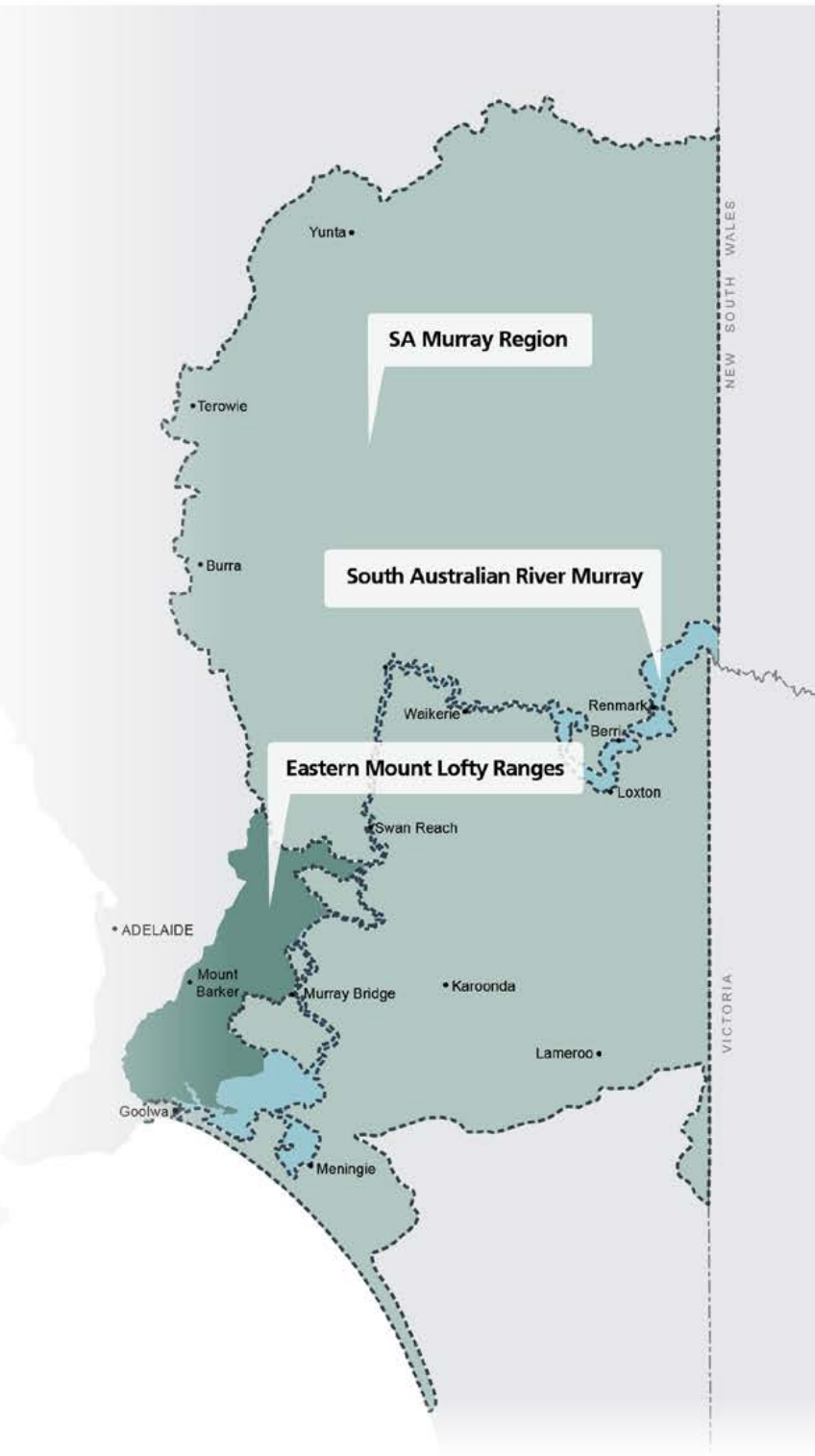
South Australia has three Water Resource Plan Areas

South Australia's Water Resource Plans (WRP) were accredited by the Commonwealth Water Minister in 2019 and are now operational for each of the three areas:

- The South Australian River Murray - includes the surface waters and floodplain of the South Australian River Murray and Lakes Alexandrina and Albert and was accredited by the Commonwealth Minister on 16 November 2019.
- The Eastern Mount Lofty Ranges - includes the groundwater and surface waters of the Eastern Mount Lofty Ranges and the Marne Saunders Prescribed Water Resources Area and was accredited by the Commonwealth Minister on 16 November 2019.
- The South Australian Murray Region - includes the surface and groundwater resources of the remainder of the South Australian Murray-Darling Basin and the Coorong and Murray Mouth and was accredited by the Commonwealth Minister on 20 August 2019.

These plans (above) demonstrate how we manage water to meet our obligations under the Basin Plan, including the use of water for the environment and consumptive purposes such as urban, agricultural and industrial use.

See: Water resource plans for more information.



Targets and objectives for environmental outcomes

Basin Plan

The overall environmental objectives for the water-dependent ecosystems of the Murray-Darling Basin within the context of the Basin Plan are to:

- Protect and restore water dependent ecosystems (rivers, wetlands, floodplains and their plants and animals).
- Protect and restore the ecosystem functions of water dependent ecosystems (connectivity, mobilisation of carbon, nutrients and propagules, salt export).
- Ensure water dependent ecosystems are resilient to climate change and other risks and threats.

Basin-wide Environmental Watering Strategy

- Sets measurable outcomes for river flows and connectivity, vegetation, waterbirds and fish across the whole Basin.
- See: Basin-wide Environmental Watering Strategy.

South Australian Long-term Environmental Watering Plan Targets

In accordance with the Basin Plan and the Basin-wide Environmental Watering Strategy, South Australia's targets for environmental watering are set in three Long-term Environmental Watering Plans for the following Water Resource Plan areas:

- South Australian River Murray
- Eastern Mount Lofty Ranges
- South Australian Murray Region

See: Environmental Water Planning for more information on these plan.

This evaluation report describes progress towards specific targets listed in the South Australian River Murray Long-term Environmental Watering Plan through the assessment of expected environmental outcomes for flows and ecosystem function, vegetation, fish and birds.

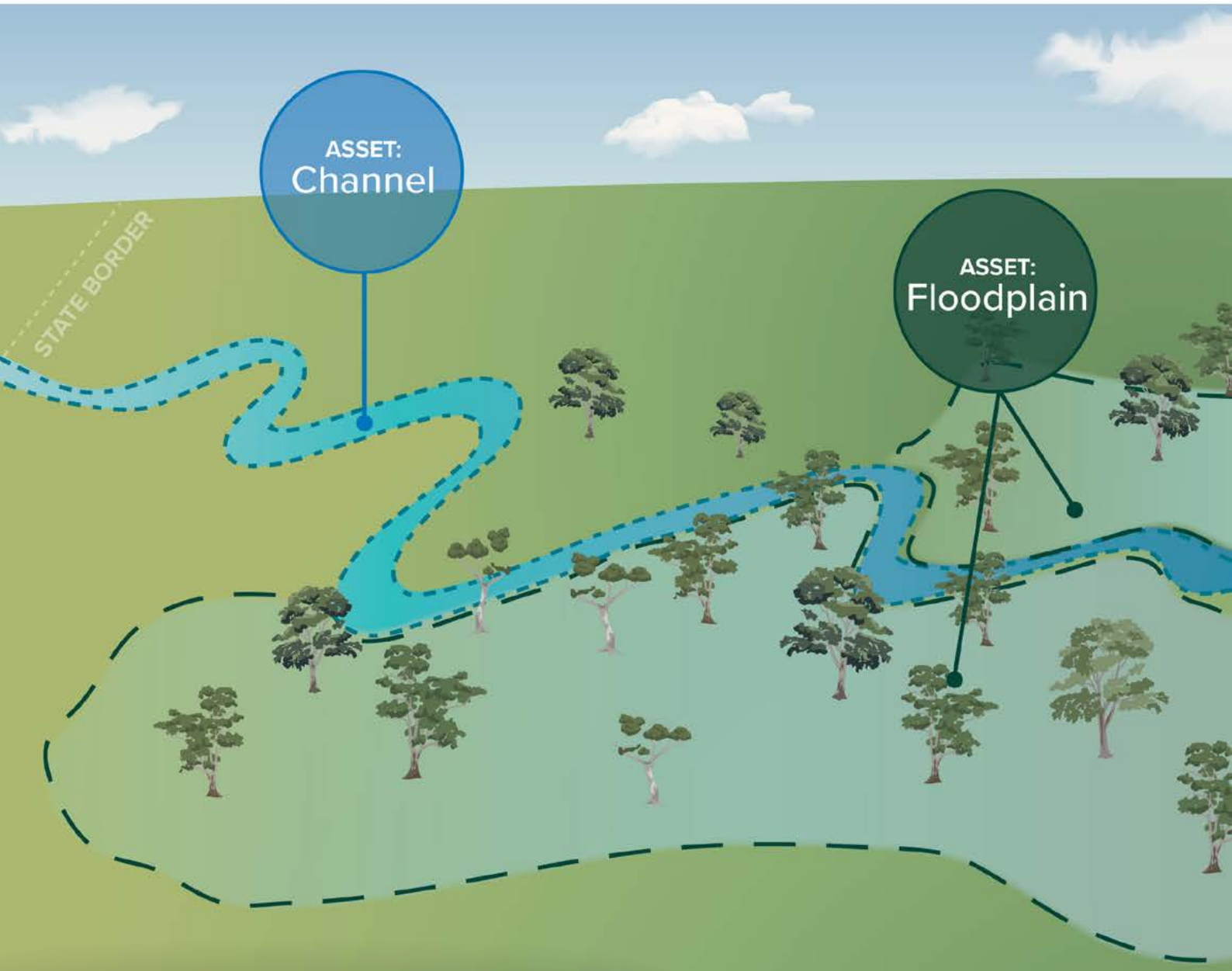
How we evaluated environmental outcomes

It's time for South Australia to assess and report on what we are seeing since the adoption of the Basin Plan.

This report provides our five year evaluation of progress towards achieving the Basin Plan environmental outcomes in South Australia.

South Australia is required to report on the achievement of environmental outcomes at the asset scale every five years in accordance with Schedule 12 of the Basin Plan.

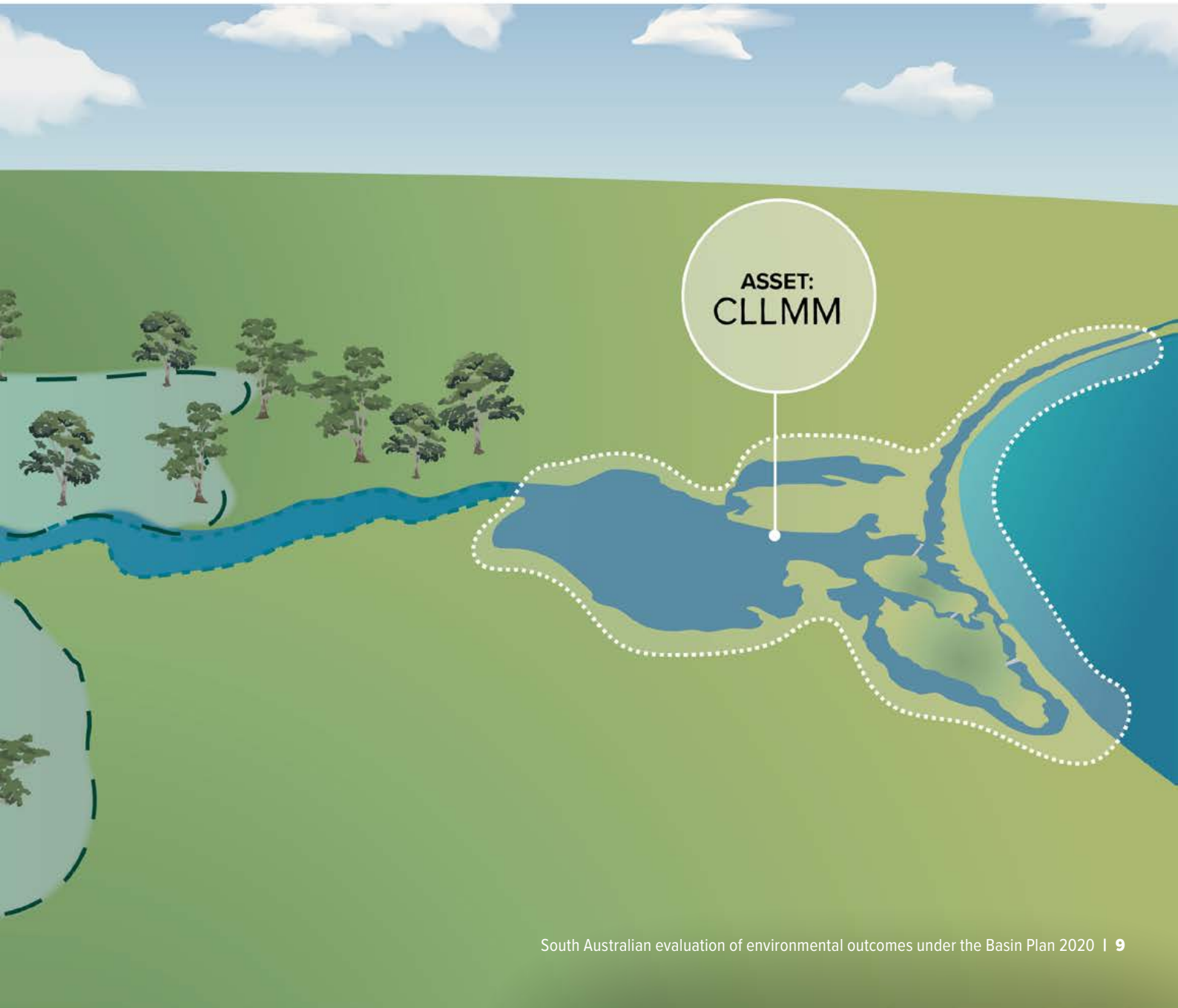
Our approach for the South Australian River Murray is underpinned by the development of expected environmental outcomes for a selection of Long-term Environmental Watering Plan targets. Expected outcomes document our expected progress towards these targets following Basin Plan adoption in 2012. In our evaluation, the assessment of `is this what we expected to see?' and `what do we expect to see in the future?' is informed by these expected outcomes. More information on the expected outcomes can be found in.



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

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

Note: even though the Coorong is included in the Murray Region Water Resource Plan Area, it relies on fresh water 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.



Coorong, Lower Lakes and Murray Mouth

Priority Environmental Asset summary

Description of the asset

The CLLMM is a Wetland of International Importance (Coorong and Lakes Alexandrina and Albert Wetland) under the Ramsar Convention and has been identified as a Priority Environmental Asset in the South Australian River Murray Water Resource Plan area.

Located at the end of the River Murray in South Australia, the estuarine waters of the Coorong and the Murray Mouth are the only connection to the sea in the Murray -Darling Basin. The site encompasses an area of 142,530 hectares that includes the Lakes Alexandrina and Albert, the lower reaches of the Finniss River and Currency Creek, Murray estuary (including the Murray Mouth) and the Coorong (North and South Lagoons). Within the CLLMM, there are a total of 23 wetland types, which range from freshwater to hypersaline, dense vegetation to open water and temporary and permanently inundated. The site supports extensive and diverse waterbird, fish and plant assemblages as well as threatened ecological communities and species.

For more information about the CLLMM please see the Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan area.

Coorong, Lower Lakes and Murray Mouth key messages:

- Following the impacts of the Millennium Drought and adoption of the Basin Plan, the CLLMM has shown positive signs of recovery.
- Water for the environment and high (unregulated) flows are both critically important for maintaining the ecological health and function of the CLLMM.
- Implementation of the Basin Plan to date has supported:
  - improved connectivity between the Lakes, Coorong and Murray Mouth with 10 years of continuous flow and increased barrage flows
  - maintenance of lake levels and salinities within optimal ranges
  - increased resilience of fish populations in dry times
  - improved health of Ruppia in the Coorong.
- However, challenges remain including:
  - The current state of the Southern Coorong is degraded due to prolonged hyper-saline and hyper-eutrophic conditions and if we do nothing it is at risk of no longer supporting key biota such as waterbirds, fish, plants and invertebrates.
  - Recovery of water bird populations to the site.
  - Improving the resilience of Ruppia in the southern Coorong.
  - Maintaining Murray Mouth openness without the ongoing need for dredging.
- Continued effort and investment is required to improve the health of the CLLMM through:
  - striving for full implementation of the Basin Plan
  - undertaking research and works through Project Coorong
  - continued involvement of the local community and First Nations to find enduring solutions.

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.

What have we assessed?

We have assessed the achievement of environmental outcomes in relation to a subset of the SA River Murray Long-term Watering Plan targets for the CLLMM using a number of indicators. Broadly, the achievement of these ecological targets aims to maintain or improve the health of vegetation, fish and bird communities, while also maintaining a permanently open Murray Mouth.

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, Smallmouth hardyhead): Key recreational, cultural and economic species in indicative of system connectivity and freshwater inflows and the persistence of estuarine conditions.

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

Evaluation findings

There have been some improvements in Coorong, Lower Lakes and Murray Mouth condition since the adoption of the Basin Plan.

Where we are seeing improvement

The delivery of water under the Basin Plan has helped to maintain lake levels and salinities within optimal ranges, increase barrage outflows and improve system connectivity.

- Lake level management and seasonal water level cycling have protected aquatic habitats and provided opportunities for aquatic plant recruitment, which has supported improvements in aquatic and littoral vegetation condition in Lakes Alexandrina and Albert.
- Lake level management and seasonal water level cycling have also been crucial in improving habitat condition and food resources which has contributed to improvements in the abundances, distribution and breeding of Lakes waterbird communities.
- Delivery of environmental flows has maintained and improved the extent of salinity conditions, supporting improvements in black bream and greenback flounder populations in the Murray estuary and Coorong and small-mouthed hardyhead in the Coorong.
- Water for the environment has improved system connectivity through freshwater flows through the barrages, providing critical pathways for movement and recruitment of key diadromous fish species.

Where we are not seeing improvement

Despite contributions of Basin Plan water recovery towards improvements, some indicators have remained stable or declined.

- Freshwater flows have been insufficient to maintain Murray Mouth openness without the need for dredging.
- Although flows have improved salinities, high nutrients, excessive algal growth and inadequate water levels have limited the recovery of Coorong waterbird communities and the resilience of Ruppia in the southern Coorong.

For more information on the assessment of condition, 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.

The impact of the Millennium Drought

The Millennium Drought (from late 1996 to 2010) had a profound impact on the CLLMM. Between 2006 and 2010, River Murray flows were at historically low levels due to the combined impacts of extreme drought and over-allocation across the Murray -Darling Basin. As a result, inflows into the Lower Lakes were not able to replenish evaporative losses resulting in average lake levels dropping to unprecedented lows and connectivity to the Coorong was lost.

Low lake levels, disconnection of the wetlands, exposure of 20,000 hectares of acid sulfate soils and increased salinity levels, severely impacted the condition of the asset which is still recovering today.

The end of the Millennium Drought coincided with the adoption of the Basin Plan, therefore results of this evaluation should be interpreted in that light. Consequently, many of the indicators that have shown improvement were still assessed as in fair or poor condition.

Coorong, Lower Lakes and Murray Mouth

Expected outcomes reports

*Trend is the change over time, calculated using all available data for an indicator

↗	Trend **Getting better**	**Getting better:** The indicator is improving over the period of assessment
—	Trend **Stable**	**Stable:** The indicator is neither improving nor declining over the period of assessment
↙	Trend **Getting worse**	**Getting worse:** The indicator is declining over the period of assessment
?	Trend **Unknown**	**Unknown:** Data are not sufficient to determine any trend in the status of this 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 on the evaluation please see the technical information:

Theme	Indicator	Trend*	Information reliability	Key findings
Flow & Ecosystem Function	Murray Mouth openness (annual barrage flows)	↗ Trend **Getting better**	★★★★★☆ Reliability **Very good**	The number of days the mouth is open has increased since Basin Plan adoption, but remains heavily reliant on dredging.
Vegetation	Aquatic and littoral vegetation	↗ Trend **Getting better**	★★★★★☆ Reliability **Very good**	Vegetation condition in the Lakes is getting better and is expected to be maintained in the future.
	Ruppia	↗ Trend **Getting better**	★★★★★ Reliability **Excellent**	The health of Ruppia has improved, however the community is still not considered to be resilient.
Fish	Black bream and greenback flounder	↗ Trend **Getting better**	★★★★★ Reliability **Excellent**	While bream and flounder has improved, the condition of both populations remains very poor.
	Diadromous fish	↗ Trend **Getting better**	★★★☆☆☆ Reliability **Good**	Recruitment of diadromous fish has improved due to increased system connectivity.
	Small-mouthed hardyhead	↗ Trend **Getting better**	★★★★★ Reliability **Excellent**	Small-mouthed hardyhead recruitment is improving and is better than we expected at this point in time.
Birds	Lakes waterbirds	↗ Trend **Getting better**	★★★★★☆ Reliability **Very good**	Lakes waterbirds are showing signs of recovery, however condition of the community is still considered to be poor.
	Coorong waterbirds	↙ Trend **Getting worse**	★★★★★☆ Reliability **Very good**	The abundance of Coorong waterbirds is getting worse, particularly for resident and migratory shorebirds.

