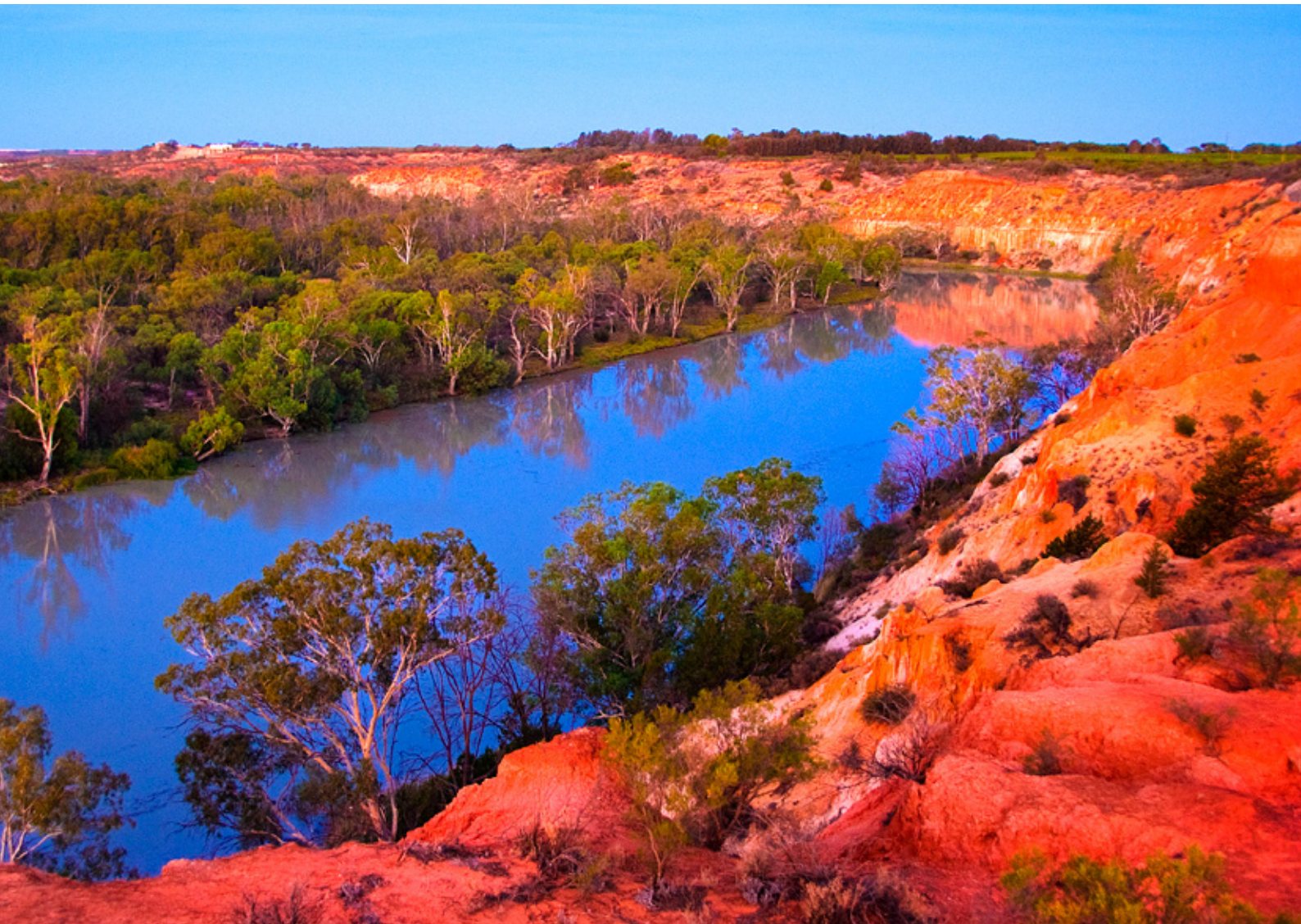
Australia's National
Science Agency

Science solutions for the Murray-Darling Basin

Managing today's resources for the future

August 2020



How CSIRO is helping to protect a national icon

The Murray-Darling Basin is a national icon under stress in a changing climate. Ensuring this Australian food bowl remains healthy and productive is vital for the communities, environment and industries relying on it. The Basin (MDB) covers 14 per cent of Australia and is home to more than two million people. Its agriculture (both dryland and irrigated) accounts for almost 40 per cent by value of Australia's agricultural production.

The Basin is in one of the world's most variable climate regions, where catchment inflows in a wet year can be more than 20 times greater than the inflow in a dry year. It's a system facing profound future challenges to adapt to a drier, hotter climate.

To better manage water under this likely future, we need to know the key climate drivers across the Basin, and how they're likely to change due to global warming. We also need to understand where and when rains will fall, and what evaporation rates and water use can be expected.

CSIRO has delivered decades of world-leading research in the Basin. Water allocation and use in this important water resource is contentious, with many different water users and beneficiaries. During average flow years there is tension around the various uses of water and through dry years, particularly in an extended drought, water allocation decisions are often contested. The challenges in the Basin also extend to the management of other natural assets beyond water.

CSIRO Murray Darling Basin research milestones over time

1986
Murray-Darling Freshwater Research Centre established.

2001
15-year strategy to manage salinity in the Basin commences.

2006
The South Eastern Australian Climate Initiative (SEACI) collaboration begins investigating drivers of the climate in south-eastern Australia, including global warming.

2007-08
Murray-Darling Basin Sustainable Yields Project (MDBSY) outlines current and future water availability in the Basin.

2009
CLLAMMEcology framework to guide management of the Coorong, Lower Lakes and Murray Mouth is released.

2009-12
SEACI phase 2 delivers answers on climate questions from the south-eastern region of Australia.

2011
CSIRO Science review into the Guide to the proposed Murray-Darling Basin Plan.

2012
MDBSY findings supports the development of the Murray-Darling Basin Plan.

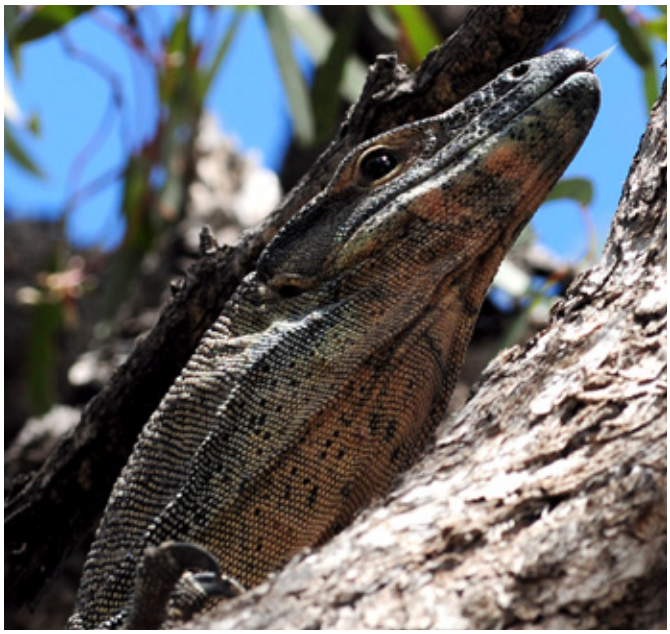
2012
CSIRO assessment of the ecological and economic benefits of environmental water in the Murray-Darling Basin (MDB).