Expected outcome report: Flow & Ecosystem Function

Open Murray Mouth: barrage outflows

Trend
Getting better

Reliability
Very good

The number of days the mouth is open has increased since Basin Plan adoption, but remains 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 provides connection between the freshwater environments (River Murray and Lakes), the Murray estuary and Coorong and the Southern Ocean. This connection is important for flushing excess salts and nutrients from the river system, as well as maintaining the quality of water in the Coorong. As the only connection from the River Murray to the ocean, it is also important for native fish that need to move between these environments.

Conditions that lead to the Murray Mouth being open have improved, however dredging is still required.

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, occurrence of dredging actions and diurnal tidal ratio (DTR). DTR is an indication of the exchange of water between the estuarine and marine environment which ranges from 0.0 (closed) to 0.3 (functionally open) to 1.0 (fully open). The MDBA has calculated the minimum annual flow required to keep the Murray Mouth open is between 730 - 1090 GL/year.

Barrage outflows fluctuated between 2000 and 2019 (Figure 1). The Millennium Drought led to nine consecutive years (2002-2010) of low to no barrage outflow. At the end of the Millennium Drought in 2010 there was widespread flooding and high barrage outflows (12,808 GL) in 2012/13, after which lows flows <1000 GL/year continued until 2016. High barrage outflows returned in 2016/17 as a result of unregulated flows reaching the Lakes, but there has been a return to low outflows from 2017 onwards.

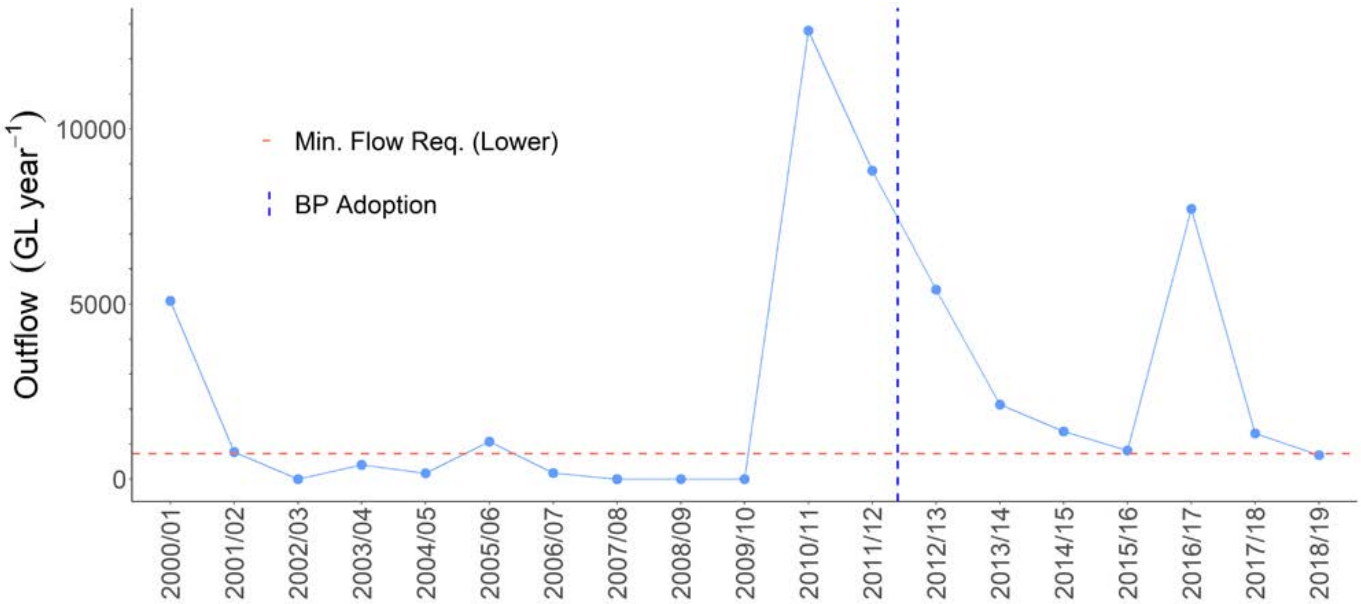


Figure 1: Outflow (GL/year) from the barrages for each water year from 2000/01 to 2018/19 with respect to the lower minimum flow thresholds (red dashed line) since Basin Plan adoption (dashed blue line). Outflow data was sourced from the MDBA.

When the DTR falls below 0.2 at Goolwa it indicates that the connection between the Southern Ocean and the Coorong is poor. This means that dredging is required to keep the Murray Mouth open and keep the DTR above 0.2. Since Basin Plan adoption DTR declined below 0.2 at times in 2015, 2016 and 2017 (Figure 2). Two dredges have been in operation for most of the past five water years (Figure 2). While barrage outflows have contributed to an increase in the frequency of years that exceeded the minimum annual outflow target (730GL/year) required to keep the Murray Mouth open from 2000 to 2019 (Figure 1), volumes were inadequate to maintain an open Murray Mouth through outflows alone.

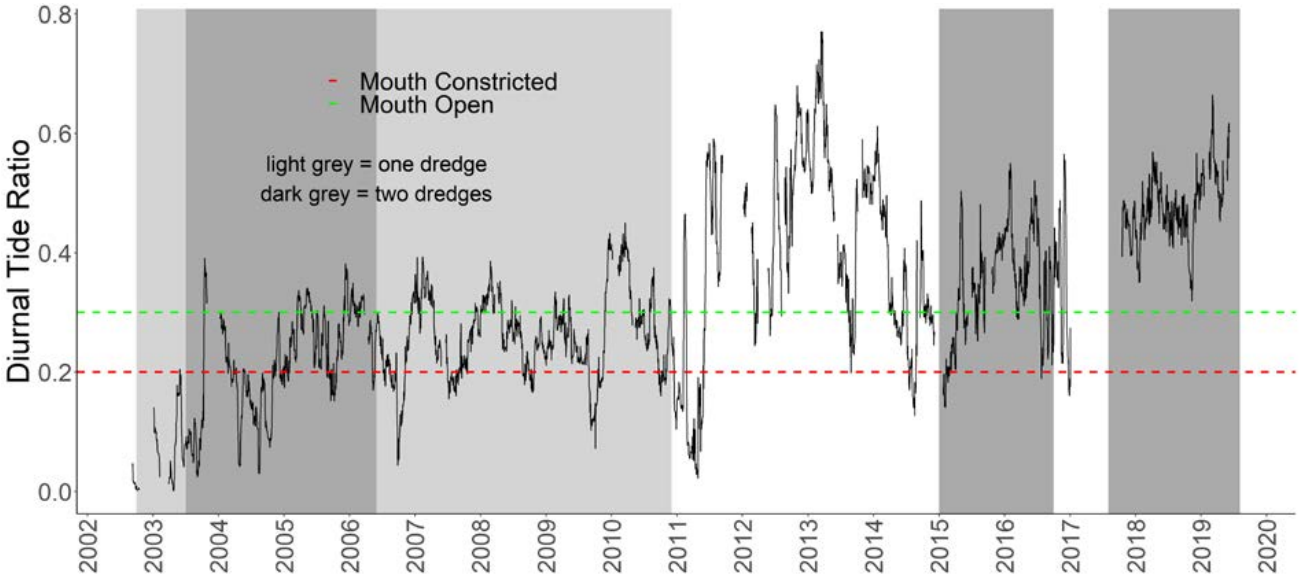
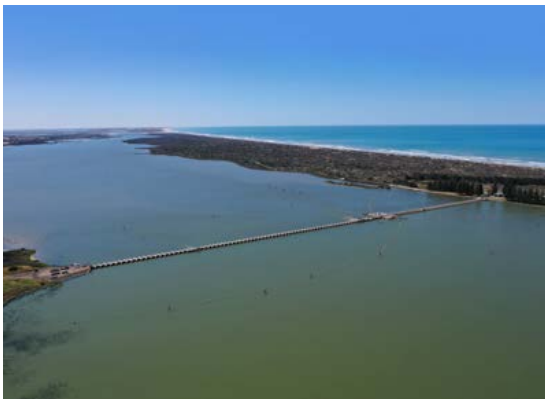


Figure 2. Diurnal Tide Ratio (DTR) at Goolwa from September 2002 to June 2019. DTR values of below 0.2 (red dashed line) are reflective of a constricted Mouth and values above 0.3 (green dashed line) are reflective of an open and functional Mouth. Dedging data was sourced from DEW, DTR data was sourced from SA Water.



Is this what we expected to see?

Climate is a key driver for this indicator as it influences water availability and freshwater inflows to the CLLMM. In the last 7 years the minimum annual outflow was met in 6 of 7 years as expected.

Evaluation: Why are we seeing these results?

Despite meeting the minimum annual outflow as expected, freshwater outflows were insufficient to prevent the Murray Mouth becoming constricted following Basin Plan adoption, particularly during low flow periods.

In addition, the following factors means dredging is still required to maintain the function of the Murray Mouth:

- Reduced rainfall conditions, along with extraction of water upstream, which have contributed to reduced freshwater inflows and barrage outflows.
- Prolonged periods of barrage outflows less than approximately 2,000 ML/day resulted in the accumulation of significant amounts of sand within the estuary, which has increased the risk of sand deposition and accumulation inside the Murray Mouth
- Lack of high flows that scour the Murray Mouth (60,000 - 70,000 ML/day), which have only been recorded for short periods between October and December 2016.

What has Basin Plan delivered?

Water delivered through the implementation of the Basin Plan has supported barrage outflows. Since Basin Plan adoption, water for the environment enabled the minimum annual outflow target of 730 GL/year to be exceeded on six of seven years (86%). In contrast, outflow from the barrages between 2000 and 2012 exceeded the minimum annual flow target (730 GL/year) in only five of 12 years (42%).The result is that minimum flow targets have been met more frequently following Basin Plan adoption.

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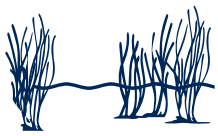
What is still to be done?

Targeted delivery of water for the environment to the Murray Mouth is unlikely to be of sufficient volume and frequency to maintain its openness without dredging, due to current water recovery volumes and physical and operational constraints to delivery. Achievement of this outcome is also reliant on large prolonged high flow events such as those experienced during floods. The management of Lakes water levels and barrage outflows during these events will be important to improve the directionality of the flow to the Mouth to ensure scouring of sand and constriction.

What do we expect to see in the future?

In future years, it is expected that the percentage of years with barrage outflow exceeding the minimum annual outflow target will be maintained. However water for the environment is unlikely to be of sufficient volume to maintain an open Murray Mouth without high flows to scour sand that has accumulated inside the Murray Mouth. Therefore, it is expected that dredging of the Murray Mouth will continue to be required in the future during prolonged low flow conditions.

It is expected that dredging of the Murray Mouth will be required in the future during prolonged low flow conditions.



Expected outcome report: vegetation

Aquatic and littoral vegetation

Trend
Getting better

Reliability
Very good

Vegetation in the Lakes is getting better and is expected to be maintained in the future.

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"*

Why is aquatic and littoral vegetation important?

Aquatic vegetation: plant species that grow partly or wholly within water. Littoral vegetation: plants occurring in areas near the edge of a wetland or lakes, between the high water mark and shoreline areas that are permanently submerged.

Aquatic and littoral vegetation in the Lakes plays an important ecological role through primary productivity, improving water quality, minimising shoreline erosion and providing habitat for invertebrates, frogs, fish and waterbirds.

Overall the condition of aquatic and littoral vegetation in the Lakes has improved.

What is the trend and current status of aquatic and littoral vegetation in the Lakes?

Aquatic and littoral vegetation is described using a 'whole of icon site score', which is comprised of individual habitat scores calculated for Lake Alexandrina, Lake Albert, Goolwa Channel and permanent and temporary wetlands around the Lakes. A whole of icon site score of 0.8-1 represents very good condition, 0.6-0.79 good condition, 0.4-0.59 fair condition and less than 0.4 poor condition.

Whole of icon site scores (Figure 3) were low during the peak of the Millennium Drought (between spring 2008 and autumn 2010) before markedly improving after the return of freshwater flows in spring 2010, and remaining high over the following year (spring 2010 – spring 2011). Since Basin Plan adoption in 2012, scores have generally been stable with only small declines seen between spring 2015 and spring 2017.

Overall the condition of aquatic and littoral vegetation in the Lakes has improved (Figure 3), with variability in the condition between habitats (Figure 4). Increased condition scores in Lake Albert and Lake Alexandrina contributed most to the improvement, while Goolwa Channel and permanent and temporary wetlands have shown a decrease in vegetation scores (Figure 4).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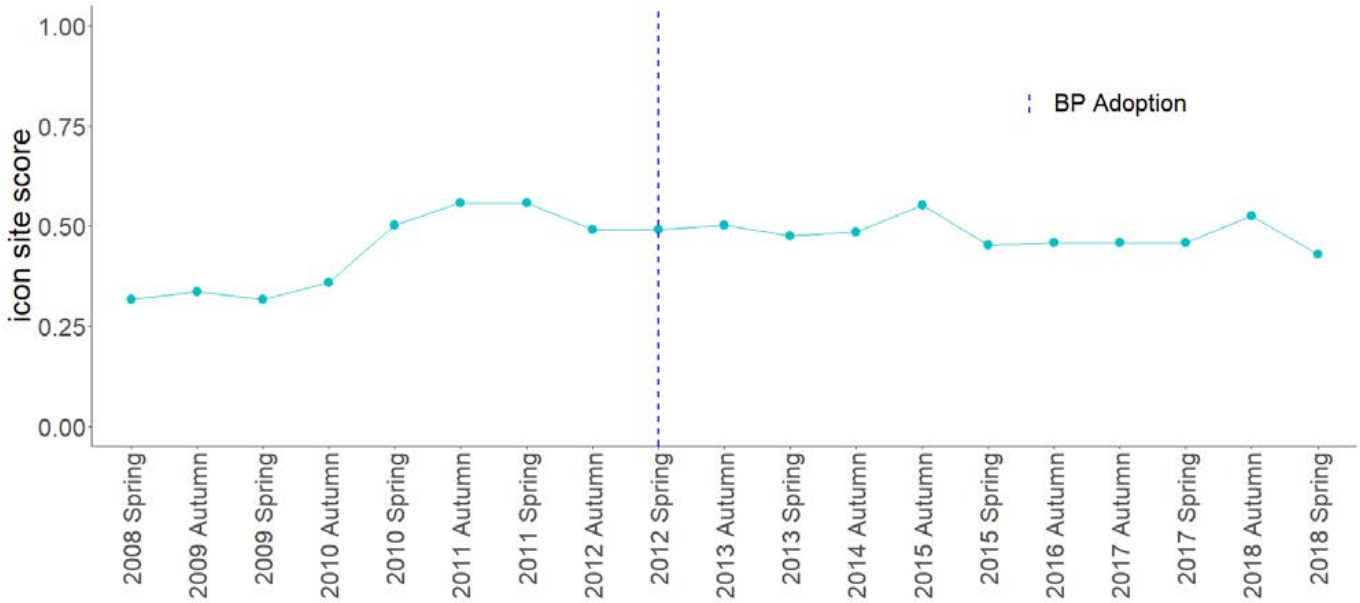

Figure 3: Icon site scores for the condition of littoral and aquatic vegetation in the Lower Lakes from autumn 2009 to spring 2018 in 2019, 2029 and 2042. Basin Plan implementation adoption is marked by a vertical dashed blue line. Data source: SARDI

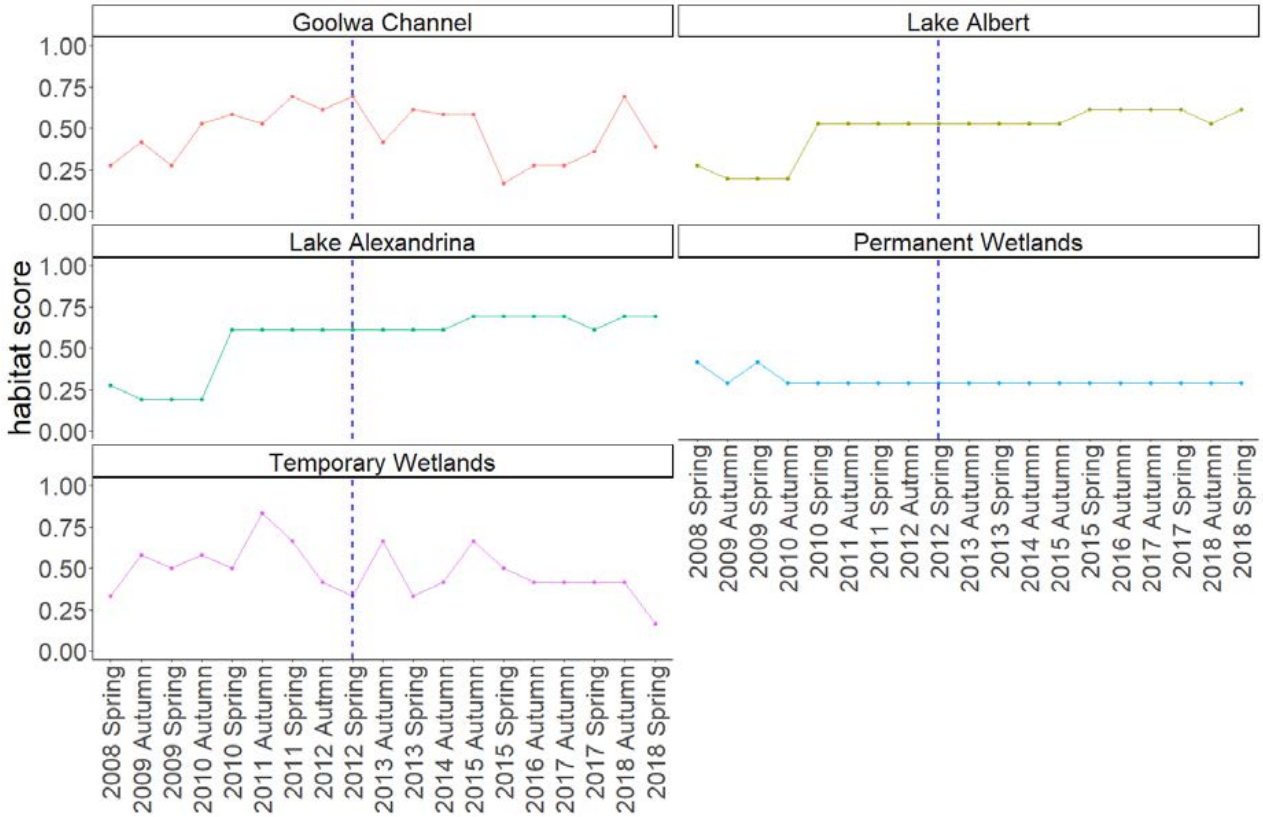

Figure 4: Habitat scores for each wetland type: Goolwa Channel, Lake Albert, Lake Alexandrina, Permanent Wetlands and Temporary Wetlands from spring 2008 to spring 2018. Note: Temporary Wetlands includes autumn and spring wetlands. Basin Plan adoption is marked by a vertical dashed blue line. Data source: SARDI


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Is this what we expected to see?

Water level and salinity are the primary drivers of aquatic and littoral vegetation communities in the Lakes. With the existing water management regime of seasonal water level cycling and salinity, we expected to see a whole of icon site condition score of 0.5 in 2019. The current condition score (spring 2018) was 0.43.

Why are we seeing these results?

Aquatic and littoral vegetation condition in the Lakes has improved since the end of the Millennium Drought in 2010 and the return of the Lakes to normal operating levels. Lake operating levels are mostly maintained through the planned (not licensed) environmental water (PEW) component of South Australia's Entitlement, and unregulated flows.

The delivery of water has enabled the improvements in condition to be sustained through the following measures:

- The management of lake levels including:
  - Seasonal water level cycling between +0.4 mAHD and +0.85 mAHD, which provides water level variability to support growth and reproduction of aquatic plants.
  - Maintenance of Lake levels above +0.4 mAHD, which has ensured that habitats are permanently inundated to support aquatic vegetation.
- Restoration of salinities in the Lakes that is:
  - reflective of pre-drought conditions
  - below critical targets (i.e. <1500 EC in Lake Alexandrina and <2000 EC in Lake Albert).

Complementary management actions, including aquatic plant revegetation and lakeshore fencing to prevent access by stock, have also contributed to improvements in vegetation condition.

How has Basin Plan contributed?

The implementation of the Basin Plan has contributed to actions that have sustained improvement in Lakes aquatic and littoral vegetation through the protection of water for the environment. In dry years, Held Environmental Water (HEW) has been important in maintaining water levels prior to that water being released to the Coorong, which in turn supports the condition of aquatic and littoral vegetation.

What is still to be done?

The current hydrological and salinity regimes, especially seasonal lake level cycling, need to be maintained to provide conditions for the continual improvement of the aquatic and littoral vegetation condition in the Lakes. Although, outside of current management influence, periodic high (unregulated) flow events are important and are needed more frequently to support the maintenance of key processes in the Lakes, particularly the flushing of salt to support suitable salinity regimes.

Other management actions such as land management and direct vegetation management including weed control are also likely to be required to achieve greater improvement in the condition of Lakes vegetation.

What do we expect to see in the future?

We expect that the condition of aquatic and littoral vegetation in the Lakes will be maintained from 2019. It is expected that the peak benefits will likely occur between now and the next ten years, due to greater water recovery and through addressing water delivery constraints. Over the longer-term, climate variability is likely to be an important driver of Lakes vegetation condition. The influence of climate on water availability and management could limit future improvements to the Lakes vegetation condition.

We expect that the condition of aquatic and littoral vegetation in the Lakes will be maintained from 2019.

Expected outcome report: vegetation

Ruppia

Trend
Getting better

Reliability
Excellent

The health of Ruppia has improved, however the community is still not considered to be resilient.

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 tuberosa important?

Ruppia tuberosa (Ruppia) is a species of aquatic plant that plays an important role in the structure and function of the southern Coorong. It is one of the most important aquatic plants in the system, where it influences key environmental processes such as nutrient cycling. It also provides critical habitat and food resources for other biota, particularly waterbirds, fish and invertebrates.

What is the trend and current status of Ruppia?

Ruppia condition and resilience is assessed using measures of distribution, area of occupancy and reproductive success. Ruppia distribution is assessed according to its extent of occurrence over its historic 43 km length. Area of occupancy is assessed as the proportion of sites occupied by Ruppia across this distribution, with plants present in both winter and summer. Reproductive success is assessed using the number of seeds, within the seed bank at these sites.

The distribution of Ruppia declined significantly during the Millennium Drought.

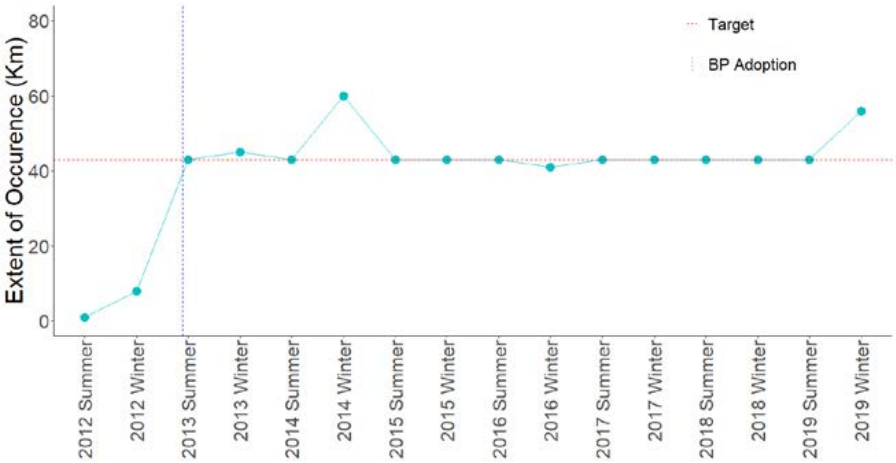

Figure 5: Distribution (extent of occurrence) of R. tuberosa along the Coorong in summer and winter between 2012 and 2019. University of Adelaide). The ecological target is shown by a horizontal dashed red line. Basin Plan (BP) Adoption (November 2012) is marked by a vertical dashed blue line. Data source: University of Adelaide

The distribution of Ruppia declined significantly during the Millennium Drought. Ruppia was no longer present within the South Lagoon between 2008 and 2010. Ruppia was detected in the northern end of the South Lagoon following the unregulated flow event in 2010/11. By 2013, following adoption of the Basin Plan, Ruppia had returned to its historic 43km extent along the Coorong, and this has been largely maintained, except for winter 2016 (Figure 5).

Within this extent, the area occupied by Ruppia has improved since the return of freshwater flows in 2010. This improvement continued until 2014 (Figure 6) and has been relatively stable since.

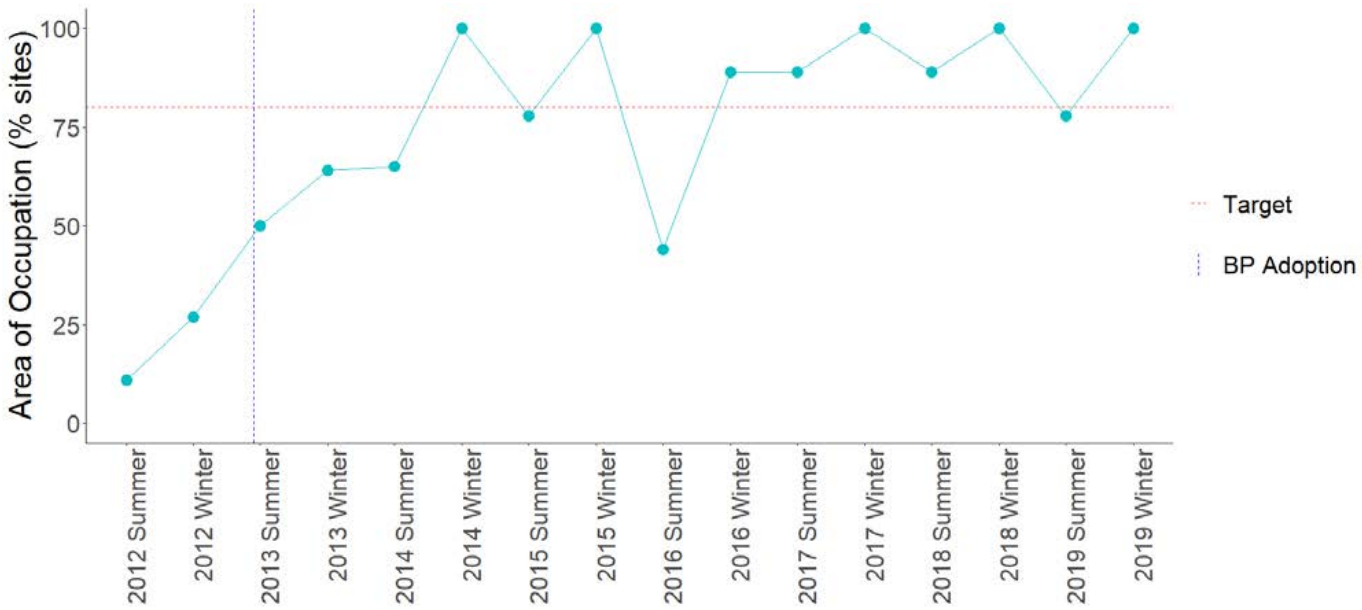

Figure 6. Abundance (area of occupation) of R. tuberosa along the Coorong in summer and winter between 2012 and 2019. Abundance is the percentage (%) of sampled sites within the 43 km sampled distribution that had live R. tuberosa shoots during summer and winter monitoring periods from 2012–2019. The ecological target (Target) is shown by a horizontal dashed red line. Basin Plan (BP) Adoption (November 2012) is marked by a vertical dashed blue line. Data source: University of Adelaide

The number of Ruppia seeds has varied greatly both between sites and across years. During the peak of the Millennium Drought seed numbers were generally very low. Recovery of Ruppia seed numbers since the Millennium Drought has been limited, with numbers at all sites remaining well below those reflective of a resilient population (i.e. >2000 seeds per m^2) (Figure 7).

Figure 7. Average number of R. tuberosa seeds (per m2) along the Coorong in summer between 2012 and 2019. Data source: University of Adelaide

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Is this what we expected to see?

Water depth and salinity are key drivers of the health of Ruppia in the southern Coorong. Given the current conditions, including water levels in spring and summer, we were expecting to see some recovery of the Ruppia population in the Coorong from Millennium Drought levels. We observed the following:

- The current distribution of Ruppia in summer and winter was ≥43 km, as expected.
- Ruppia was present at 78% of sites, in summer 2019, which is lower than the expected.
- The number of Ruppia seeds in summer 2019 was 278 seeds per m^2 which is higher than what was expected.

Why are we seeing these results?

The distribution of Ruppia has recovered with the return of barrage outflows reaching the Coorong and resulting improvements in salinity. There has been, however, slow and limited recovery in the area occupied by Ruppia and number of seeds. This has been influenced by several factors, including:

Timing and volume of barrage outflows has rarely been sufficient to support suitable water levels in spring and into summer, which has limited the ability of Ruppia to complete its lifecycle.

Lack of freshwater flows to flush the system, which has created undesirable high nutrient and algae conditions in the southern Coorong.

Salinity conditions, which have not been suitable to support key life cycle stages, including seed production, despite some improvements in Ruppia distribution.

What has the Basin Plan delivered?

The delivery of water, including water for the environment and high (unregulated) flows, has prevented salinities in the Coorong from becoming reminiscent of the Millennium Drought. It has also contributed to:

- Limiting the extent of the Coorong with salinities above 85g/L between April and July, which is unsuitable for the germination of seeds.
- Small improvements in suitable conditions to support Ruppia reproduction.
- Enhancing the export of salt from the system and minimising salt entering the Coorong.

However, inadequate water levels and high nutrient conditions have hampered the recovery of Ruppia, particularly seed numbers, in the Southern Coorong.

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What is still to be done?

In order to improve the health and resilience of Ruppia in the Coorong, the following are required:

- Maintenance of favourable water levels, with monthly barrage flows of at least approximately 1000 GL between September and January.
- Maintenance of water levels in the Coorong South Lagoon above 0.3m AHD in spring and into summer.
- Avoiding a fall in water levels over spring to avoid the drying out of plants before they have been able to set seed.
- Ensuring salinity conditions remain within the ranges required to support Ruppia reproduction.
- Strategic delivery of water at the tail end of high flow events, to prolong more favourable conditions in the southern Coorong, to support Ruppia growth and reproduction.

Full implementation of the Basin Plan, including addressing current water delivery constraints, is required to deliver sufficient volumes of water at a frequency needed to achieve desired water level conditions.

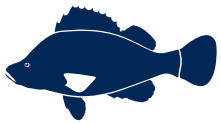
Although outside of current management influence, periodic high (unregulated) flow events are important and are needed more frequently to support improvement in the health of Ruppia in the southern Coorong.

Additionally, on-ground works and research as part of the Healthy Coorong, Healthy Basin Program are seeking to:

- Restore Ruppia plants and remove filamentous algae in the Coorong fill key knowledge gaps and inform management actions required to:
    - reduce nutrient loads and algal abundance in the Coorong
- switch the Coorong south lagoon back to an aquatic plant dominated system rather than an algal dominated system.

What do we expect to see in the future?

Longer-term improvements in Ruppia distribution, area of occupancy and numbers of seeds will be strongly influenced by climate conditions, which will impact water availability and resulting water level and water quality conditions in the Coorong. The resilience of Ruppia is currently low, due to the limited recovery since the Millennium Drought. This population is therefore more vulnerable to any additional perturbations on the system, such as further prolonged drought conditions.



Expected outcome report: Fish

Black bream and greenback flounder

Trend
Getting better

Reliability
Excellent

While bream and flounder has improved, the condition of both populations remains very poor.

What are we trying to achieve?

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

Why bream and flounder important?

Black bream (bream) and greenback flounder (flounder) are two fish species that inhabit estuarine and coastal waters of the CLLMM. They are important commercial, recreational and cultural fish species and are influenced by barrage outflows and salinity conditions within the Murray estuary and Coorong.

There has been some improvement in the population condition of black bream and greenback flounder.

What is the trend and current status of bream and flounder?

Bream and flounder communities are assessed using a population condition index, which combines abundance, distribution, recruitment and age structure to determine an overall population condition score. Scores of 1 and 2 represent very poor and poor population condition, a score of 3 means the population is in moderate condition, while a score of 4 reflects a population in good condition.

Overall, population condition scores of bream and flounder have improved, with variability between species and through time (Figure 8). Population condition scores of both bream and flounder were poor during the peak of the Millennium Drought (2008-2009). With high flows between 2011 and 2013, flounder population condition scores increased, but bream declined. In 2016, bream fish stocks in the Lakes and Coorong were classified as 'over-fished' and declared a 'no take species'. In recent years (2018 to 2019) both species have declined to a score of 1 under low flow conditions.

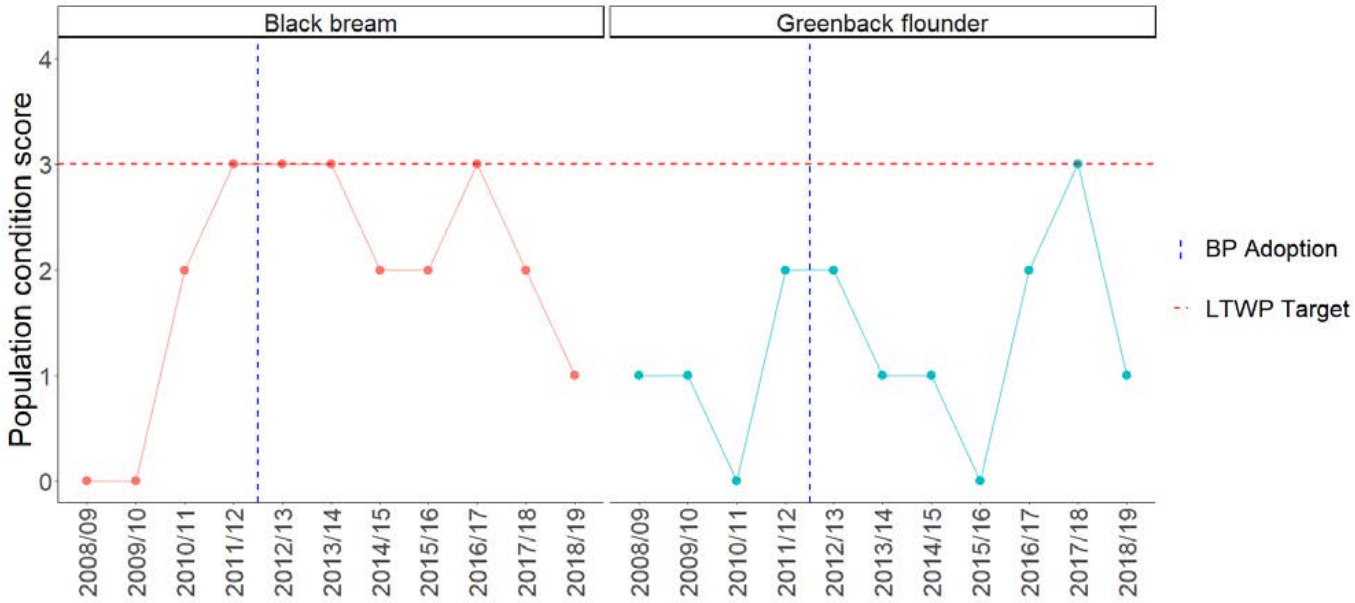


Figure 8: Population condition scores for black bream and greenback flounder from 2008/09 to 2018/19 in the Coorong. Basin Plan adoption is marked by a vertical dashed blue line and the Long-term Environmental Watering Plan (LTWP) is marked by the horizontal dashed red line. Data source: SARDI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Is this what we expected to see?

Barrage outflows are important for maintaining the salinity conditions, which provide suitable habitat for bream and flounder. Based on the status of fish populations in the Coorong and Lakes, along with knowledge of barrage outflow volumes and salinity conditions in the Murray estuary, we expected to see a population condition score of 2.25 for bream, and 2.75 for flounder, in 2019. The observed scores of 1 for both species are lower than we expected at this point in time.

Why are seeing these results?

Freshwater outflows from the barrages, including the volumes and timing of flows, have contributed to some improvements in population condition for both species since 2008/09. These outflows have contributed to more favourable salinity conditions in the Murray estuary and Coorong. The delivery of water for the environment, and the maintenance of an open Murray Mouth (primarily through dredging), have provided opportunities for recruitment in some years. Further improvements in population condition of these species have likely been limited by fisheries. Commercial and recreational catches of larger, older black bream reduce the number of fish that are capable of reproducing, which limits the resilience of the population.

What has the Basin Plan delivered?

The implementation of the Basin Plan, including the delivery of water for the environment, has contributed to actions which have led to some improvements in the population condition of black bream and greenback flounder, including the management of barrage outflows, in particular:

- Low (< 1000 GL/year) to moderate (4,000 – 6,000 GL/year) outflows, particularly the timing and volume of outflows, which provide conditions to support the recruitment of both species
- Outflows to support the creation of salt wedge habitat conditions (i.e. an area where freshwater sits above saltwater) during black bream spawning periods. This has helped keep eggs and larvae buoyant and provide food for newly hatched fish to develop and grow.

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- improved system connectivity and productivity has supported more favourable habitat and nursery grounds for both species.

With the contribution of water for the environment, there have been greater extents of estuarine salinity conditions in the Murray estuary and Coorong to support adult fish from both species.

What is still to be done?

Ongoing measures to improve the future outlook for black bream and greenback flounder include:

- Management of barrage outflow at key times of the year to maintain the extent of estuarine habitat conditions and increase occurrence of salt wedge habitat to support recruitment.
- Maintaining an open Murray Mouth to provide system connectivity and favourable salinity conditions for both fish species.
- Ongoing fishery management including closures during the spawning season near the barrages to ensure the sustainability and resilience of these fish populations.

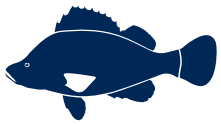
Although outside of our current management influence, periodic high (unregulated) flow events are important and are needed more frequently to enable the maintenance of suitable habitat conditions in the Coorong and Murray estuary, particularly following low flow years. High flow events also enhance the productivity in the system which in turn supports increases in the numbers and distribution of both species, including new recruits.

What do we expect to see in the future?

It is expected that with effective fisheries management, continued maintenance of estuarine conditions, and continued implementation of the Basin Plan, the population condition of both bream and flounder in the Murray estuary and Coorong will continue to improve.

In the longer-term, the easing of water delivery constraints will support the delivery of water for the environment to the CLLMM during spring and summer, which is a critical time for recruitment of these fish species.

Easing of water delivery constraints will support these fish species in the longer-term.



Expected outcome report: Fish

Diadromous fish recruitment

Trend
Getting better

Reliability
Good

Recruitment of diadromous fish has improved due to increased system connectivity.

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 is diadromous fish recruitment important?

The CLLMM is the only location in the Murray-Darling Basin where there is an interface between freshwater, estuarine and marine environments. Diadromous fish species in the Basin need to pass through and use all of these habitats to complete their lifecycle. Subsequently, recruitment of diadromous fish provides a good indication of the level of system connectivity.

This evaluation has assessed two species of diadromous fish, congolli and common galaxias, which represent different movement and life-cycle habitat requirements.

Overall, diadromous fish recruitment has improved since Basin Plan adoption.

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

The diadromous fish recruitment index is determined by the rate of upstream migration for fish less than one year old (young of year). The Long-term Environmental Watering Plan sets target values of 44.5 young of year/hour for congolli and 6.1 young of year/hour for common galaxias.