The Basin is a complex social-ecological system facing many drivers of change and an understanding of this is vital for informing its long-term management.

Acknowledging this complexity, we collaborate to provide the best scientifc advice to those who depend on, or benefit from, the Basin. Our lessons and scientific achievements from the Basin have been shared with water managers globally. We continue to provide science to support the best possible outcomes for communities, industries, and the Basin as a whole, now and into the future.

CSIRO conducts research across four important areas in the Basin. In the following pages we look at the work CSIRO has delivered and what we are doing now in these four areas:

1. Assessing water availability in the Basin
2. Adapting to less water
3. Sustaining the environment
4. Ensuring resilient, diverse and healthy communities



Our research informs management of the complex social-ecological system that is the Basin. Pictured is a lace monitor (goanna) perched on an upper tree branch on the Chowilla Floodplain, South Australia.

2014

Delivery of the MDB Environment Flows Cluster project (following CLLAMM Ecology Cluster project).

2014

The development and implementation of the Sustainable Diversion Limit (SDL) Adjustment method by CSIRO.

2015

MDB Salinity Management Strategy is released.

2015

CSIRO and the Bureau of Meteorology provide an assessment on the MDB, as part of the latest *Climate Change in Australia* report.

2017-18

Bioregional Assessment Programme assesses impacts of coal seam gas and coal mining developments, including the MDB's Namoi and Condamine regions.

2018

CSIRO's SDL work leads to an amendment of the Murry-Darling Basin Plan by the Australian Government.

2019

CSIRO convenes the *Future Ready Murray-Darling Basin Forum: Beyond 2030.*

2020

Release of CSIRO-led Lower Lakes Science Review for the Murray-Darling Basin Authority's science advisory committee ACSEES.

2020

Risk assessment for Australian Government regarding the release of the Carp virus (*Cyprinid herpesvirus 3*) to manage Carp numbers across the waterways of the MDB.

Assessing water availability in the Basin

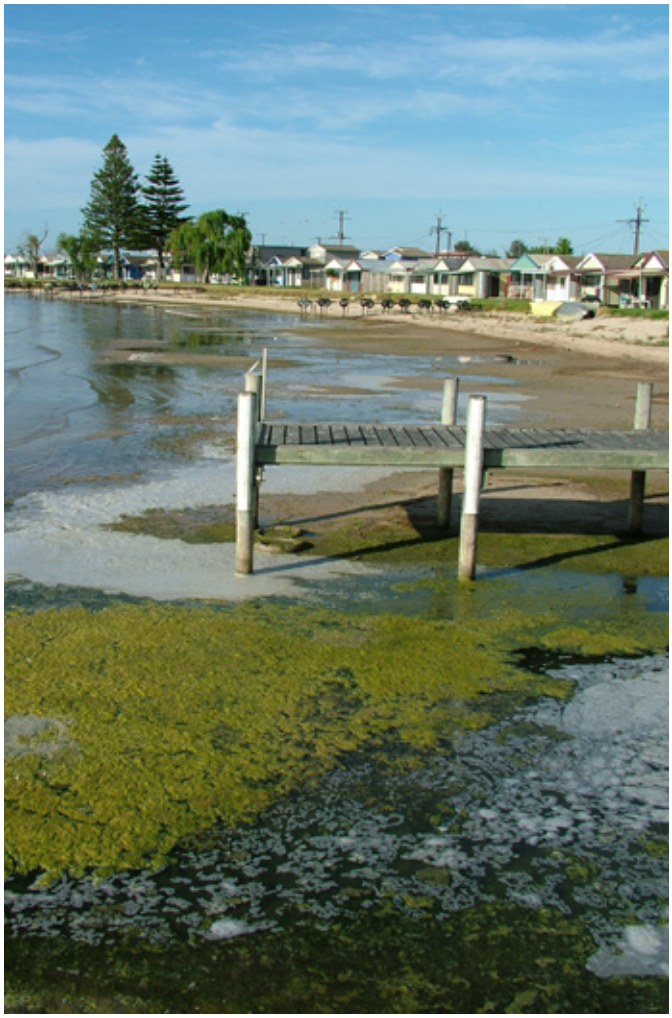
Managing water in the Murray-Darling Basin (MDB) requires an in-depth assessment of the actual water available in the Basin. To support this, CSIRO has been undertaking research for 30 years into understanding patterns of rainfall, evapotranspiration and water use over time and space, across the whole Basin. This has further deepened our knowledge to better identify the key climate drivers across the Basin, as well as how these are likely to change as a result of climate variability and change.

What have we done?

CSIRO and the Bureau of Meteorology assessed the observed climate change in Australia, including in the Murray-Darling Basin, and its causes, as well as projected future changes over the 21st century. This was part of the 2015 Climate Change in Australia (CCIA) report for Australia's Natural Resources Management (NRM) and the earlier South Eastern Australian Climate Initiative (SEACI). More recently the climate change impact on Australia and its water resources is featured in the biennial *State of the Climate* report.

CSIRO research has characterised the following climate change-related impacts on the Basin:

- increased air temperature by nearly 1.5 degrees relative to the 1910-1950 average. This is around 30 per cent greater than the global average temperature increase
- overall reductions in rainfall, particularly in the south
- large reductions in winter rainfall, with possibly some increases in summer rainfall
- an increase in extreme rainfall events
- a greater number of hot, and fewer cold days
- an increase in the number and intensity of extreme fire days.



Lower Lakes (Image: Kane Aldridge).

What are we doing now?

National hydroclimate projections to prepare for the future

CSIRO is developing rigorous and credible methods for projecting hydrological metrics for Australia, including the Basin, as part of the National Environmental Science Program (NESP). These methods will underpin the science and modelling capability required for the next generation of national climate projections following the release of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report in 2021. They continue to help us assess and predict water availability in the Basin and plan for the future scenarios.

We are also developing a suite of 'hydroclimate storylines' that will be used to communicate the range of potential futures to the broader community and water users. These storylines are based on projections of future climate such as planning for a a drier future and changes in the total annual flow.

Red gums at Katarapko Creek, South Australia.

The Barmah-Millewa Forest, Australia's largest red gum forest in flood.

Improved water accounting

CSIRO, in collaboration with universities and other research agencies, including OzFlux and TERN, has developed methods to quantify water loss from the land, plant and water surface to the atmosphere using a combination of satellite data and in-situ observations. These eight-day measurements of evapotranspiration help us understand how much water is being evaporated and therefore how much is available for agriculture, towns, industry and the environment. Research focusses particularly on the floodplains of the southern Basin where understanding the magnitude of water losses from River Red Gum and Black Box trees via field measurements is important to manage floodplain health. We are also looking at how best to account for the impact of numerous small farm dams on the overall water availability.