Overall, diadromous fish recruitment has improved since Basin Plan adoption. During the Millennium Drought, and prior to Basin Plan adoption, recruitment index scores were very low for both species (Figure 9). There was almost no upstream migration of congolli between 2007/08 and 2010/11, or in common galaxias between 2007/08 and 2009/10, leading to very low recruitment index scores in those years. Low to moderate recruitment index scores were observed and neither species surpassed the recruitment index values prior to 2012 with the exception of common galaxias in 2006/07.

Since Basin Plan adoption both species have exceeded the recruitment index values in all years, with the exception of common galaxias in 2016/17. This is thought to be because in that year the peak migration period occurred in January, while the index is calculated for the period between October to December only. Recruitment index values peaked for both species between 2013-2016 but have remained higher that values recorded prior to 2013.

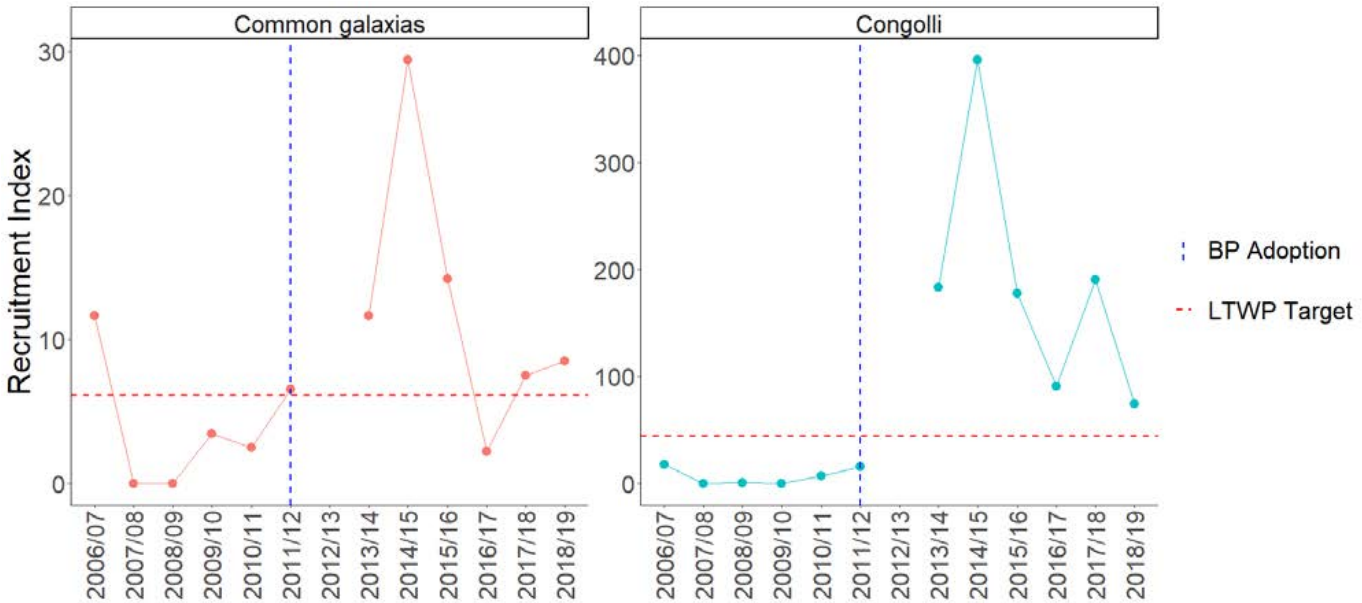


Figure 9: Annual recruitment index (RI, number of upstream migrating YOY/hour) for common galaxias and congolli from 2006/07 to 2018/19 (no monitoring was conducted in 2012/13). Basin Plan adoption is shown as a vertical dashed blue line and the Long-term Watering Target is shown as a horizontal dashed red line. Data source: SARDI

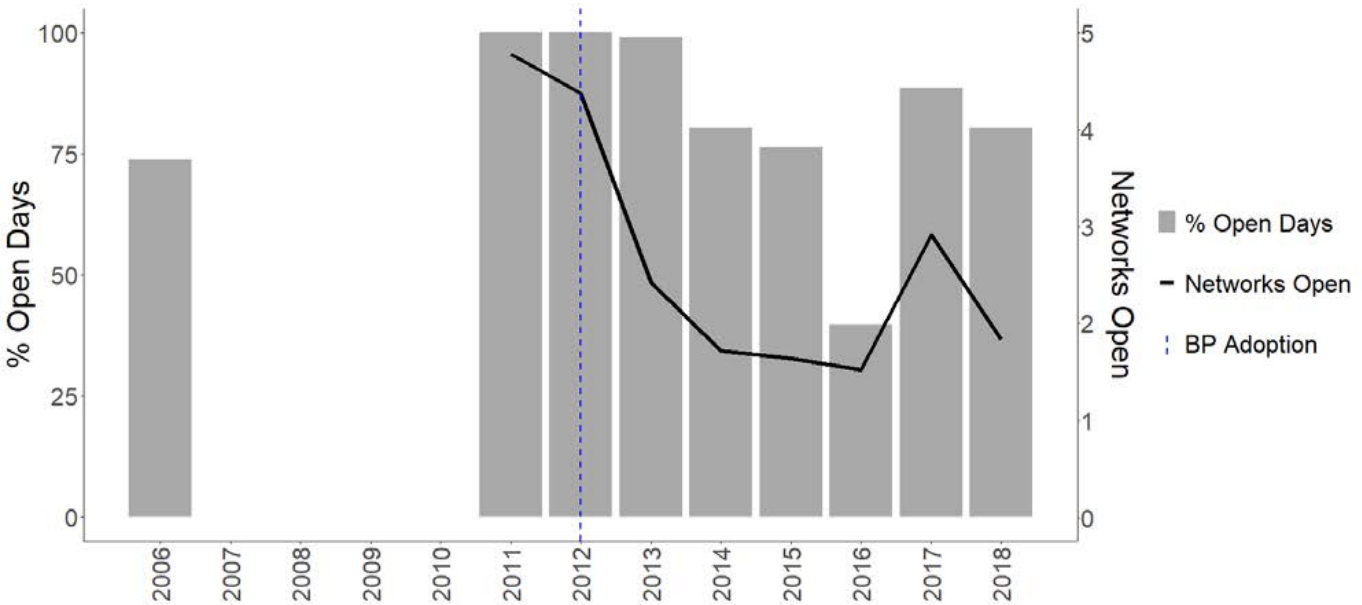


Figure 10: The percentage (%) of open days (i.e. when one or more barrage gates were open) from 2006-2018 and the mean number of barrage networks open (barrages with one or more gates open) per day from 2011-2018 during the downstream migration period (May-August) for diadromous fish in the CLLMM. Basin Plan adoption is shown by the vertical dashed blue line. Data source: SARDI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Is this what we expected to see?

Freshwater flows and system connectivity are important to enable the movement of diadromous fish species within the CLLMM. Based on the short term management of the water regime, including barrage outflows and connectivity through barrages (including fishways), we expected to meet the recruitment index values in all years (100%) for congolli and 6 of 7 years (86%) for common galaxias. The observed recruitment index values for both congolli and galaxias were as expected.

Why are seeing these results?

The lack of barrage outflows and loss of connectivity due to closure of the barrages (Figure 10) and fishways during the Millennium Drought, resulted in negligible recruitment of diadromous fish and a depletion of the population of reproductively mature adults. Since the end of the Millennium Drought, and the adoption of the Basin Plan, system connectivity has improved, allowing diadromous fish to migrate during critical times for reproduction and recruitment.

The construction of additional fishways since 2004 has helped to increase the geographical spread of migration pathways for diadromous fish. Since the break of the Millennium Drought in October 2010, a minimum of four fishways have remained open at all times.

Dredging of the Murray Mouth to maintain openness has supported the recruitment of congolli, as females complete their downstream migration by passing through the Murray Mouth to meet males in the Southern Ocean for spawning.

Maintaining connectivity between freshwater, marine and estuarine environments is critical for supporting diadromous fish in the future.

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What has the Basin Plan delivered?

The delivery of water for the environment recovered through the Basin Plan, has contributed to improved system connectivity by maintaining open barrage gates in winter and operation of fishways in spring and summer, including:

- Winter flow pulses when lake levels were low, which enabled barrage gates to remain open to support downstream migration of adult females to spawning grounds.
- Increased volumes of water reaching the Lakes in spring and summer, which supported the operation of fishways and provided flow cues for upstream movement of young of year fish to freshwater environments.

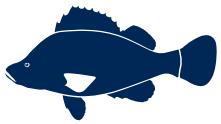
In years when high (unregulated) flows did not occur during winter months (i.e. 2015, 2017, 2018 and 2019), the coordinated delivery of water for the environment with upstream catchments (particularly the Goulburn) contributed to winter flow pulses in the South Australian River Murray, which supported diadromous fish movement and recruitment.

What is still to be done?

Maintaining connectivity between key freshwater, marine and estuarine environments within the CLLMM is critical for managing diadromous fish migration and recruitment in the future. Continued delivery of freshwater flows through open barrage gates and fishways during critical times, as well as dredging of the Murray Mouth, will support this connectivity.

What do we expect to see in the future?

The recruitment of congolli and common galaxias is expected to be maintained as Basin Plan implementation progresses, through the continued delivery of water to support connectivity through open barrage gates and fishways. Over the longer-term climate variability may influence the availability of water during spring and summer, which could limit future improvements to diadromous fish recruitment.



Expected outcome report: Fish

Small-mouthed hardyhead

Trend
Getting better

Reliability
Excellent

Small-mouthed hardyhead recruitment is improving, and is better than we expected at this point in time.

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 small-mouthed hardyhead important?

small-mouthed hardyhead are an important part of the Coorong foodweb, particularly in the South Lagoon. They are the most abundant species in the southern Coorong and are a major food source for other biota, including fish and waterbirds. Maintaining or improving small-mouthed hardyhead abundance and distribution is an important part of managing the health of the Coorong.

The proportion of sites with significant recruitment of smallmouth hardyhead is increasing.

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 population. A value of greater than 60% of juveniles within the population 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 proportion of sites with significant recruitment of small-mouthed hardyhead is increasing. During the peak of the Millennium Drought (2008 to 2010) only 20% of monitoring sites showed significant recruitment (Figure 11). During periods of increased flows from 2010 to 2014 the number of sites meeting the target proportion of juveniles increased to between 88 to 100% of sites, surpassing the target for small-mouthed hardyhead in the Coorong. Between 2014 and 2016 there was a reduction in sites meeting the target to 63%, which was associated with periods of low flow.

With a return to high flows in 2016, all sites showed significant recruitment, which was maintained through low flow periods in 2017/18. When low flows continued in 2018/19 recruitment decreased to 75% of sites.

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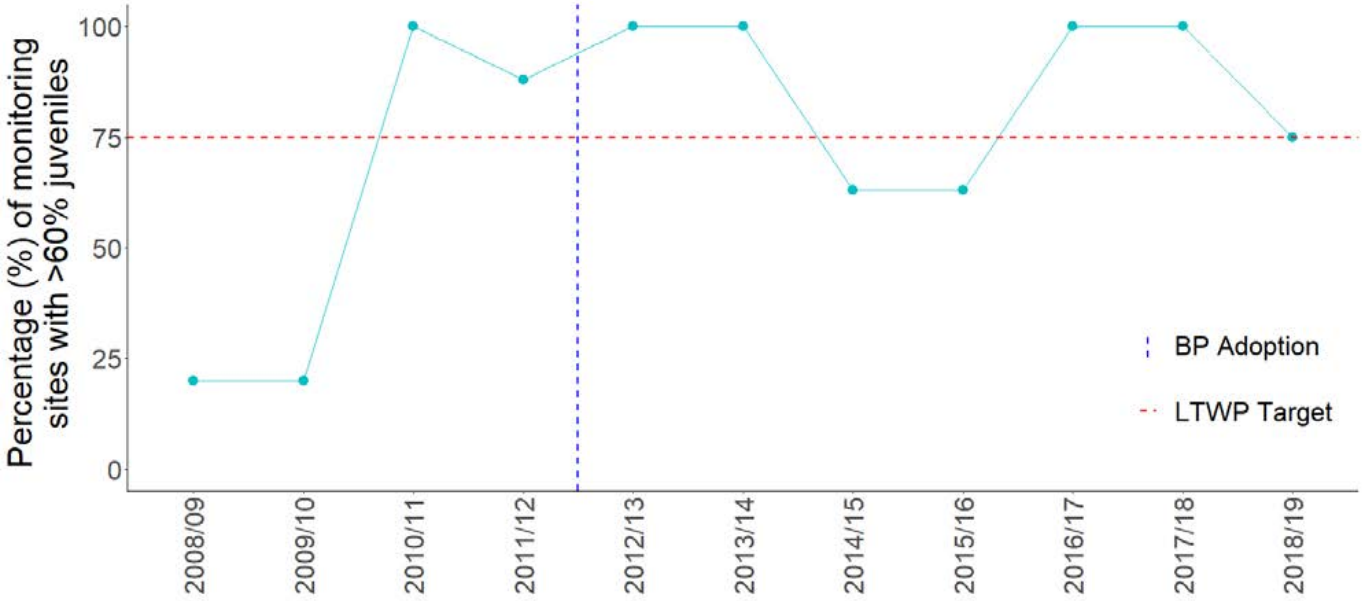

Figure 11: Percentage (%) of monitoring sites where the proportional abundance of juvenile small-mouthed hardyhead was >60% from 2008/09 to 2018/19. The LTWP Target is marked by a horizontal dashed red line. Basin Plan adoption is marked by a vertical dashed blue line. Data source: SARDI


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Is this what we expected to see?

Hydrology and salinity are key drivers of small-mouthed hardyhead populations in the CLLMM. Based on the short-term management of the water regime, including River Murray inflows and barrage outflows and current salinity, conditions we expected that 63% of sites would meet the target in 2019. The target was met at 75% of sites in 2019, which is better than we expected at this point in time.

Why are we seeing these results?

The absence of barrage outflows during the Millennium Drought led to salinities exceeding the threshold of the preferred salinity range for small-mouthed hardyhead throughout much of the Coorong, particularly the South Lagoon. This limited the distribution and recruitment of the species. The return of flows since the end of the Millenium Drought, and the delivery water for the environment, restored water levels, reduced salinities and enhanced productivity in the Coorong.

Dredging has also helped to maintain an open Murray Mouth which enables salt export and helps to maintain water levels in the Coorong. This has supported a greater availability of habitat for small-mouthed hardyhead.

What has the Basin Plan delivered?

The implementation of the Basin Plan, including the delivery of water for the environment, has supported small-mouthed hardyhead populations by contributing to actions, including:

- Barrage outflows, which have increased the extent of favourable salinity conditions in the Coorong that support small-mouthed hardyhead populations.
- Delivery of water for the environment, which has been critical in low flow years, ensuring that Coorong salinities

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were below 100g for a majority of the time (the upper threshold of the preferred salinity range for small-mouthed hardyhead).

- Increasing the spatial and temporal extent of favourable salinity conditions leading to greater habitat availability and a broader distribution of small-mouthed hardyhead in the Coorong.

What is still to be done?

Ongoing actions to support maintain and/or improve the resilience of small-mouthed hardyhead populations include:

- Management of barrage outflows and inputs to the southern Coorong to maintain the extent of suitable habitat conditions to support small-mouthed hardyhead.
- Maintain an open Murray Mouth to provide system connectivity, enhance system productivity and enable improvements in salinity conditions in the Coorong to support small-mouthed hardyhead recruitment.

Although outside of current management influence, periodic high (unregulated) flow events are important and are needed more frequently to enable the maintenance or increase in extent of suitable habitat conditions (particularly following low flow years). High flow events also enhance the productivity in the system which in turn supports increases in the distribution and recruitment of small-mouthed hardyhead.

What do we expect to see in the future?

It is expected that the extent of recruitment of small-mouthed hardyhead will be maintained from 2019 as we continue to implement the Basin Plan. The peak benefits for small-mouthed hardyhead populations will likely occur during the next ten years, due to greater water recovery and through easing current water delivery constraints. Over the longer-term, increased climate variability and the influence on water availability is likely to be a big driver of small-mouthed hardyhead populations.

The implementation of the Basin Plan, including the delivery of water for the environment, has supported small-mouthed hardyhead populations.

Expected outcome report: Birds

Lakes waterbird abundance

Trend
Getting better

Reliability
Very good

Lakes waterbirds are showing signs of recovery, however condition of the community is still considered to be poor.

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 recognised as part of a wetland of international importance and supports nationally or internationally threatened species and species listed on international migratory bird agreements. The Lakes provide important habitat for waterbird feeding and breeding. The permanent wetlands of the Lakes provide refuge habitat for waterbirds during summer, with their importance increasing during dry years.

Waterbirds are sensitive to changes in environmental conditions, as well as the quality and availability of habitat and food resources. Therefore waterbirds are an important indicator of ecosystem health. Many waterbirds are also culturally and recreationally significant.

The abundance of waterbirds in the Lakes has improved since Basin Plan adoption.

What is the trend and current status of waterbirds in the Lakes?

Waterbirds are grouped into 'guilds' based on their diet, the way they search for food and their life history. In the Lakes ten species of waterbirds representing three guilds (generalists, herbivores and piscivores) have been assessed (Figure 12).

The abundance of waterbirds in the Lakes varied greatly between years. Despite this variability, the overall abundance of the selected species within the guilds is likely to have improved between 2009 and 2019.

The condition of waterbirds in the Lakes 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 selected species within the guild have exceeded their long-term median abundance target.

Prior to Basin Plan adoption, very few generalist and herbivore species and no piscivore species exceeded their abundance target (Figure 12). Following Basin Plan adoption, the proportion of selected species that exceeded their abundance targets increased for generalists and herbivores between 2013 and 2019, while piscivores improved between 2013 and 2016 and then declined between 2016 and 2019 (Figure 12).

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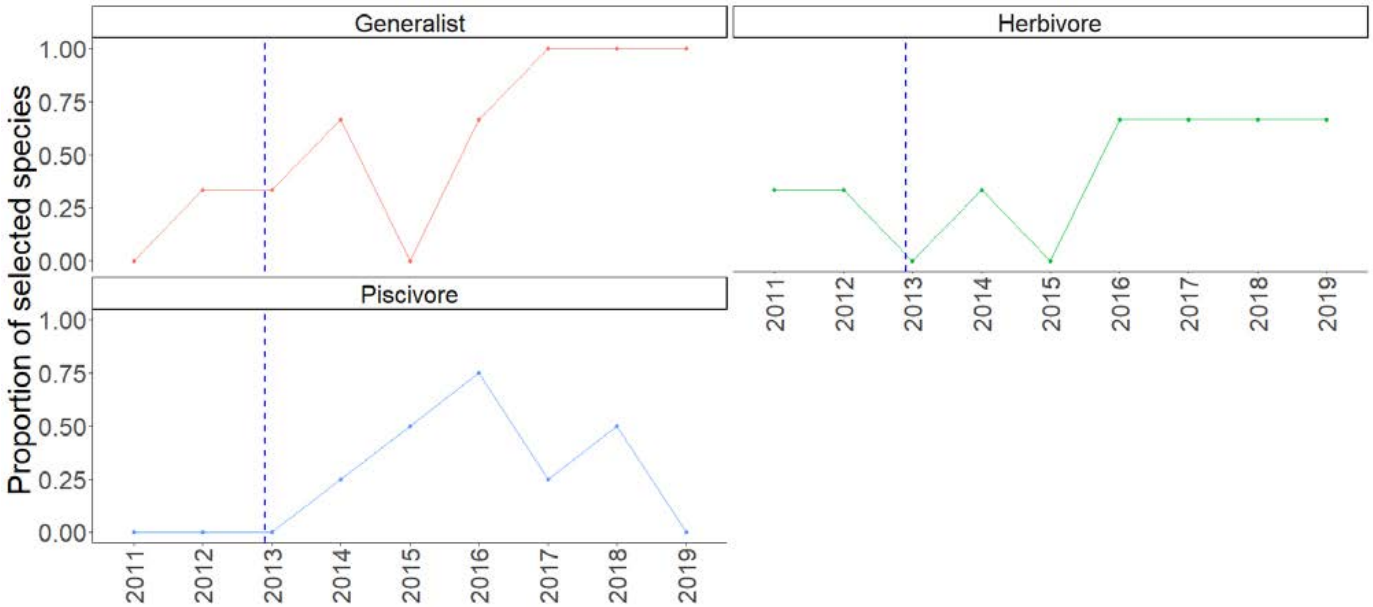

Figure 12: The proportion of selected species within each guild that were at or above their recent (2013–2015) median abundance in two of the last three years in the Lakes from 2011–2019. Basin Plan adoption (November 2012) is shown by the vertical dashed blue line. Data source: University of Adelaide

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Is this what we expected to see?

The availability and quality of waterbird habitat in the Lakes is driven by freshwater inflows, water level and salinity. Based on the current water management regime, and changes in habitat condition, we expected 78% of generalist species, 78% of herbivore species and 40% of piscivore species to have exceeded their abundance target.

In 2019 the proportion of generalist species that exceeded their abundance target was higher than expected (100%), while herbivores (67%) and piscivores (0%) were lower than expected.

Why are we seeing these results?

The abundances of selected waterbird species in the Lakes have improved since the end Millennium Drought and are considered to have recovered. Improvement in the abundances of guilds was influenced by the delivery of water; namely through management of lake levels, improved system connectivity and the restoration of salinities to pre-drought conditions:

- Management of lake levels leads to seasonal water level variability to support aquatic and fringing vegetation, which provides key habitat for waterbirds, particularly for breeding.
- Maintenance of lake levels above +0.4 m AHD provides permanently inundated habitats, which support key food resources and breeding of waterbirds
- Improved system connectivity and the restoration of salinities reflective of pre-drought conditions may have helped to maintain food resource availability and distribution and provided conditions to support waterbird breeding.

These factors are mostly maintained through the planned (not licensed) environmental water (PEW) component of South Australia's Entitlement and high (uregulated) flows.

What has Basin Plan delivered?

The implementation of the Basin Plan has contributed to actions that have sustained improvement in Lakes waterbirds through the protection of


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water for the environment. In dry years, Held Environmental Water (HEW) has been important in maintaining water levels prior to that water being released to the Coorong, which in turn supports Lakes waterbird communities.

What is still to be done?

The current hydrological and salinity regimes, including the management of lake levels, need to be maintained to support the continual improvement of key waterbird habitats in the Lakes. Although outside of current management influence, periodic high (unregulated) flow events are important and are needed more frequently to support the maintenance of key processes in the Lakes, particularly the flushing of salt to support suitable salinity regimes.

In addition, the continuation and enhancement of management actions such as fringing wetlands management, including the wetting and drying of key waterbird wetlands around the Lakes (e.g. Tolderol, Teringie, Waltowa), will contribute to greater improvement in the condition of Lakes waterbirds.

What do we expect to see in the future?

Through implementation of the Basin Plan it is expected that the abundances of waterbird species in the Lakes will be variable between guilds, due to changes in the availability and quality of food resources and habitat. In the longer-term it is expected that these abundances will be maintained, however climate variability will influence local and Basin-scale water and habitat availability for waterbirds. Whether this will result in improvements or declines in Lakes waterbird abundances is yet to be determined, but will likely increase the importance of the Lakes as key refuge habitats for waterbirds within the Basin.

The current hydrological and salinity regimes need to be maintained to support the continual improvement of key waterbird habitats in the Lakes.

Expected outcome report: Birds

Coorong waterbirds

Trend
Getting worse

Reliability
Very good

The abundance of Coorong waterbirds is getting worse, 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 Coorong waterbirds important?

The Coorong is recognised as part of a wetland of international importance and supports nationally or internationally threatened species and species listed on international migratory bird agreements. The permanent wetlands of the Coorong provide refuge habitat for waterbirds during summer, with their importance increasing during dry years.

Waterbirds are sensitive to changes in environmental conditions, as well as the quality and availability of habitat and food resources. Therefore waterbirds are an important indicator of ecosystem health. Many waterbirds are also culturally and recreationally significant.

Migratory shorebirds have declined in the Coorong at a rate greater than elsewhere in Australia.

What is the trend and current status of waterbirds in the Coorong?

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 abundance of waterbirds in the Coorong varied greatly between years (Figure 13). Despite this variability, the overall abundance of species within the guilds is likely to have declined between 2000 and 2019.

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 2000 the proportion of species that exceeded their abundance targets increased for generalists, herbivores and piscivores, remained stable for resident shorebirds and declined for migratory shorebirds (Figure 13). Since Basin Plan adoption, the proportion of species that have exceeded their abundance targets since Basin Plan adoption increased for piscivores; was maintained for generalists, herbivores and resident shorebirds; and has fluctuated greatly for migratory shorebirds (Figure 13).

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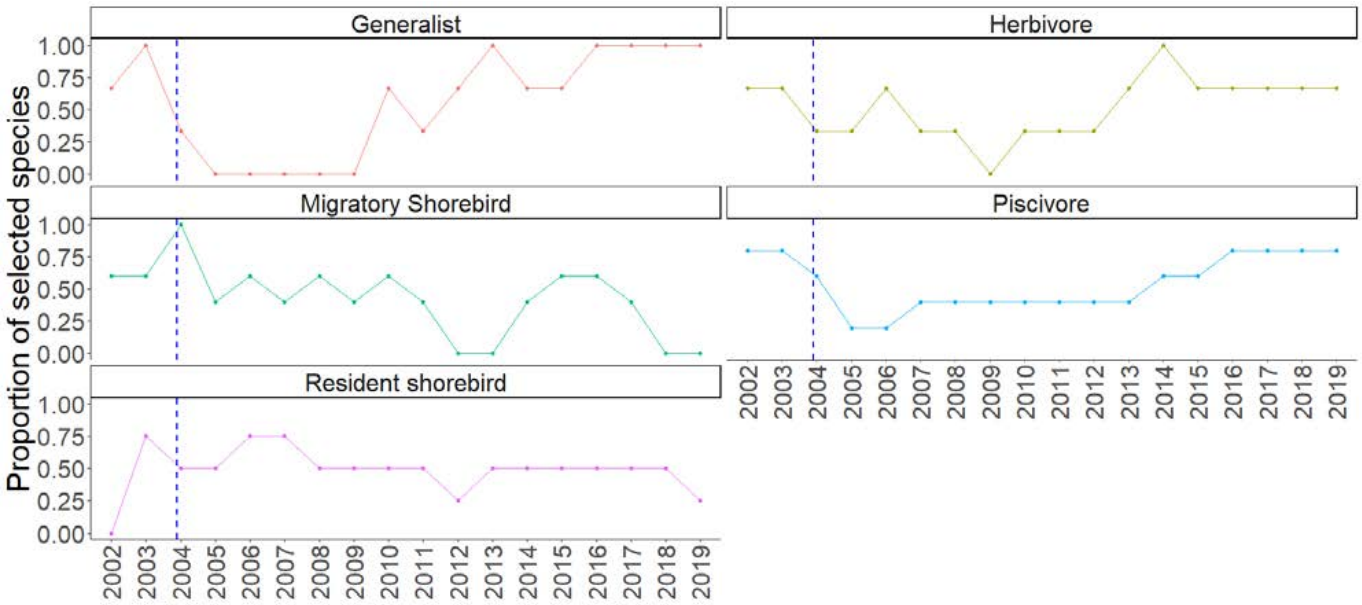

Figure 13. The proportion of selected species within each guild that exceeded their long-term median abundance in two of the last three years in the Coorong from 2002–2019. Basin Plan adoption (November 2012) is shown by the vertical dashed blue line. Data source: University of Adelaide


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Is this what we expected to see?

The availability and quality of waterbird habitat in the Coorong is driven by barrage outflows, Coorong water level and salinity. Based on the current water management regime, and changes in habitat condition, we expected 67% of generalist species, 67% of herbivore species, 60% of piscivore species, 33% resident shorebirds and 20% migratory shorebirds to have exceeded their abundance target.

In 2019, the proportion of species that exceeded their abundance target was higher than expected for generalists (100%) and piscivores (80%), while herbivores (67%) were as expected. Resident shorebirds (25%) and migratory shorebirds (0%) were lower than expected.

Why are we seeing these results?

The abundances of waterbird species in the Coorong have declined, however trends in abundance vary greatly between guilds. High (unregulated) flows events, particularly in 2010/11 and 2016/17, increased the extent of estuarine salinity conditions throughout the Murray estuary and Coorong north lagoon, which likely contributed to improved food resource availability for piscivore, herbivore and generalist species.

Resident and migratory shorebirds are declining, with migratory shorebirds declining at a rate greater than elsewhere in Australia. This decline is influenced by barrage outflows, Coorong water levels, salinity, nutrients and the occurrence of filamentous algae. These factors have impacted the availability and quality of food resources and habitats to support Coorong waterbirds.

Off-site changes in the availability of wetlands at national and international scales and the breeding success of waterbirds at these wetlands have likely also influenced the abundances and types of waterbirds in the Coorong.

What has the Basin Plan delivered?

Water for the environment and high (unregulated) flows have prevented salinities in the Coorong from becoming reminiscent of the Millennium Drought. Inadequate water levels and water quality have hampered the recovery of key waterbird habitats and food resources and subsequently the abundance of waterbirds in the Coorong.

© Martin Stokes

What is still to be done?

In order to improve abundances of key waterbird species in the Coorong more is still to be done.:

- We need adequate water level regimes to support available mudflat habitat in spring and summer and the quality and availability of food resources, including Ruppia and benthic invertebrates. Adequate water level regimes would also support the protection of important breeding sites, including islands, from terrestrial predators and human disturbance.
- Increased flows are needed to flush the system to improve nutrient conditions and limit the occurrence of filamentous algae, which will support productivity and a healthy, functioning food web for waterbirds
- An open Murray Mouth, along with periodic high (unregulated) flow events, are important and are needed more frequently to support the maintenance of key processes in the Coorong, particularly the flushing of salt and nutrients to support suitable water quality conditions.

Inadequate water levels and poor water quality have hampered the recovery of key waterbird habitats.

What do we expect to see in the future?

Through implementation of the Basin Plan it is expected that the abundances of waterbird species in the Coorong will be variable between guilds, based on the water regime and quality of habitat and food resources in the Coorong. In the longer-term it is expected that there may be declines in some species, however climate variability will influence local and Basin-scale water and habitat availability for waterbirds. Whether this will result in improvements or declines in Coorong waterbird abundances is yet to be determined, but will likely increase the importance of the Coorong as key refuge habitats for waterbirds within the Basin.

Channel and Floodplain

Priority Environmental Asset summary

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Description of the assets

River Murray Channel - stretches from the South Australian border to Wellington, a distance of approximately 560 river kilometres. The lateral extent comprises the area inundated at flows up to 40,000 ML/day QSA under normal River operations. This asset includes an array of aquatic habitats, including fast and slow flowing channels and anabranches as well as still backwaters. These environments provide habitat for a variety of native fish, frogs, waterbirds and macroinvertebrates. The Channel asset intersects two Ramsar-listed Wetlands of International Importance - the Riverland Ramsar Site and the Banrock Station Wetland Complex.

River Murray Floodplain - is the equivalent length to the River Murray Channel asset and consists of the area that is inundated at flows between 40,000 ML/day QSA and 80,000 ML/day QSA (under normal River operations). It is comprised of ephemeral habitats, including shedding floodplains and temporary wetlands. When inundated the Floodplain PEA provides productive habitat for wetland-dependent fauna and drives key processes including primary productivity. When dry, it also provides habitat for terrestrial flora and fauna species.

For more information about the Channel Floodplain and PEAs please see the Long-Term Environmental Watering Plan for the South Australian River Murray water resource plan area.

River Murray Channel and River Murray Floodplain key messages

- Following the impacts of the Millennium Drought and adoption of the Basin Plan, the Channel and Floodplain areas of the River Murray in South Australia have shown some positive signs of recovery, particularly in areas where water for the environment has been delivered.
- High (unregulated) flows are important for the system and are critical to reach areas of the floodplain that cannot be supported through managed inundation, including areas of floodplain at Chowilla, Pike and Katarapko that sit outside of the management influence of regulators.
- Many indicators are constrained to sites where there has been targeted delivery of water for the environment, including through weir pool manipulation and managed floodplain inundations. Therefore the results may not be representative of conditions across the wider channel and floodplain assets.
- Full implementation of the Basin Plan, including addressing current water delivery constraints, is required to achieve greater frequency, duration and magnitude of overbank flows along the South Australian River Murray to further improve environmental outcomes in these assets.
- Implementation of the Basin Plan to date has supported:
  - provision of small-scale fast-flowing habitats and enhanced productivity
  - managed floodplain inundations using infrastructure, at key sites
  - improvements in river red gum and black box tree condition at sites where water has been delivered
  - improvements in the population structure and recruitment of Murray cod, creating a more resilient population
- However, challenges remain including:
  - addressing the physical and policy constraints to enable the delivery of water to greater areas of the floodplain when it is most needed, including to areas outside managed assets
  - providing fast-flowing habitats over larger areas of the River Murray channel
  - improving the resilience of the golden perch population.
- Continued effort and investment is required to improve the health of the Channel and Floodplain through:
  - striving for full implementation of the Basin Plan
  - undertaking the investigations and works planned under South Australia's Supply Measures and Southern Basin Constraints Measures Projects
  - continued involvement of the local community and First Nations to find enduring solutions.

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.

Irrigation and agriculture leading to land clearance, soil disturbance.

Pressures

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

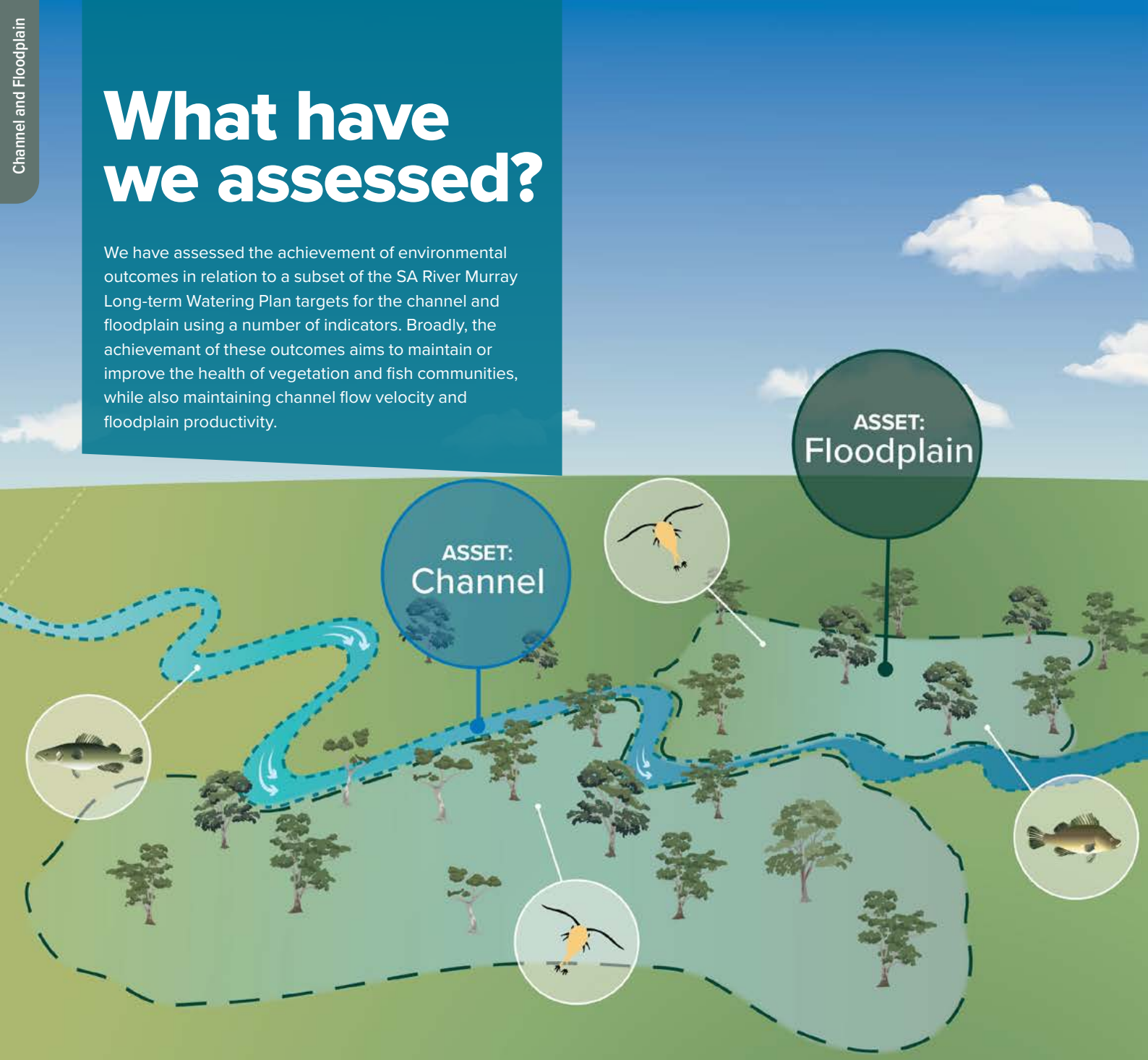
River regulation, including water diversions and barriers have led to reduced flows, reduced levels of surface and groundwater, and altered hydrological regimes.

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

Invasive species and problematic natives.

What have we assessed?

We have assessed the achievement of environmental outcomes in relation to a subset of the SA River Murray Long-term Watering Plan targets for the channel and floodplain using a number of indicators. Broadly, the achievemant of these outcomes aims to maintain or improve the health of vegetation and fish communities, while also maintaining channel flow velocity and floodplain productivity.



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

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

River red gum: habitat provision and contribution of organic matter to the channel ecosystem.

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

River red gum: habitat provision and contribution of organic matter to the channel ecosystem.

Fish (Golden Perch and Murray Cod): Key recreational, cultural and economic species responsive to flow.

Evaluation findings

There have been some improvements in channel and floodplain condition since the adoption of the Basin Plan.

Where we are seeing improvement

The delivery of water has helped to:

- Support managed floodplain inundations which has contributed to limited improvement in river red gum and black box condition within the inundated areas, as well as increases in microinvertebrates in response to flooding events.
- Deliver of water has also helped to provide overbank and spring-summer flows, and more localised fast-flowing habitats which may have supported the recruitment and dispersal of Murray cod and an increase in food resources for these fish.

Where we are not seeing improvement

Some indicators have not improved:

- Since the adoption of the Basin Plan, volumes of water delivered were insufficient to provide desired flow velocity conditions across large areas and for extended periods of time.
- Golden perch recruitment has been limited by the lack of fast-flowing habitats over large areas of the River Murray channel and a hypoxic blackwater event in 2016/17.

The SA River Murray channel and floodplain had already been experiencing dry conditions prior to the Millennium Drought, and this was further exacerbated during dry years. With only two natural high (unregulated) flows since the breaking of the drought, much of the SA floodplain has not been inundated for a long time. Although conditions are improving in areas that we can manage with environmental water delivery, this is likely not to be representative of condition of the broader floodplain.

Integrated floodplain infrastructure

Floodplain infrastructure at Chowilla, Pike and Katarapko aims to improve the environmental health and resilience of parts of these three floodplains and associated wetlands by maximising the benefits from water delivery. The use of this infrastructure will enable us to manage flows into and around these key floodplain environments, inundating a greater area than previously possible at lower flows.

The Chowilla environmental regulator has been in operation since 2014. Infrastructure at Pike and Katarapko floodplains will be operational from 2020.

Channel and Floodplain
Expected outcomes reports

*Trend is the change over time, calculated using all available data for an indicator

↗	Trend **Getting better**	**Getting better:** The indicator is improving over the period of assessment
—	Trend **Stable**	**Stable:** The indicator is neither improving nor declining over the period of assessment
↙	Trend **Getting worse**	**Getting worse:** The indicator is declining over the period of assessment
?	Trend **Unknown**	**Unknown:** Data are not sufficient to determine any trend in the status of this 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 on the evaluation please see the technical information:

Theme	Indicator	Trend*	Information reliability	Key findings
Flow & Ecosystem Function	Flow velocity	Trend **Stable**	Reliability **Good**	The extent of fast-flowing habitats has increased; however we have not seen the range of velocity classes as desired.
	Productivity (micro-invertebrates)	Trend **Unknown**	Reliability **Very good**	Microinvertebrate densities and species numbers increased following the two largest inundation events between 2014 and 2018.
Vegetation	River red gum	Trend **Getting better**	Reliability **Poor**	The proportion of red gums in good or excellent condition has increased at some Pike, Katarapko and Chowilla floodplain habitats.
	Black box	Trend **Getting better**	Reliability **Poor**	The condition of black box has increased at some Chowilla, Pike and Katarapko floodplain habitats.
Fish	Murray cod	Trend **Getting better**	Reliability **Fair**	Recruitment of Murray cod has improved since Basin Plan adoption, with recent recruits present each year of sampling.
	Golden perch	Trend **Stable**	Reliability **Fair**	The age structure of the golden perch population in 2019 is characteristic of a population with low resilience.