Impacts on climate and water availability

Through the Victorian Water and Climate Initiative (VicWACI), CSIRO is continuing previous work with the South Eastern Australian Climate Initiative (SEACI). We are working with a consortium including the Bureau of Meteorology and the University of Melbourne to study current trends in Victorian rainfall, and particular looking at: what is known about the drivers, assessing how these may change in the future, and how these will affect streamflow and water availability. This research involves incorporating knowledge of the main drivers of local-scale rainfall to re-interpret results from coarse resolution global climate models (referred to as downscaling) and then enabling us to better represent future rainfall projections at a catchment scale. This work will also assess how best to use the research to inform adaptation.

Adapting to less water

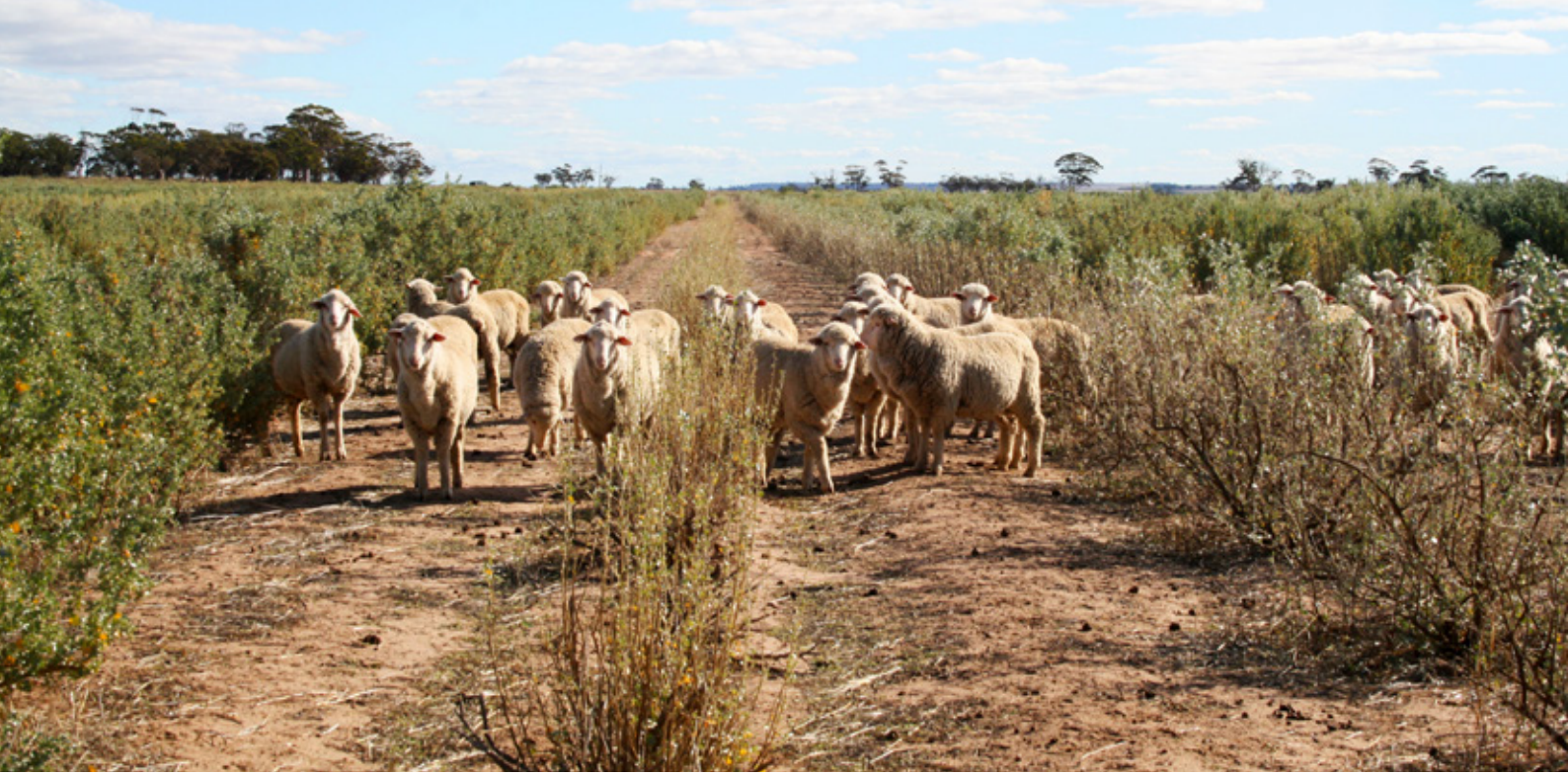
Over the past 20 years, the average inflow to the Basin was around half of the 20th century average. Sixteen of the past 20 years have seen below average winter rainfall. Most climate models also project that rainfall is likely to continue to decrease, particularly in the southern half of the Basin, as global average temperatures rise. Longer and more intense droughts are also more likely in the future. As a result, we need to adapt to less water overall. There will be changes in the timing and geographical distribution of water availability, and there is much uncertainty about what kinds of extremes different localities will be faced with. It is not simply about making do with less water but adapting to a complex mix of changes and consequences at different scales in the Basin.

What have we done?

The Murray-Darling Basin Sustainable Yields (MDBSY) project undertaken in 2007 and 2008 represented the first attempt to build a linked model of all the catchments and major aquifers in the Basin. It showed that under the water allocation rules in operation at the time, the impacts of drought were felt much more keenly by the environment than by irrigators. The findings of the MDBSY helped lead to the development of the Basin Plan (2012) which attempts to ensure an equitable allocation of water in a changing climate for all users, including the environment.

The subsequent Bioregional Assessment Programme assessed the cumulative impacts of coal mines and CSG on existing water users and the environment. This included the Basin regions of Namoi and Condamine, which were assessed between 2017 and 2018.

The Victorian side of Lake Hume, a major dam across the Murray River, at 4% capacity in 2007 (Image: Tim J Keegan via Flickr).



Planting AnamekaTM saltbush can provide extra on-farm forage for sheep in times of drought.

What are we doing now?

Improving agriculture

- We are researching ways to improve crop efficiency across the Basin through both genetic improvement and farming system approaches. These include irrigated annual crops such as cotton and soybean as well as perennial crops such as grapevines, citrus and nut trees. We are also working to improve the efficiency of dryland crops such as cereals, oilseeds, legumes and dryland cotton. Research is also being carried out on mixed farming systems and livestock systems.
- Some of the new approaches being explored are digital and data-driven technologies to improve water-use efficiency, livestock management and increase the rate of genetic improvement of the animals and crops we farm.
- Practices being examined include the use of break crops, controlling summer weeds, early sowing, irrigation timing, wider rows, and optimised application of fertilizer. The CSIRO-bred Phalaris cultivar provides high quality forage which is acid tolerant, deep rooted and water efficient. Similarly, Anameka saltbush commercialised in 2014 is a drought-tolerant shrub adapted to low rainfall environments.
- We explore how alternative water sources, such as treated wastewater and water from unconventional gas, can be safely used for sustainable irrigated agriculture/horticulture.

Drought resilience

- CSIRO is working with partners on a focussed drought resilience research effort that aims to reduce the impacts of drought on producers, communities and the environment.
- A range of activities that bring together existing and emerging technologies and practices and develop novel ones are planned. These will be complemented by new ways of sharing risk through financial and other tools.
- In some places the increased frequency of low rainfall years will challenge even the best producers, consequently, re-designing some systems or changing the type of enterprise conducted also needs to be explored. We propose developing the analytical tools to support this.
- To smooth the variation in supply of irrigation water and to prevent rural towns approaching day zero (the day they run out of water) we are exploring managed aquifer recharge (or water banking). This is the intentional recharge of water to underground aquifers for subsequent use or environmental benefit. Research into this includes an assessment of the hydrogeologic and hydrochemical suitability of target aquifers as well as understanding the legal framework for extraction of water under current licencing conditions.
- Droughts and extended periods of low rainfall increase the risk to on farm environmental assets, as well as of the farm itself. We are seeking to develop practices that are economically productive and reduce soil losses and undesirable changes such as salinisation.

Sustaining the environment

Water extraction from the Basin through human activities has increased dramatically in recent decades. This increase has brought great benefits to the communities that live in the Basin but has caused increased stress on ecological communities that also rely on this water. These ecological impacts affect livelihoods, such as tourism and cultural values. Ensuring that the natural environment of the Basin is not compromised by these human activities is therefore a key issue.

What have we done?

Human activities and water use

CSIRO contributed greatly to the Murray-Darling Freshwater Research Centre (MDFRC) over more than 30 years, particularly determining the requirements to maintain the condition of rivers and wetlands in the Basin. This research helped develop clear understanding of the effect of human activities on water quality, particularly carbon, nutrients, and salinity, and subsequent functioning of rivers and wetlands.

Sustainable diversion limits (SDLs) determine how much water, on average, can be used in the Basin by towns, communities, industry and farmers. The Basin Plan allows SDLs to be increased if environmental, social and economic outcomes are maintained. This requires an 'environmental equivalence test' to assess whether environmental outcomes will be maintained if the SDL is increased. The Ecological Elements Method (EEM) developed by CSIRO does just that. The EEM method assesses how three ecological classes: vegetation, waterbirds and fish are affected by changes to water availability. The environmental outcomes need to remain equal to or higher than a defined benchmark scenario under potential SDL adjustments. This method is now in use in the southern part of the Basin.

Mapping willow trees

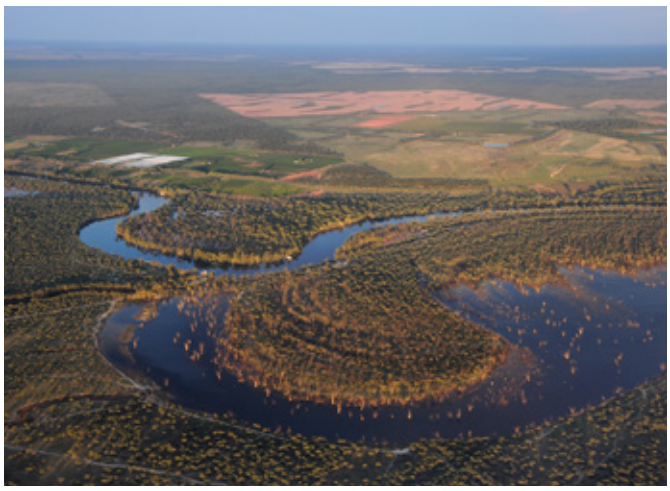
We have developed a set of tools to allow water managers to understand where and how many hectares of willow trees exist and how much water they use. This allows managers to calculate the total water savings if willows are removed from individual rivers.

Managing salinity

CSIRO made a significant contribution to the establishment of the Murray-Darling Basin Salinity Management Strategy in 2015 which aims to maintain the cap on salinity through the existing Basin Salinity Target and the existing accountability framework. It also explores opportunities to responsively manage salt interception schemes so that operations can be further optimised and costs can be reduced when river salinity is forecast to be low.

Restoring ecology

CSIRO contributed to the development of a suite of modelling tools to help land and water managers to restore the ecology of the Coorong and Murray Mouth region as part of the CLLAMMecology research cluster.



Aerial view of River Murray, wetlands and floodplains in the southern Murray-Darling Basin.

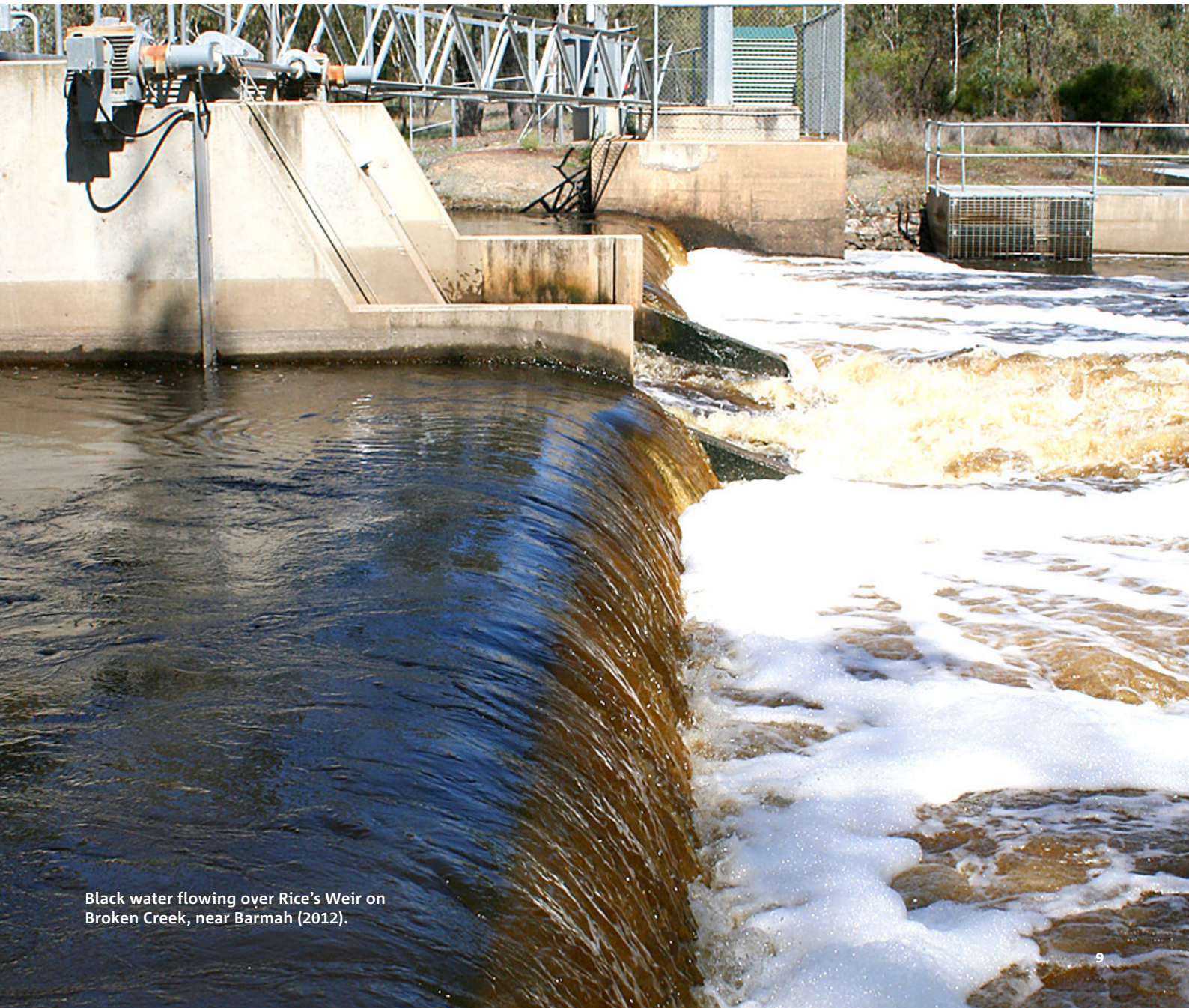
What are we doing now?