Expected outcome report: Flow and Ecosystem Function

Flow velocity

Trend
Stable

Reliability
Good

The extent of fast-flowing habitats has increased; however we have not seen the range of velocity classes as desired.

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. Fast-flowing water (≥0.3m/sec) is an important driver of 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, sediments and biota.

Since Basin Plan adoption, high spring-summer flows of ≥20,000 ML/day for 60 consecutive days have been recorded only 1 of the 7 years.

What is the trend and current status of velocity?

Fast-flowing conditions are important for ecological processes such as fish recruitment and the transport of larvae and microinvertebrates within the river. It is important that these conditions occur for at least 60 consecutive days between September and March at least every two years. These fast-flowing conditions are expected to occur in weir pools when flows across the South Australian Border are ≥20,000 ML/day.

During the Millennium Drought, between 2001 and 2010, there were no flows above 20,000 ML/day recorded in SA weir pools (Figure 14).

In late 2010-2011, following the end of the Millennium Drought, flows of ≥20,000 ML/day were recorded for 186 consecutive days.

Since Basin Plan adoption, high spring-summer flows of ≥20,000 ML/day for 60 consecutive days have been recorded only 1 of the 7 years (Table 1). However, there was an increase in the number of years where flows did reach ≥20,000 ML/day, but for less than 60 days. No days of high spring-summer flow have been recorded in the past 2 years.

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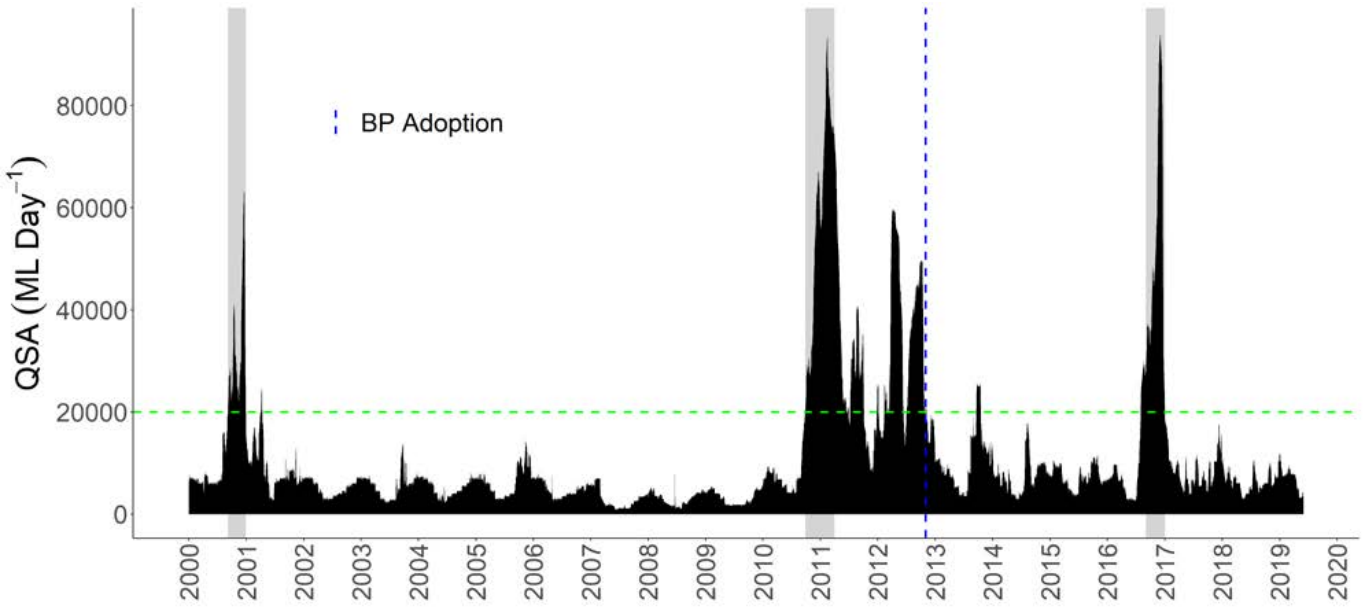


Figure 14: Flow to SA (QSA) (ML/day) from 2000-2019 showing periods where flow met the ecological index (≥20,000 ML/day for at least 60 consecutive days between September and March) as shown by grey shading. Basin Plan (BP) adoption is marked by the vertical dashed blue line (data source: Department for Environment and Water)

Year	Number of consecutive days QSA ≥20,000 ML.day-1 in September-March
2000/01	114
2001/02	0
2002/03	0
2003/04	0
2004/05	0
2005/06	0
2006/07	0
2007/08	0
2008/09	0
2009/10	0
2010/11	186
2011/12	35
2012/13	54
2013/14	29
2014/15	0
2015/16	0
2016/17	123
2017/18	0
2018/19	0

Table 1: The number of consecutive days of QSA ≥20,000 ML/day in September-March. Red shading = zero days of consecutive flow of QSA ≥20,000 ML/day in September-March; orange shading = some days of consecutive flow of QSA ≥20,000 ML/day in September-March but below the 60 day duration target; green shading = ≥ 60 consecutive days of QSA ≥20,000 ML/day in September-March. (data source: Department for Environment and Water)

Is this what we expected to see?

Based on the modelled expected water regime, including timing and duration of flow, we expected to see flows meeting the duration of 60 days during spring and summer in 2 of 7 years (29%). The desired flow conditions were observed in 1 of 7 years (14%), which is less than we expected during this time.

Why are we seeing these results?

Following Basin Plan adoption the velocity target was only achieved during a high (unregulated) flow event in 2016/17 (Figure 15). Volumes of water for the environment, coupled with SA entitlement flows and additional dilution flows, were insufficient to achieve flow of ≥20,000 ML/day for 60 consecutive days.

The Basin Plan is yet to have a significant impact on flow velocities at large scales across the extent of the SA River Murray Channel.

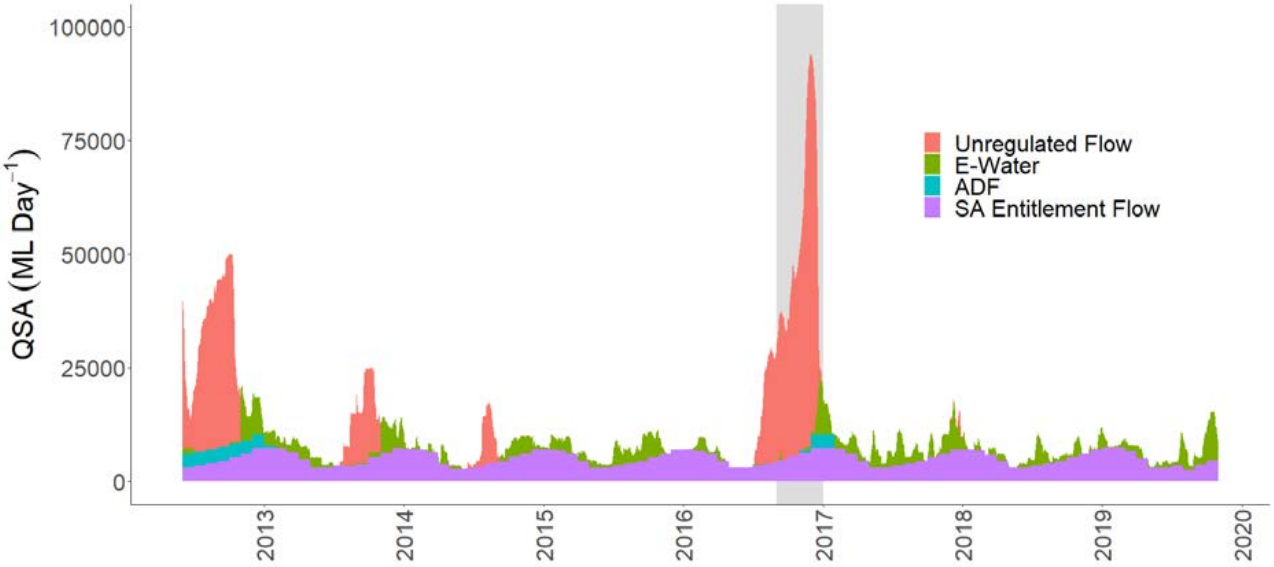


Figure 15: Contribution of unregulated flow, water for the environment (E-Water), additional dilution flow (ADF) and SA entitlement flow to Flow (ML/day) to the South Australian border (QSA) from June 2012 to November 2019. Periods where QSA was ≥20,000 ML.day-1 for at least 60 consecutive days between September and March are shaded in grey. Data source: MDBA

How has Basin Plan contributed?

The Basin Plan is yet to have a significant impact on flow velocities at large scales across the extent of the SA River Murray Channel. South Australia's Entitlement is insufficient alone, to achieve fast-flowing conditions within the SA River Murray. To meet the required flow volume and duration, both high (unregulated) flows and water for the environment will be required.

The implementation of the Basin Plan, including water for the environment, has however supported a localised increase in the area of fast-flowing habitats, particularly in 2017/18 which may have contributed to key ecological processes including fish recruitment.

It has also contributed to an increase in the number of consecutive days where flows were ≥20,000ML/day, but below 60 days, in spring-summer (Table 1).

What is still to be done

A significant improvement on flow velocities is only likely to occur with full implementation of the Basin Plan, including addressing current water delivery constraints. The relaxation of flow constraints is critical to the achievement of more frequent flows of ≥20,000 ML/day in September-March in South Australia.

Fast-flowing conditions, however, may be enhanced under current constraints and volumes of environmental water through coordination of water delivery and actions such as weir pool lowering. The use of weir pool management to support flow velocities in the SA River Murray channel needs further investigation, particularly any potential impacts on sites that already provide fast-flowing habitats, such as Chowilla.

Although outside of current management influence, high (unregulated) flow events help to restore diverse flow velocities within the River Murray channel. These events have reduced in frequency, due to river regulation and climatic conditions, but are critical to ensure that sufficient flow volumes and durations are provided during spring and summer.

What do we expect to see in the future?

Through implementation of the Basin Plan it is expected that the number of years with flows ≥20,000 ML/day for 60 consecutive days in spring-summer is expected to increase from 2019. It is expected that peak benefits for flow velocities will likely occur following full implementation of the Basin Plan in 2024 due to implementation of the Constraints Management Strategy, leading to improved delivery and management of water. Over the longer-term climate variability may limit future improvements to flow velocities in the lower River Murray.

Expected outcome report: Flow and Ecosystem Function

Floodplain productivity: microinvertebrates

?

Trend
Unknown

Reliability
Very good

Microinvertebrate densities and species numbers increased following the two largest inundation events between 2014 and 2018.

What are we trying to achieve?

The Long-term Environmental Watering Plan objective is to *"Provide for mobilisation of carbon, nutrients and propagules from the floodplain to the river."*

The corresponding Long-term Environmental Watering Plan target is: *"During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients and DOC relative to those available during base flow".*

Why are microinvertebrates important?

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, amphibians and macroinvertebrates. Microinvertebrates respond to overbank flooding and floodplain inundation, which influences the productivity within the floodplain and channel ecosystems.

Microinvertebrate density and species richness increased during the inundation event at Chowilla in 2014 and during overbank flooding in 2016-17.

What is the trend and status of microinvertebrates in the SA River Murray?

There is no pre-Basin Plan data available for this indicator. Due to this limited data, the trend for this indicator is unknown. The density and species richness (number of species) of microinvertebrates were compared between years with and without floodplain inundation. This was assessed using two of the largest inundation events between 2014-2018:

- Managed floodplain inundation in 2014, of 2,142 ha through the operation of Chowilla regulator and raising of Lock and Weir 6.
- Overbank flooding in 2016/17 with flow to SA peaking at >93,000 ML/day.

Microinvertebrate density and species richness increased during the inundation event at Chowilla in 2014 (Figure 16) and during overbank flooding in 2016-17 (Figure 17). The increases recorded at Chowilla however, were spatially and temporally limited.

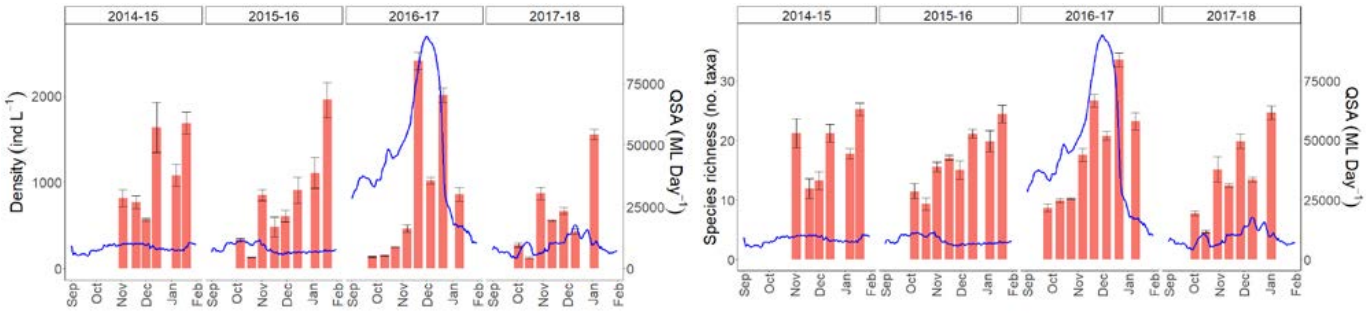


Figure 16: Mean (±S.E.) density (individuals/L) and species richness (no. taxa) of microinvertebrates collected at sites below Lock 6 from 2014-15 to 2017-18. Data are plotted against flow (ML/day) at the South Australian border (QSA). Sampling were conducted between 26 October and 21 January (Data source: SARDI)

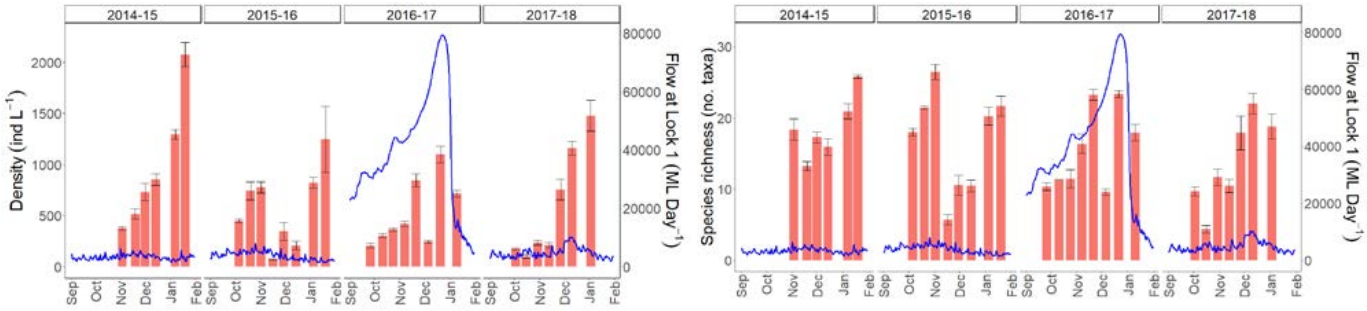
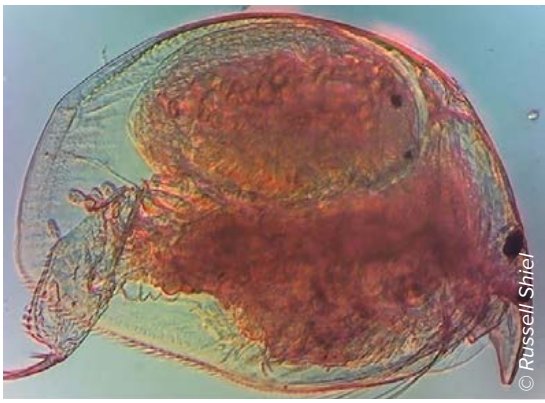


Figure 17: Mean (±S.E.) density (individuals/L) and species richness (no. taxa) of microinvertebrates collected at sites below Lock 1 from 2014-15 to 2017-18. Data are plotted against flow (ML/day) at the South Australian border (QSA). Sampling were conducted between 26 October and 21 January (Data source: Data source: SARDI)



Is this what we expected to see?

We expected to see an increase in microinvertebrates during overbank flooding and managed floodplain inundation, because these events:

- trigger the emergence of microinvertebrates from dormant eggs stored within sediments (egg banks)
- provide access to still or slow-flowing habitats where survival, feeding and reproduction of microinvertebrates is increased.

The timing duration and frequency of inundation influences the microinvertebrate community, which in turn influences the food resources available for key floodplain and channel biota.

The observed increases in microinvertebrate density and species richness were consistent with our conceptual understanding of how these communities respond to overbank flooding and managed floodplain inundations.

Why are we seeing these results?

Water for the environment, in combination with the operation of the Chowilla regulator and weir pool raising 2014/15 contributed to increased microinvertebrate densities and species richness. Although observed at limited temporal and spatial scales, it contributed to increased transport of microinvertebrates along parts of the river channel.

Further monitoring and research are required to improve our understanding the changes of microinvertebrates communities over the longer-term.

How has Basin Plan contributed?

The contribution of environmental water to this outcome is unclear and targeted monitoring is required to better understand and evaluate the responses of microinvertebrate to environmental water delivery.

Water for the environment contributed between 3,000 and 4,500 ML/day to the operation of the Chowilla regulator in 2014/15. This increase in flow lead to enhanced lateral and longitudinal connectivity, which facilitated dispersal of microinvertebrates and potentially contributed to increases in their density and species richness.

The contribution of water for the environment in 2016/17 was limited as overbank flooding occurred due to high (unregulated) flows. Water for the environment was delivered at Chowilla ahead of the natural high flows to extend the watering as well as to the tail-end of these flows to mitigate the impact of hypoxic blackwater, and this may have contributed to the recovery of microinvertebrate densities following this event.

What is still to be done

Measures to enhance microinvertebrate densities and species richness in the SA River Murray may include environmental water delivery combined with managed floodplain inundations.

Consideration of the timing and duration of managed floodplain inundation events should include:

- Inundation during spring and early summer with warmer water temperatures which enhances microinvertebrate densities.
- Protection and restoration of spring-flow pulses which are needed for the transport of microinvertebrates down the river, which in turn has a positive effect on the foodweb.
- Duration of at least 3 weeks to enable microinvertebrate reproduction and replenishment of the egg bank, although the most beneficial duration of inundation events is currently unknown.

There is currently a lack of data for microinvertebrates in the South Australian River Murray. Further monitoring and research is required to fill knowledge gaps, particularly around how microinvertebrates respond to different flow and management scenarios. This is a current priority of South Australia's Integrated Operations Program and is also included as part of the Commonwealth Environmental Water Monitoring, Evaluation and Research Program.

What do we expect to see in the future?

Construction of regulators at Pike and Katarapko floodplains was completed in 2020 and will enable greater areas of each floodplain to be inundated in future years. This should contribute to an increase in channel and floodplain productivity in the SA River Murray.

Close collaboration with other states and environmental water holders to deliver coordinated spring pulse flows along the whole River Murray is occurring with coordinated River channel watering in 2019 and planned for 2020. As flow constraints through the Basin are addressed it is expected that these spring pulses could make an increasing contribution to improved channel and floodplain productivity throughout the system including in the SA River Murray.

Further monitoring and research are required to improve our understanding the changes of microinvertebrates communities over the longer-term.

Expected outcome report: Vegetation

River red gum

Trend
Getting better

Reliability
Poor

The proportion of red gums in good or excellent condition has increased at some Pike, Katarapko and Chowilla floodplain habitats.

What are we trying to achieve?

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

Why are river red gum important?

River red gums 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. They support food webs and provide important habitat for diverse species of birds, reptiles, bats, insects and amphibians.

There has been overall improvement in river red gum condition for both channel and floodplain trees between 2009-10 and 2011-12.

What is the trend and status of river red gum in the SA River Murray?