System-level understanding of environmental outcomes of the Basin Plan

To understand the broader impacts of management on ecosystem function, resilience and system-level environmental outcomes, CSIRO has undertaken Basin-scale ecosystem function research. This multi-disciplinary research will provide an improved Basin-wide understanding of the complex interactions and scales of change between hydrological and biological connectivity, productivity, habitat provision and maintenance with changing hydrological regimes.

Assessing environmental flow releases

To measure the benefits of environmental water releases, CSIRO in collaboration with the Commonwealth Environment Water Holder is carrying out a monitoring, evaluation and research program. This provides the critical evidence we need to understand how water for the environment can best be used to maintain, protect, and restore ecosystems and native species across the Basin. This multi-disciplinary program of monitoring and research is assessing the productivity benefits of environmental flow releases through a systems-level approach.



Black water flowing over Rice's Weir on Broken Creek, near Barmah (2012).

Predicting and monitoring blue-green algal outbreaks and blackwater events

- We are combining remote sensing, hyperspectral and satellite remote sensing with hydrodynamic modelling in order to produce a continuous forecast of algal growth. This approach is being trialled in Lake Hume, NSW, and is providing early warning of bloom formation across the reservoir.
- Simulation and monitoring tools for blue-green-algae form the basis of on-ground activities for the AquaWatch Australia Program which will develop a comprehensive, national monitoring system that can provide precise, decision-ready information on the quality of water across Australia's inland waterways, reservoirs, and coastal environments and its variations over time. This will enhance existing monitoring systems already in place across states and territories.
- Blackwater (hypoxic) events occur during flooding when organic material is washed off the floodplain and into the river systems. It can lead to a sudden decrease in the oxygen available to fish and other organisms in our rivers and result in fish kills, disruption of small businesses such as fisheries and increased cost of water treatment. We are researching the sources and processes leading to hypoxic events in order to develop a scenario modelling tool which will assess the impacts of flow management options to minimize future blackwater events.

Understanding ecological trajectories of change

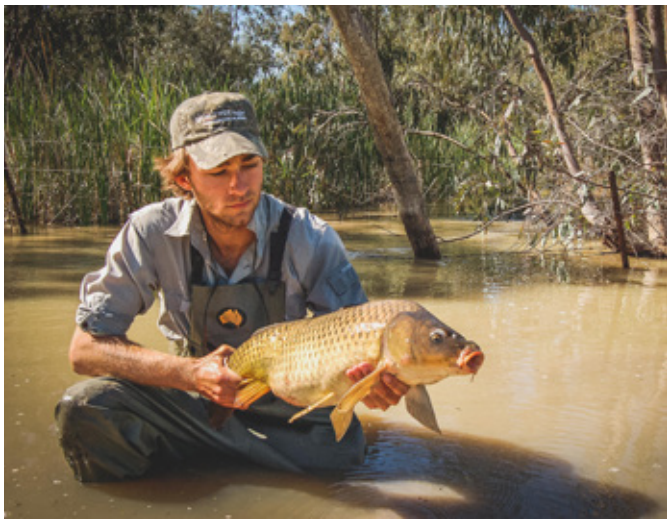
- Understanding how and when recovered environmental water is best used and achieving Basin Plan objectives can be assisted by understanding how environmental conditions change through time, and predicting future flow conditions.
- CSIRO research aims to develop a modelling approach which predicts trajectories of ecological change over space and time, as a result of water management, climate variability and climate change. This will allow a comparison of relative outcomes from different management scenarios into the future, as well as tracking environmental progress towards Basin Plan objectives.
- CSIRO is engaging and collaborating with the Murray Darling Basin Authority (MDBA) to assess change in environmental indicators in response to various climate characteristics in the lower Murray region as part of the Earth Systems and Climate Change Hub (ESCC) under the National Environmental Science Programme (NESP). The results can contribute to modelling development for ecological change trajectories.

Assessing biocontrol of European carp

As part of the National Carp Control Plan, an assessment of the feasibility of using the Carp virus (Cyprinid herpesvirus 3) as a biological control agent for introduced common carp in Australia was delivered to the Australian Government in January 2020.

To inform the National Carp Control Plan:

- Through modelling the epidemiology of the virus, risks to non-target species such as trout and frogs as well as broader risks to the environment and people, whose livelihood may be impacted, can be estimated.
- CSIRO is providing a risk assessment related to the release of the Carp virus to help manage Carp numbers across the waterways of the Basin.
- The epidemiological model is linked with a population dynamic model and based on large scale hydrological simulations, remote sensing derived inundation mapping and water temperature estimates in catchments of the Basin to evaluate the most effective release strategy for the virus.



An ecologist holds an adult carp collected during fish surveys in the Macquarie Marshes, NSW.

Swans and signets in the Lower Lakes (Goolwa) after floodwaters renew water during the 2010-2012 floods.

Bushfire and water quality

The 2019-20 bushfires across south east Australia led to a massive release of sediment and ash into waterways with an implication for aquatic ecosystems. We estimated the potential risk to waterways. This involved combining data on burn severity so agencies could better target hotspot areas in the landscape with erosion models to simulate sediment loading of waterways. We estimated potential risks of:

a. increased sediment load and low oxygen on fish kill,
b. toxic effects of released metals and other substances on aquatic life, and
c. increased sediment deposition and subsequent internal nutrient loading in reservoirs, leading to toxic blue-green algal blooms.

Coorong, Lower Lakes and Murray Mouth

An independent expert panel led by CSIRO delivered a review of South Australia's Lower Lakes, including the Coorong, in May 2020.

The independent panel reviewed the existing science relating to the management of the Lower Lakes and Coorong, noting that under climate change, the management of the Coorong, Lower Lakes and Murray Mouth would become increasingly challenging.

As part of our contribution to the South Australian Government's Healthy Coorong Healthy Basin Action Plan we are determining what is required to restore the ecological character of the South Lagoon of the Coorong. This project aims to determine how future climate change will affect the ecological character of the Coorong, determine which values are most at risk, and what management actions could be taken to reduce this risk.

Ensuring resilient and healthy communities

What have we done?

Murray Darling Basin Forum

In March 2019, CSIRO convened the *Future Ready Murray-Darling Basin Forum: Beyond 2030* in Canberra. The forum considered future constraints and opportunities for the Basin, identified critical gaps in knowledge, and ensured investments would deliver impact. The forum involved more than 100 leaders and stakeholders from the Murray-Darling Basin. The priority actions from this forum included developing a science prospectus for investment in knowledge, undertaking an annual report card, mainstreaming Aboriginal voices, and improving partnerships to focus CSIRO research efforts.

Regional communities

As part of the Physical Environment Analysis Network (PEAN), we have explored the effects of water management in regional communities. This project drew on water data from a range of sources, including the Bureau of Meterology, Murray-Darling Basin Authority and Australian Bureau of Statistics as well as the Multi-Agency Data Integration Project and the Business Longitudinal Analysis Data Environment.

Incorporating social values

In a collaboration with the MDBA, and in parallel with our eco-hydrological trajectories modelling work mentioned earlier, CSIRO reviewed and extended our understanding of the multiple ways in which people benefit from environmental water being delivered and ecological objectives being met. The review recommended improving the way these benefits are shared so that the Basin Plan ecosystem targets can be evaluated, not only according to biophysical indicators, but relevant social indicators. Also, the study found that an improved understanding of the relevant social values also enables more informed decisions when trade-offs between different values are necessary.

What are we doing now?

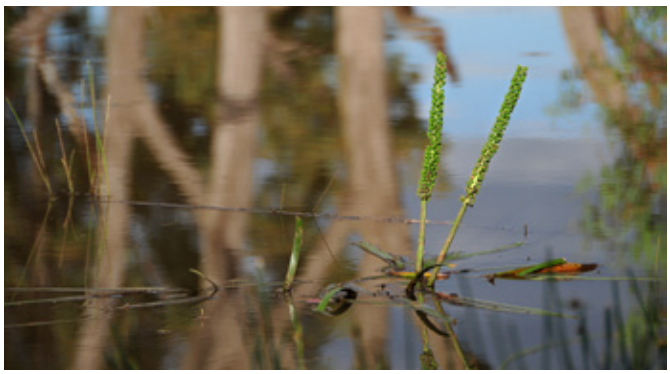
Social research

All communities are different. Understanding the gender distribution, occupation and income of communities allows us to better predict which types of policy interventions will be successful across the diversity of the Murray-Darling Basin region.

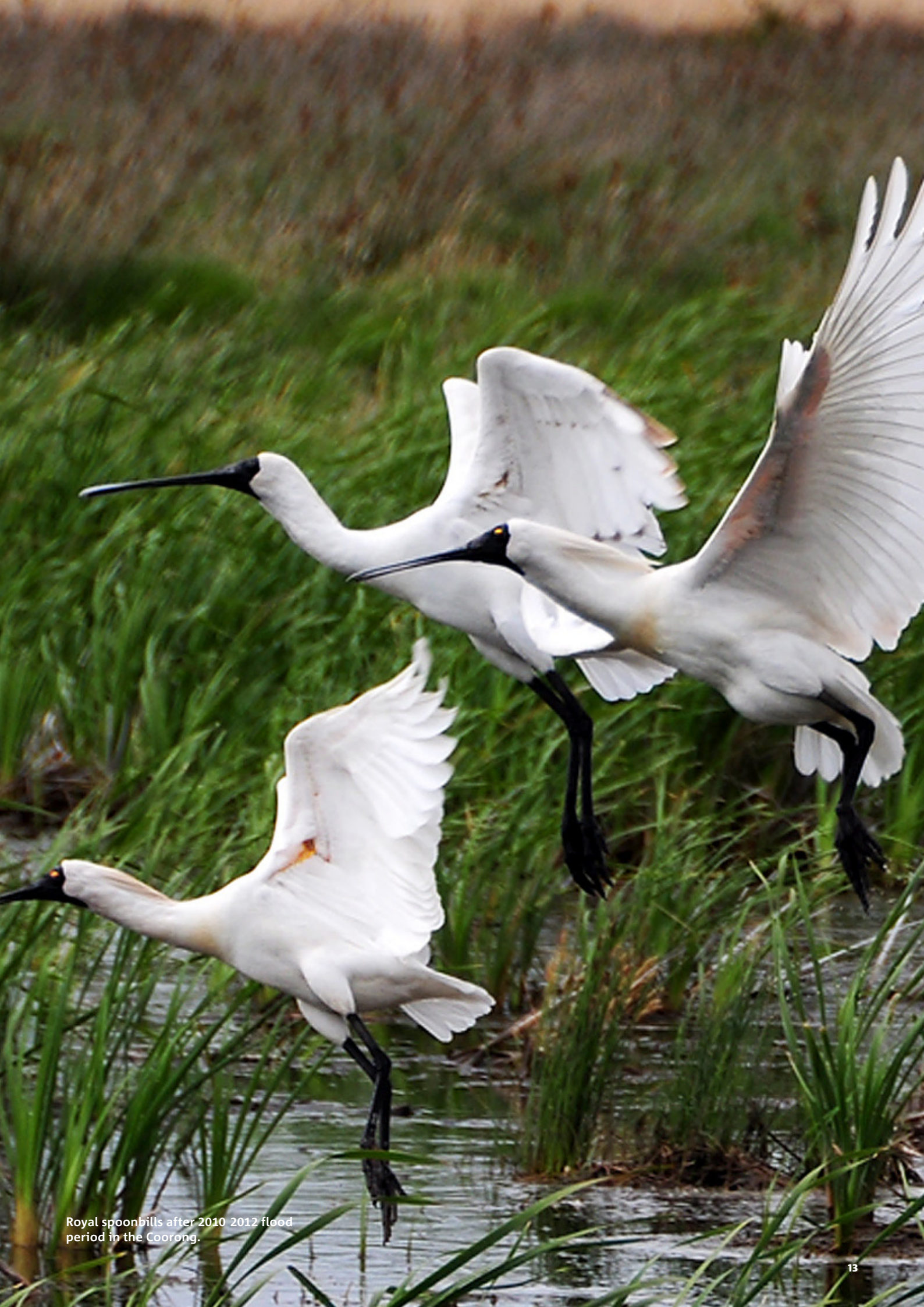
Previous research under the *Strategic Foresight for Regional Australia* project identified key scenarios likely to affect Basin communities. Ensuring that these communities are able to survive droughts and other system shocks is now a focus of research. This may be through improved resilience or through adaptation to short and long-term changes and may involve widespread modification of agricultural or social systems.