The condition of River red gums within 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 suggests a tree in in good health, while a TCI of 4-9 suggests a tree is in fair condition and may respond to water delivery. A TCI below 4 is indicative of a tree in poor condition, which may have a slow response to watering and require multiple watering events to resume a trajectory towards good condition. Data used for the assessment is limited to assets with floodplain infrastructure (Chowilla, Pike and Katarapko floodplains), which may not be representative of the entire SA River Murray channel and floodplain assets.

There has been overall improvement in River red gum condition both channel and floodplain trees between 2009/10 and 2011/12.

At channel sites, the percentage of trees with a TCI score ≥10 has increased from 4% in 2007/08 to 69% in 2018/19 (Figure 18). At floodplain sites, the percentage of trees with a TCI score ≥10 increased from 10% in 2007/08 to 65% in 2018/19 (Figure 19). Short declines in condition were seen in 2009/10 and 2013/14.

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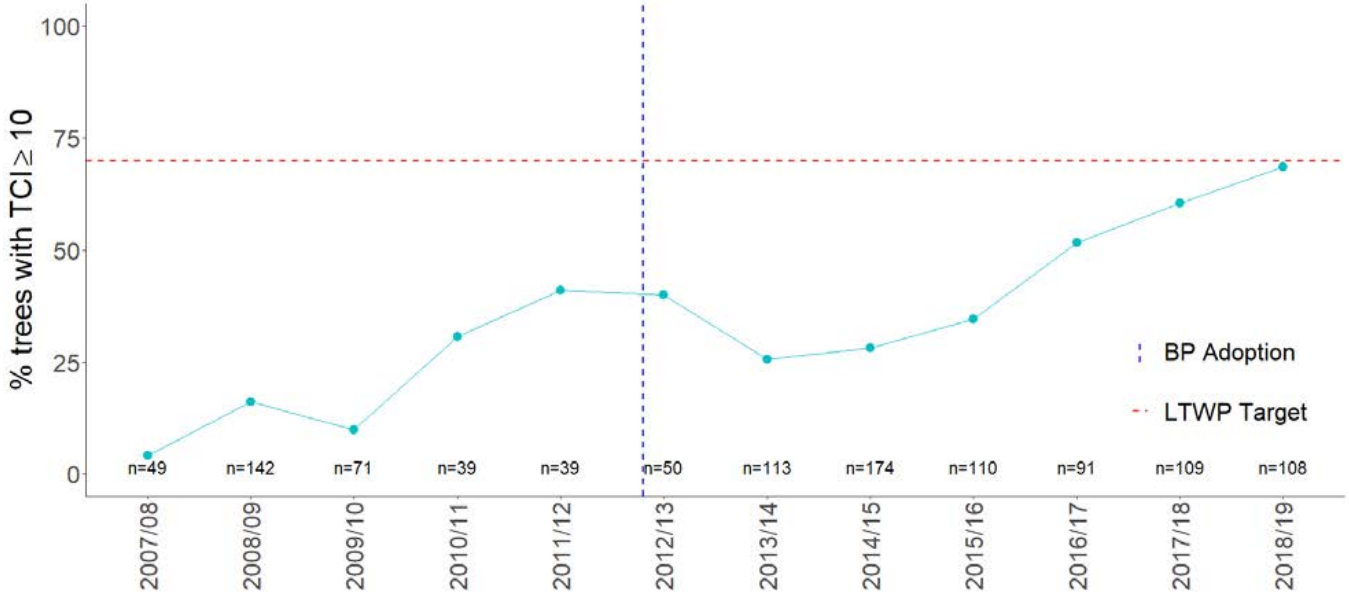

Figure 18: Percentage (%) of river red gums with TCI ≥10 in the Channel PEA extent of the Chowilla, Pike and Katarapko floodplains from 2007/08 to 2018/19. Sample size (n) is provided above the x axis for the corresponding water year (Data source: Biological Database of SA)

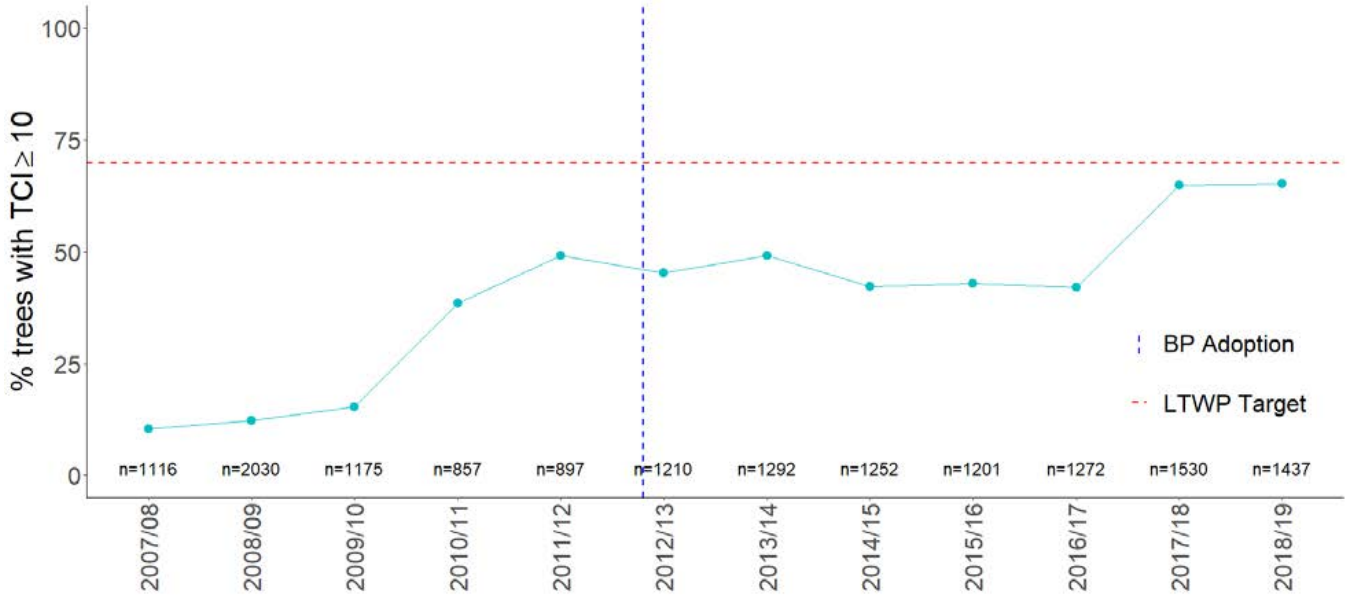

Figure 19: Percentage (%) of river red gums with TCI ≥10 in the Floodplain PEA extent of the Chowilla, Pike and Katarapko floodplains from 2007/08 to 2018/19. Sample size (n) is provided above the x axis for the corresponding water year (Data source: Biological Database of SA)

Is this what we expected to see?

River red gum population condition is influenced by a number of factors, including the frequency of flooding, rainfall, groundwater level, soil moisture and salinity. Based on the historical condition of trees and the forecasted current water regime for trees within management influence, we expected to see:

- 52% of trees with a TCI ≥10 within the channel
- 46% of trees with a TCI ≥10 within the floodplain.

Currently, the observed condition of trees within both the selected channel and floodplain sites are higher than expected, with 69% of trees with a TCI ≥10 in the channel and 65% of trees with a TCI ≥10 within the floodplain. However, it should be noted that this data is derived from monitoring undertaken from sites where there has been targeted delivery of water for the environment, thus the results for the entire SA channel and floodplain may be lower than the observed condition.

Why are we seeing these results?

River red gum condition at channel and floodplain sites within Pike, Katarapko and Chowilla has improved from poor condition in 2007/08 to good condition in 2018/19. Improvements across the channel and floodplain were likely influenced by:

- High (unregulated) flow events 2010/11 and 2016/17, which led to improvements in tree condition in subsequent years.
- High rainfall events (particularly in 2010/11 and 2016/17) may have improved River red gum condition.
- Water delivery, supported by water for the environment and actions including:
  - Elevated within channel flows in 2009/10 and 2011/12 prior to the unregulated flow event.
  - Managed floodplain inundations during inter-flood dry years, through pumping, weir pool raising and the operation of the Chowilla regulator.

How has 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, increasing river water levels and improving hydrological connectivity between habitats. This helped to limit the deterioration of river red gum condition between periods of floodplain inundation.

Delivery of water has also enabled floodplains to be inundated via operation of infrastructure, which may have maintained the condition and increased resilience of trees, which improves the response of trees to future flooding events. It also supported a small increase in the area of inundation, with more trees receiving water.

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What is still to be done

River regulation and the historical changes to the water regime have contributed to a decline in river red gum condition in the SA River Murray channel and floodplain. Delivery of water for the environment is an important management tool to improve the condition and resilience of river red gum populations, by:

- helping to increase the proportion of trees in good condition
- improving the ability of trees to tolerate dry periods
- supporting improved responses of trees to watering when water is available.

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 sit outside of management influence.

Monitoring to date has been concentrated at those sites that are actively managed. There was unequal sampling effort between sites used for this assessment, with differences in sampling effort through time. Future assessments should incorporate data that is more representative of the broader SA channel and floodplain which may require complementary methods such as remote sensing to cover a larger area.

What do we expect to see in the future?

Through implementation of the Basin Plan, it is expected that the condition of river red gum within the channel and floodplain will marginally improve. This improvement will be highly dependent on rainfall and flow conditions. In addition, larger volumes of water will be required to inundate greater extents of the floodplain through the operation of regulators at Chowilla, Pike and Katarapko. Weir pool management and delivery of water for the environment may also contribute to improved tree condition at these sites.

Full implementation of the Basin Plan, including addressing current water delivery constraints, is required to achieve greater frequency, duration and magnitude of overbank flows along the SA River Murray, which may lead to improvements in river red gum condition. Over the longer-term climate variability may limit future improvements to river red gum condition in the SA River Murray.

Delivery of water for the environment is an important management tool to improve the condition of river red gum populations.

Expected outcome report: Vegetation

Black box

Trend
Getting better

Reliability
Poor

The condition of black box has increased at some Chowilla, Pike and Katarapko floodplain habitats.

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."*

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 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 birds, reptiles, bats and insects.

The condition of black box has increased at some Chowilla, Pike and Katarapko floodplain habitats.

What is the trend and status of black box on the SA River Murray floodplain?

The condition of black box within the SA River Murray floodplain was assessed at Chowilla, Pike and Katarapko using a standardised tree condition index (TCI). A TCI above 10 suggests a tree in in good health, while a TCI of 4-9 suggests a tree is in fair condition and may respond to water delivery. A TCI below 4 is indicative of a tree in poor condition, which may have a slow response to watering. Data used for the assessment is limited to assets with floodplain infrastructure (Chowilla, Pike and Katarapko floodplains), which is unlikely to be representative of the entire SA River Murray floodplain asset.

The percentage of trees with a TCI score ≥10 has improved from 10% in 2008/09 to 65% in 2018/19 (Figure 20). The most notable improvement was recorded between 2009/10 and 2011/12, which coincided with very high rainfall and widespread flooding in 2010/11.

Improvements across the floodplain were recorded prior to Basin Plan adoption between 2009/10 and 2011/12, and following adoption of Basin Plan between 2016/17 and 2018/19. In 2009/10 and between 2013/14 and 2016/17 declines were seen despite overall improvements within the areas monitored.

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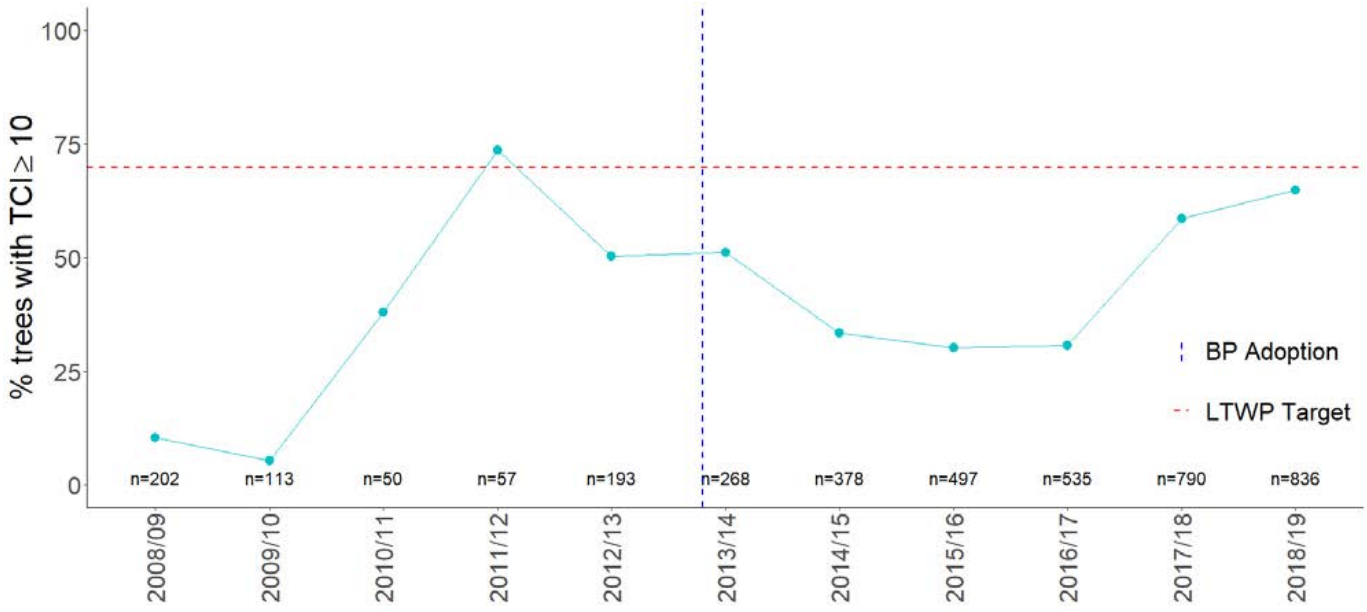

Figure 20: Percentage (%) of black box in good or excellent condition (TCI score ≥10) in the Floodplain PEA extent of the Chowilla, Pike and Katarapko floodplains from 2008/09 to 2018/19. Sample size (n) is provided above the x axis for the corresponding water year. Data source: Biological Database of SA


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Is this what we expected to see?

Black box population condition is influenced by a number of interrelated factors, including the frequency of flooding, rainfall, groundwater level, soil moisture and salinity. Based on the historical condition of trees and the forecasted current water management regime we expected to see 35% of trees with a TCI ≥10. Currently the observed condition of trees is higher than expected with a total of 65% of trees with a TCI ≥10. However, it should be noted that this data is derived from monitoring undertaken from sites where there has been targeted delivery of water for the environment, thus the results for the entire SA floodplain may be lower than the observed condition.

Why are we seeing these results?

Black box condition at floodplain sites within Pike, Katarapko and Chowilla has improved from 2008/09 to 2018/19. Improvements across the floodplain were likely influenced by high (unregulated) flow events 2010/11 and 2016/17, which led to improvements in tree condition in the following year and a moderate increase in the resilience of the population and the ability to withstand short dry periods. In addition, high rainfall events (particularly in 2010/11 and 2016/17) may have improved black box condition.

Improvements across the floodplain were also likely influenced by water delivery supported by water for the environment and actions including managed floodplain inundations during inter-flood dry years through pumping and the operation of the Chowilla regulator.

Declines of black box condition between 2013/14 to 2016/17 were generally due to the combination of absence of overbank flows and low rainfall.

How has 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, in addition to managed floodplain inundations, may have maintained the condition and increased resilience of trees, which improves the response to future flooding events.

Water for the environment may have also supported a minor increase in the area of inundation, with more trees receiving water.

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What is still to be done

The historical changes to the water regime have contributed to a decline in black box condition in the SA River Murray floodplain. Delivery of water for the environment is an important management tool to improve the condition and resilience of black box populations, by:

- helping to increase the proportion of trees in good condition
- improving the ability of trees to tolerate dry periods
- supporting improved responses of trees to watering when water is available.

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 sit outside of management influence.

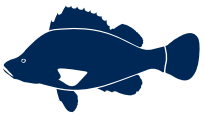
There was unequal sampling effort between sites used for this assessment, with differences in sampling effort through time. Future assessments should seek to incorporate data that is more representative of the broader SA channel and floodplain, which may require complementary methods such as remote sensing to cover a larger area.

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 floodplain will remain stable within areas able to be influenced by the delivery of water for the environment. It is expected that black box will decline at areas of higher elevation outside of management influence. Black box condition will be highly dependent on rainfall and flow conditions. In addition, larger volumes of water will be required to inundate greater extents of the floodplain through the operation of regulators at Chowilla, Pike and Katarapko. Weir pool management and delivery of water for the environment may contribute to improved tree condition at these sites.

Full implementation of the Basin Plan, including addressing current water delivery constraints and continued protection of high flow events, is required to achieve improvements in black box condition. Over the longer-term climate variability may limit future improvements to black box condition in the SA River Murray.

Since Basin Plan adoption, improvements in black box condition have largely been supported by rainfall and high (unregulated) flow events.



Expected outcome report: Fish

Murray cod

Trend
Getting better

Reliability
Fair

Recruitment of Murray cod has improved since Basin Plan adoption, with recent recruits present each year of sampling.

What are we trying to achieve?

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

Why are black box important?

Murray cod is an iconic and nationally threatened fish species within the Murray-Darling Basin. It is a key predator in the river ecosystem, as well as an important cultural and recreational species.

Overall, Murray cod recruitment has improved since data collection began in 2002.

What is the trend and status of Murray cod in the SA River Murray

Population condition of Murray cod is determined by the age classes (recent recruits, sub-adults and adults) identified within the population. The age of Murray cod is determined by length. The presence of all age classes represents a good population structure, which is required for a resilient population.

Overall, Murray cod recruitment has improved since data collection began in 2002 (figure 21). Prior to Basin Plan adoption, and during the Millennium Drought, the population of Murray cod featured all age classes in only 20% of years. Following the end of the Millennium Drought, and Basin Plan adoption, population condition has improved as all age classes were seen in every year (100%).

Since Basin Plan adoption, recruitment has been recorded during low flow years in the main channel of the River Murray, which did not occur during the Millennium Drought.