Evaluating the benefits of Indigenous land and water management

CSIRO is working with Murray Lower Darling Rivers Indigenous Nations, Northern Basin Aboriginal Nations and the MDBA to evaluate the socio-economic benefits of assessing the return on investment from the Federal Government support for Indigenous programs working on country in the Basin. The program is generating insights that will improve the delivery of government programs including the MDBA – ASEI Monitoring Framework, Indigenous Rangers program, Indigenous Protected Areas program and the National Landcare program.



Growth of aquatic vegetation in response to flooding in a Murray-Darling Basin weltand.



Royal spoonbills after 2010 2012 flood period in the Coorong.

Looking to the future

CSIRO researchers have used key outcomes of Basin research to support water resource sharing and integrated management in overseas river basins and sub-basins. We aim to improve the livelihoods and economic well-being of people in large and complex river basins. This is not only in Australia, but also in Nepal, Asia, India, South Pacific and Pacific.

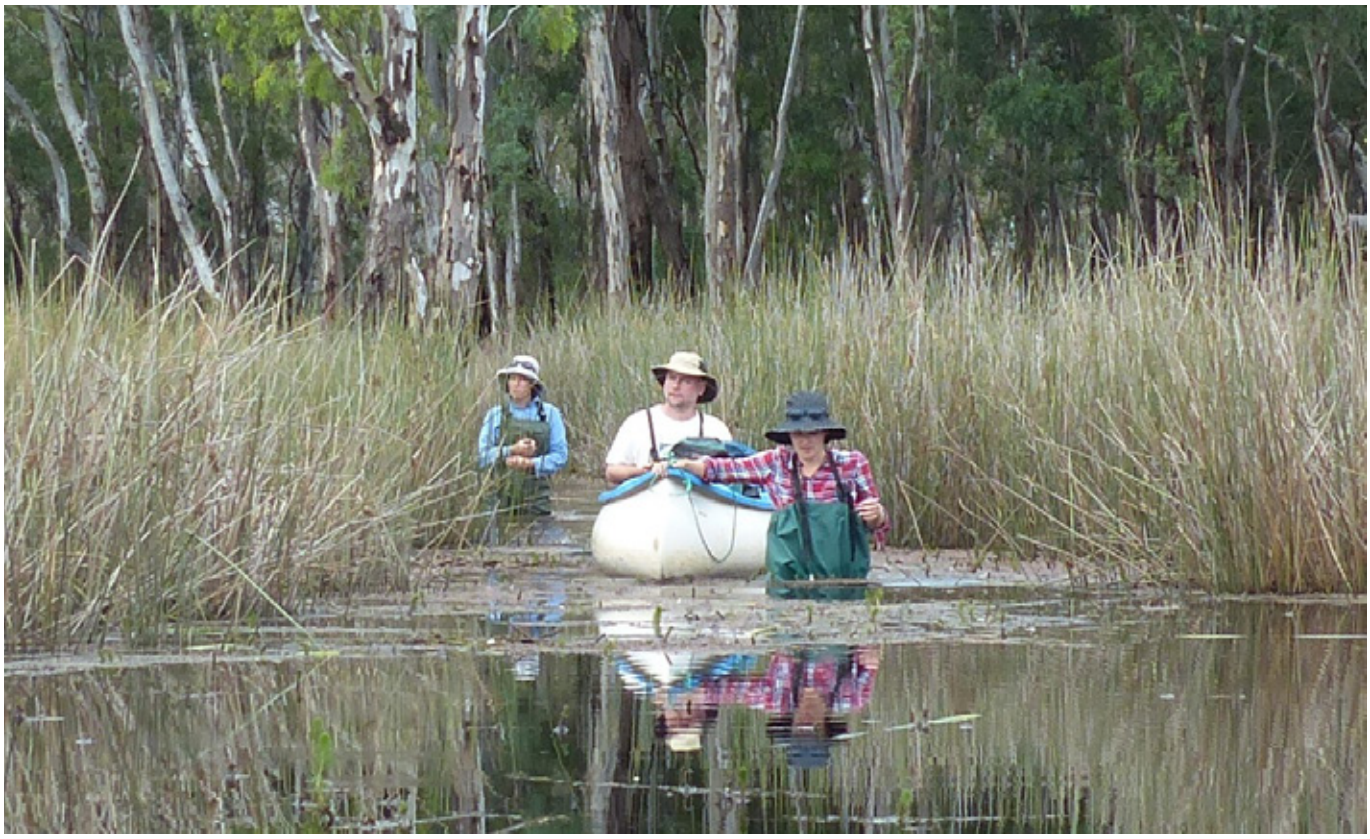
As we look to the future, we need a better understanding of how ecosystems respond to changes in water availability, increased temperatures, longer dry spells and other hydrological changes predicted under climate change.

Further research to better understand climate drivers, reductions in rainfall and water availability promises benefits for decision makers across government, industry and agriculture.