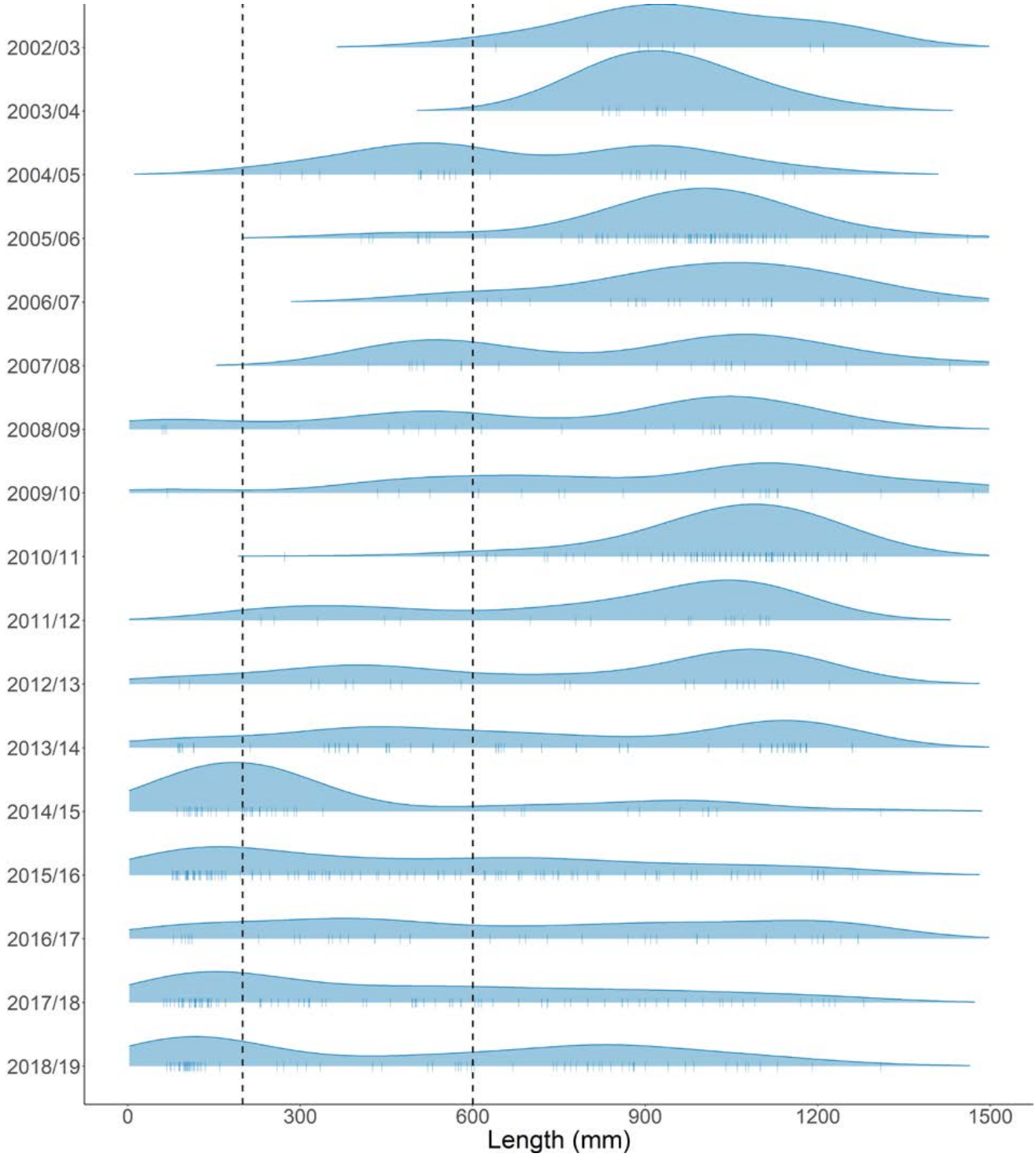
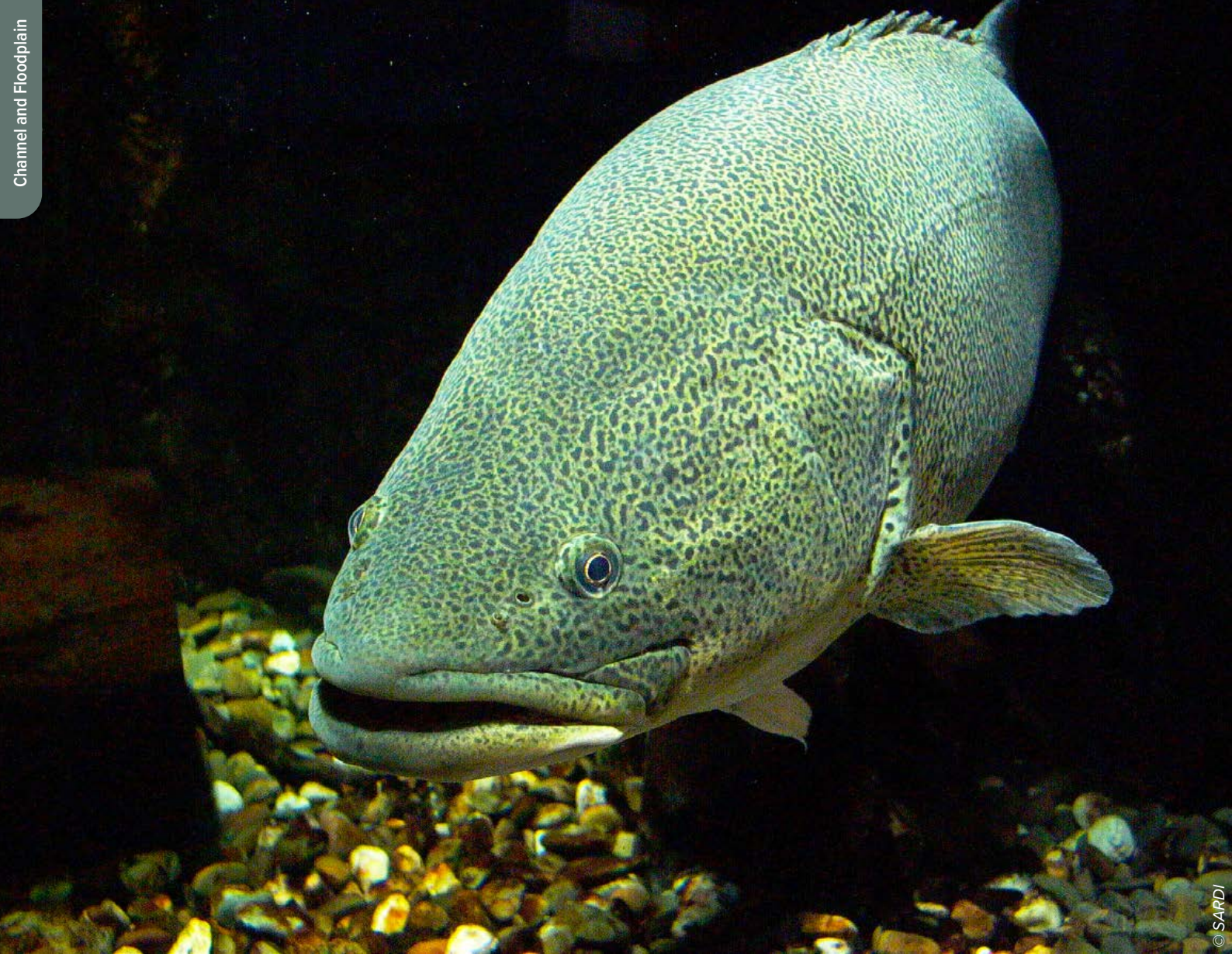


Figure 21: Density plot of Murray cod length (mm) sampled from 2002/03-2018/19. Lengths of individual fish in each water year are marked by \|. Note: recent recruits (includes YOY and 1+ fish) are <200 mm, sub-adults are 200-600 mm and adults are >600 mm in length (Data source: SARDI)



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Is this what we expected to see?

Recruitment of Murray cod appears to be strongly linked to the diversity of flow velocities within the channel. Based on the current water management regime, including flow conditions and water quality, it was expected that the population age structure of Murray cod would include all age classes in 5 of 7 (71%) years since Basin Plan adoption (2013-2019). All age classes were recorded within the Murray cod population in all seven years (100%) following Basin Plan adoption, which was higher than expected.

Why are we seeing these results?

While there are data available for 17 years, the numbers of Murray cod caught were low and our understanding of the influence of water delivery on the recruitment and population structure of Murray cod is limited. It is likely that a number of factors contributed Murray cod recruitment and population age structure since Basin Plan adoption, including the provision of localised fast-flowing conditions may have supported recruitment and the dispersal of Murray cod larvae. Overbank flows and spring-summer flows may have also contributed to an increase in food resources for Murray cod larvae, which supports their recruitment.

Recent improvements may also have been supported by local In-stream woody habitat (snags) restoration projects downstream of Lock 4 and Lock 3. These were undertaken through the South Australian Riverland Floodplains Integrated Infrastructure Program.

A hypoxic blackwater event associated with overbank flows in 2016/17 may have prevented strong recruitment and caused some mortality of adult Murray cod.

How has Basin Plan contributed?

The contribution of water for the environment to this outcome to date is unclear.

Water for the environment was delivered to mitigate the impacts (i.e. low dissolved oxygen) of the blackwater event in 2016/17 and may have lessened the impact on Murray cod populations.

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What is still to be done

The continued delivery of water, including water for the environment through the implementation of the Basin Plan, aims to improve flows for fish reproduction and recruitment. Key water management and delivery actions to support Murray cod populations include restoration of late spring/summer flow pulses, in particular:

- ≥15,000 ML/day to increase flow velocities in the upper SA River Murray
- ≥20,000 ML/day to restore diversity of flow velocities along the entire extent of the SA River Murray which support productivity and provide important food resources for fish

In addition, weir pool lowering can increase the length of fast-flowing conditions and may further improve Murray cod recruitment.

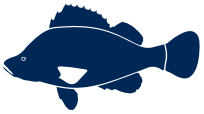
Complementary management actions that may benefit Murray cod include re-snagging to support regular recruitment and enhance the response of Murray cod to improvements in hydraulic diversity.

The flowing habitats and in-channel woody habitat within the Chowilla Anabranch system are an important site supporting the population and regular recruitment of Murray cod in South Australia. This should be considered if weir pool raising is undertaken at Lock 6.

Murray cod monitoring currently being undertaken at critical sites such as Chowilla should be maintained. However, targeted research and data collection are needed to determine the factors influencing the recruitment and population size of Murray cod in the SA River Murray. This would improve our understanding of how the Murray cod population responds to water delivery, including water for the environment. Improved monitoring would also provide more data and increase our confidence in evaluation and reporting for this species, as well as inform the use of management levers to promote recruitment outcomes.

What do we expect to see in the future?

Although its broadly expected that the delivery of water for the environment will continue to support Murray cod populations in the SA River Murray, further monitoring and research are required to inform the suite management actions to support Murray cod communities over the longer-term.



Expected outcome report: Fish

Golden perch

Trend
Stable

Reliability
Fair

The age structure of the golden perch population in 2019 is characteristic of a population with low resilience.

What are we trying to achieve?

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

Why are black box important?

Golden perch are a medium to large bodied fish. Golden perch are widespread in the Murray-Darling Basin and occur within the SA River Murray. The species is an important commercial, recreational and cultural fish species. Golden perch can live up to 26 years, although most individuals live less than 10–12 years.

The overall population age structure of golden perch has not significantly changed between 2004-05 and 2018-19.

What is the trend and status of golden perch in the SA River Murray?

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

The overall population age structure of golden perch has not significantly changed between 2004/05 and 2018/19, therefore the overall trend is considered stable. Recruitment has not been detected since 2013/14.

During the Millennium Drought the population age structure of golden perch consisted predominantly of adult fish (Figure 22). With the breaking of the drought but prior to Basin Plan adoption, all age classes were present in the population. Since Basin Plan adoption the population has contained all age classes in only 2 of 7 years.

Diversity in age structure is currently low, as a vast majority of individuals are adults aged between five and nine years and there are few individuals in younger age classes. This is characteristic of a population with low resilience.

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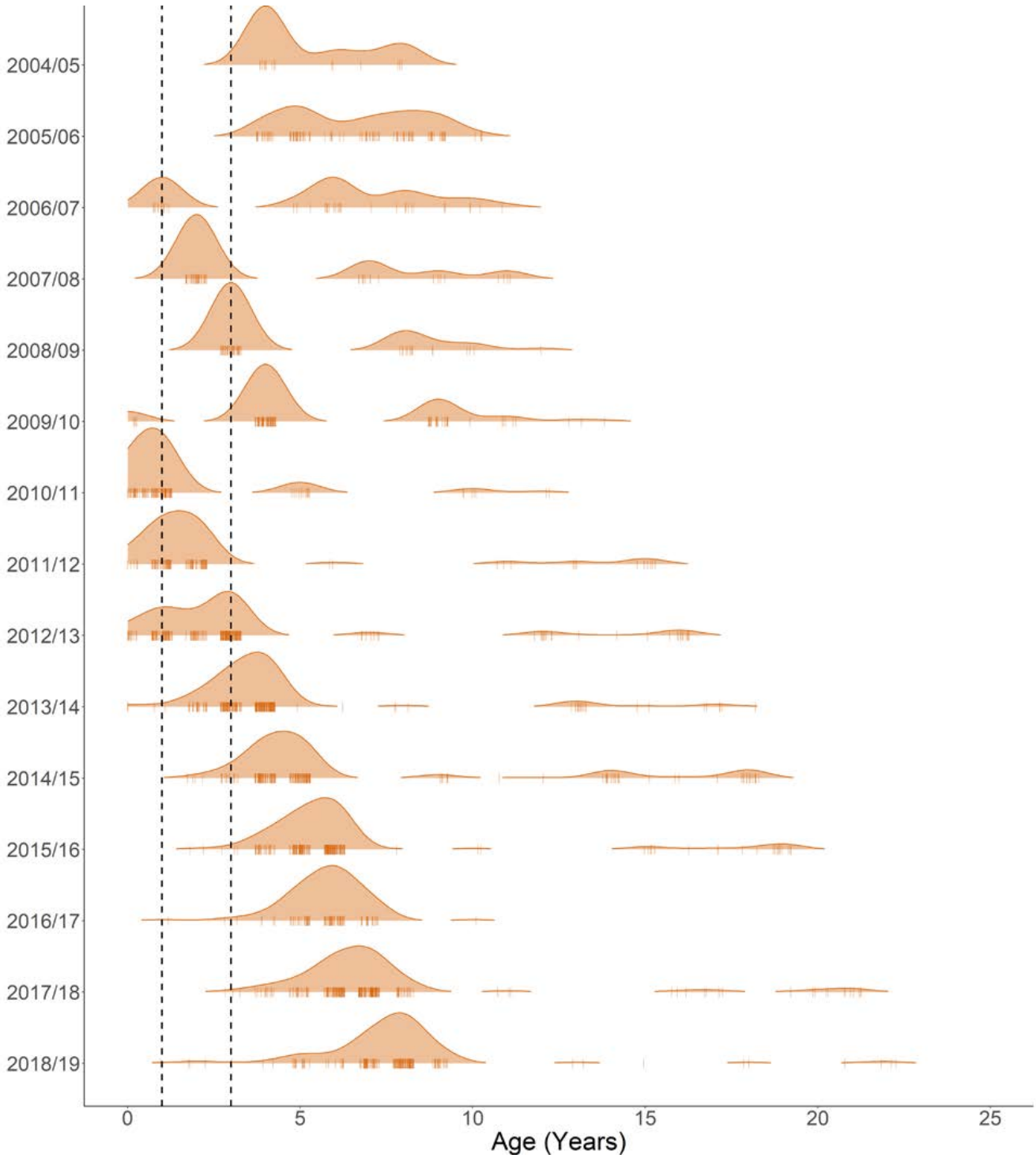

Figure 22 Density plot of golden perch age (years) from 2004/05-2018/19 in the Channel PEA. Ages of individual fish in each water year are marked by |. Markers have been jittered to prevent overlap of individual fish with the same age. Note: YOY are <1 year of age, sub-adults are 1-3 years old and adults >3 years old (Data source: SARDI)

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Is this what we expected to see?

Flow and system-wide connectivity are important drivers of golden perch age structure and recruitment. Based on the current water management regime, including flow to SA and diversity of flow within the channel, we expected the population age structure of golden perch to include sub-adults and adults in 5 of 7 (71%) years since Basin Plan adoption. In the last 7 years the desired age structure was observed in 6 of 7 (85%) years, which is slightly higher than expected. However, we also expected the population to feature large recruitment events in 3 of 7 (43%) years, however this was observed in only 2 of 7 (29%) years.

Why are we seeing these results?

Despite the improved flow conditions following the Millennium Drought and adoption of the Basin Plan, recruitment and population age structure of golden perch has remained stable, neither improving nor declining. This is likely due to:

- A hypoxic blackwater event associated with overbank flows in 2016/17, which likely prevented strong recruitment in that year.
- A lack of fast-flowing conditions over large spatial scales (>100 km), which are needed to stimulate and improve local spawning and recruitment and facilitate immigration of fish and transport of larvae from other regions within the Basin.

How has Basin Plan contributed?

The Basin Plan is yet to have a significant impact on golden perch populations in the SA River Murray Channel. Water for the environment contributed to a minor increase in the extent of localised fast-flowing habitats in 2015/16, 2016/17 and 2018/19, and moderate increases in 2017/18.

Water for the environment was delivered to mitigate the impacts of the blackwater event in 2016/17 which may have lessened the potential negative impact on golden perch populations.

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What is still to be done

The continued delivery of water for the environment through Basin Plan implementation aims to improve flows for fish reproduction and recruitment. Improvements in water delivery and management to support golden perch populations include:

- Spring-summer flow pulses ≥20,000 ML/day, which would help to restore hydraulic diversity and support productivity outcomes and food resources, along the SA River Murray.
- Weir pool lowering, which may increase the length of fast-flowing habitat and may further improve golden perch recruitment.
- Coordinated delivery of water out of all tributaries (Darling, Murrumbidgee and Goulburn) and improved flexibility in water delivery from Lake Victoria to support transport of larvae and recruitment of golden perch.

Other management actions that may benefit golden perch include re-snagging (the reintroduction of woody debris to fast-flowing habitats) to support regular recruitment and enhance the response of golden perch to improvements in hydraulic diversity.

What do we expect to see in the future?

Improvements in water delivery and complementary management actions such as the reintroduction of woody debris into fast-flowing habitats, are needed if we are to see further improvements in the golden perch populations in the SA River Murray.

Close collaboration with other states and environmental water holders to deliver coordinated spring pulse flows along the River Murray is occurring with coordinated River channel watering in 2019 and planned for 2020. As flow constraints through the Basin are addressed these spring pulses will likely make an increasing contribution to improved channel and floodplain productivity throughout the system, including in the SA River Murray , which would support outcomes for species such as golden perch.

Improvements in water delivery and complementary management actions are needed to see further improvements in golden perch populations in the SA River Murray.

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.
Aquatic vegetation	Plant species that grow partly or wholly within aquatic environments.
Barrages	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 event	Blackwater events occur during flooding when organic material is washed off the river bank and floodplain and into the river system.
Constraints measures	Measures that would facilitate environmental flows, improve infrastructure, erosion control works and easement negotiation.
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)	A 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.
Electrical Conductivity (EC)	A unit commonly used to indicate the salinity of water (1 EC = 1 microsiemen per centimetre, measured at 25˚C).
Ecosystem function	The exchange of energy and nutrients in the food chain.
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 1850 GL/year.
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).
Floodplain infrastructure	The regulators, blocking banks and culverts that assist in delivering water to wetlands and floodplains.
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.
Held Environmental Water (HEW)	Environmental water that is available under a water access right for the purposes of achieving environmental outcomes.

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.
Hypersaline	A waterbody that contains significant concentrations of sodium chloride (salt), with saline levels surpassing that of the ocean water.
Hypoxic blackwater	Blackwater events occur during flooding when organic material is washed off the river bank and floodplain and into the river system. The water can then become hypoxic (low oxygen) when the material decomposes reducing the oxygen in the water.
Invertebrates	Cold-blooded animals without a backbone or bony skeleton, such as insects, worms and crabs.
Littoral vegetation	Plants occurring in areas near the edge of a wetland or lakes, between the high water mark and shoreline areas that are permanently submerged.
Estuary	The part of a river in which water levels are affected by tides, and where freshwater and saltwater mix.
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.
Overbank flows	Flow that rises over the river bank and connects the river to the floodplains and wetlands.
Piscivore (waterbird)	A group of waterbirds that primarily feed upon fish.
Population age structure	The distribution of individuals' ages within a population.
Planned Environmental Water (PEW)	Planned environmental water is water committed in a water plan for achieving environmental outcomes as defined in Section 6 of the *Water Act 2007*.
Priority Environmental Asset	An environmental asset that can be managed with environmental water.
Productivity	The generation of biomass in an ecosystem.
QSA	Flow at the South Australian border, often expressed as mega litres per day (ML/day).
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.
Seasonal water level cycling	The fluctuations in the water level of the Lakes for ecological outcomes.
Lake level cycling	A rapid reduction in water level of the Lakes to flush salt from the Lakes.
Salt wedge	An area where freshwater sits above saltwater.
Seed bank	A natural storage of seed in the soil or under leaf litter that enables the production of plants in future generations.
Southern Connected Basin	A term used to describe the River Murray and regulated reaches of its major tributaries, which include Murrumbidgee, lower Darling, Kiewa, Ovens, Broken, Goulburn, Campaspe and Loddon rivers.
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.
Supply measures	New ways to manage the Basin's rivers to more efficiently achieve outcomes for the environment. These can include: new river operating rules that make environmental water delivery more effective; smarter ways to use dams, locks and weirs to reduce evaporation losses; and building innovative water management structures that deliver water more efficiently.
Sustainable Diversion Limits	The maximum long-term annual average quantities of water that can be taken, on a sustainable basis, from the Basin water resources as a whole, and the water resources, or particular parts of the water resources, of each water resource plan area.
Taxa	A unit used to biologically classify fungi, plants and animals.
Temporal	Lasting for a time only.
Tree Condition Index (TCI)	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.
Waterbird guilds	A waterbird species that is grouped based upon similarities in their diet, foraging strategy and life history.
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.

Weir pool	The body of water stored behind a weir.
Weir pool lowering	The lowering of a weir pool height to lower water levels.
Weir pool raising	The raising of a weir pool height to increase water levels.
Whole of Icon Site (Vegetation)	An area covering the entire Lakes system, including Goolwa Channel, Lake Albert, Lake Alexandrina and fringing seasonal wetlands.
Young of Year (fish)	The fish of a species younger than one year of age.

SOUTH AUSTRALIA

Government of South Australia

Department for Environment and Water