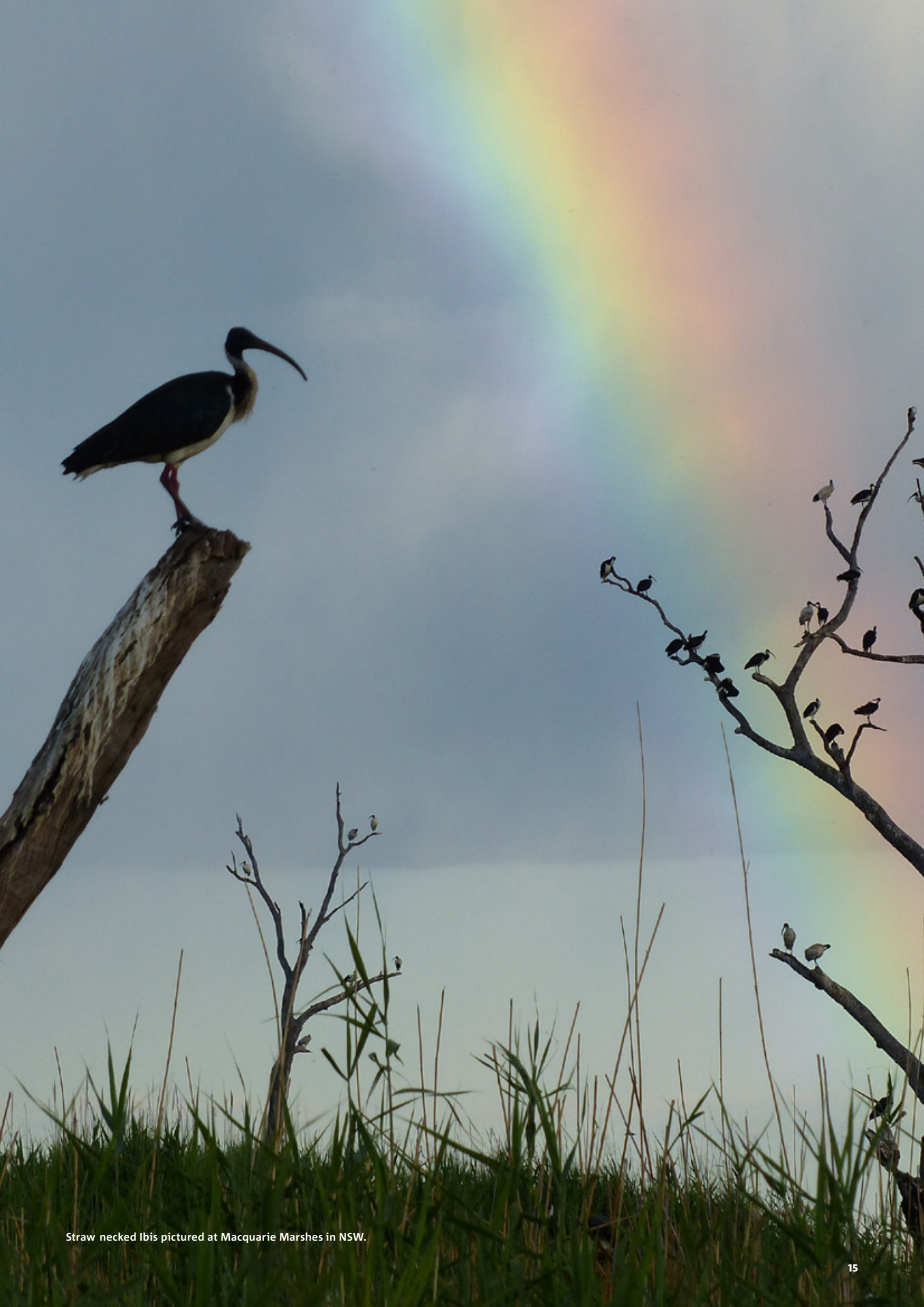
This will lead to a better understanding of how the people of the Basin, its critical agricultural assets, and ecology may be impacted, allowing time to develop and assess adaptation options.

Future opportunities include exploring:

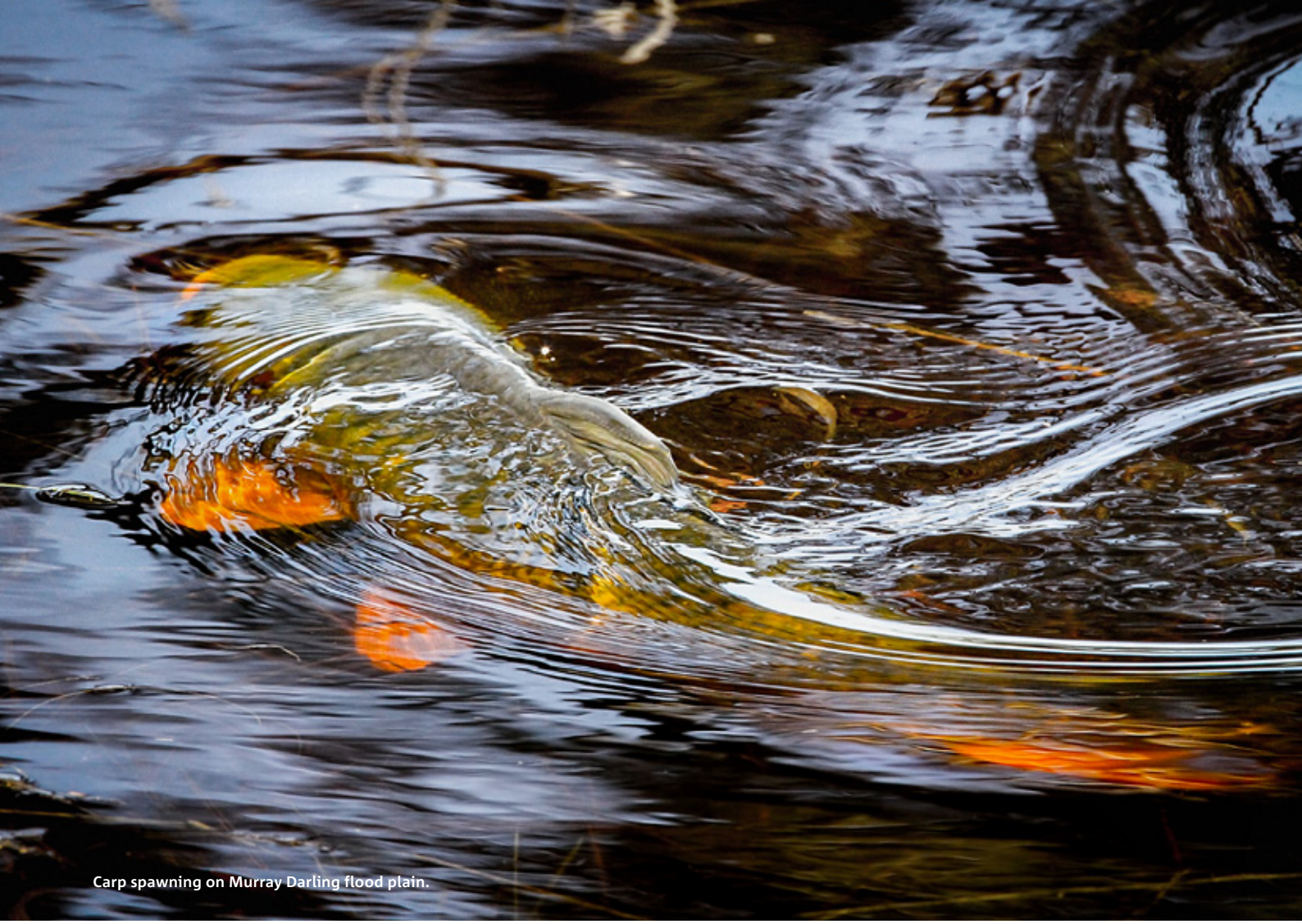
- the economics of dual water supply source options, such as using surface water resources when available, and groundwater resources during particularly dry periods;
- different possible futures to inform robust decision-making options; and
- the value of local and traditional knowledge, values and social interactions as drivers for decision-making and effective water management in conjunction with traditional monitoring and enforcement strategies.



A CSIRO Waterbird Research Team entering the Reed Beds Wetland in Barmah-Millewa Forest.



Straw necked Ibis pictured at Macquarie Marshes in NSW.



Carp spawning on Murray Darling flood plain.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

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