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MURRAY–DARLING BASIN AUTHORITY

Native vegetation

2017 Basin Plan Evaluation

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Environment | Report

Basin Plan Evaluation

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray–Darling Basin Authority acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The MDBA understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

The approach of Traditional Owners to caring for the natural landscape, including water, can be expressed in the words of the Northern Basin Aboriginal Nations Board:

> …As the First Nations peoples (Traditional Owners) we are the knowledge holders, connected to Country and with the cultural authority to share our knowledge. We offer perspectives to balance and challenge other voices and viewpoints. We aspire to owning and managing water to protect our totemic obligations, to carry out our way of life, and to teach our younger generations to maintain our connections and heritage through our law and customs. When Country is happy, our spirits are happy.

The use of terms 'Aboriginal' and 'Indigenous' reflects usage in different communities within the Murray–Darling Basin.

Contents

Executive Summary

The 2017 Basin Plan Evaluation (the 2017 Evaluation) is part of the regular monitoring, evaluating and reporting process built into the Basin Plan. The 2017 Evaluation assesses the social, economic and environmental outcomes of the first five years of implementing the Basin Plan. It provides information about the early indications of progress which lay the foundations for long-term Basin Plan outcomes. The findings will inform the Murray–Darling Basin Authority and partner governments and help identify opportunities to strengthen future implementation.

A key component of the 2017 Evaluation is an assessment of the Quantified Environmental Expected Outcomes (expected outcomes) of river flows and connectivity, native vegetation, waterbirds and native fish in the Basin-wide environmental strategy. This report looks at the water-dependent vegetation component. Water dependent vegetation communities were grouped into forests and woodlands, lignum shrublands and non-woody vegetation.

Environmental water needs to be delivered over multiple years to achieve the expected outcomes for water-dependent forests and woodlands Response times vary depending on the type of vegetation and outcome sought. For example, improvement in the condition of forest or woodland trees is evident soon after a flood, whereas expanding the extent of a forest will take many years. Non-woody water-dependent vegetation growth is evident relatively soon after a watering event.

In areas where environmental water can be delivered, there are early positive signs of native vegetation responding to environmental water used under the Basin Plan. These benefits have been achieved by extending flow durations and protecting flow peaks (i.e. limiting extraction), and by creating lateral connectivity between the main river channel and the adjacent wetlands and floodplains.

This evaluation of native vegetation was guided by the 2017 measures of success. These measures link to the Basin Plan's targets to measure progress towards environmental objectives and to the expected outcomes for water-dependent native vegetation identified in the Basin-wide environmental watering strategy. They exclude the many threats to achieving the native vegetation outcomes that fall outside the remit of the Basin Plan, such as habitat fragmentation, land clearing and climate change.

The results of this evaluation show some of the native vegetation 2017 measures of success, or elements of them, have been met, with others are to be determined at this early stage of Basin Plan implementation or there is insufficient evidence. Consequently, Basin Plan is on track to achieve some of expected outcomes, but it is not possible to determine if the Basin Plan is on track to meet most of the expected outcomes for most native vegetation in the strategy, the Basin Plan's intermediate (up to 2019) and long-targets (from 2019) and in turn the Basin Plan’s overall environmental objectives for native vegetation.

Introduction

The 2017 evaluation of the Basin Plan

The 2017 Basin Plan evaluation is the first evaluation of the Plan by the Murray–Darling Basin Authority (MDBA). It examines the social, economic and environmental outcomes associated with the first five years of Basin Plan implementation (2012-2017), and assesses whether the Plan is on track to deliver a healthy working Basin. The 2017 evaluation (the evaluation) also identifies opportunities for governments to improve Basin Plan implementation in the coming years.

The environment is one of 11 themes the evaluation examines. This theme covers the implementation of the Environmental Management Framework, and assesses outcomes for river flows and connectivity, environmental assets, native vegetation, waterbirds and native fish.

This report focuses on the native vegetation of the Murray–Darling Basin.

Native vegetation of the Murray–Darling Basin

The Murray–Darling Basin supports hundreds of native plant species which performs different functions and supports a multitude of species. The Basin recently has been classified into 41 different riverine, wetland and floodplain vegetation types (Brooks, 2017). While this report focuses on the water-dependent native vegetation of the Murray–Darling Basin, all these vegetation communities play and important role in the daily life of a wide cross section of the Australian population who live and visit the Murray–Darling Basin. Aboriginal communities have a deep cultural connection as well as valuing native vegetation for the shelter, food and tools it provides, and the native vegetation also provides an important aesthetic contribution to many Basin residents and visitors.

While having its own intrinsic value, native vegetation also provides valuable food and habitat for waterbirds, native fish, turtles and mammals, to name a few. Vegetation stabilises river banks which reduces turbidity, improves water quality and assists in maintaining ecosystem functions such as contributing organic matter into the water as part of the aquatic food webs.

Floodplain forests, woodlands and wetlands, have different water requirements depending on species composition and location on the floodplain.

The Basin Plan

River regulation has changed the size, frequency and timing of natural flows in the Murray–Darling Basin. This has contributed to a decline in the health of the Basin's water-dependent ecosystems – its rivers, floodplains and wetlands.

Flow regulation began in the Murray–Darling Basin in the late 19th century, with intensive development of regulators occurring along the Murray River between 1920 and 1940 (Maheshwari et al 1995). As more

water has been diverted for people, agriculture and other economic activities, flow through the system to the sea has reduced by 75% on average (BWS 2014).

The reduced flooding frequency over this extended period has caused a decline in the condition, structure and composition of non-woody vegetation, lignum shrublands and forests and woodlands of long-lived tree species. In some areas wetland plants and grasses have been replaced by trees, changing the ecological function of these areas and reducing the beneficial nutrient input into the rivers.

The decade-long millennium drought also had a significant impact on a key aquatic plant species in the Coorong, *Ruppia tuberosa*. This species in the Coorong's south lagoon provides vital habitat for macroinvertebrates and fish, and is an important food source for migratory shorebirds.

The Basin Plan was legislated in 2012 with the aim of returning the Basin to a healthy working system. The focus of the plan is to improve the Basin's environment, while balancing social and economic needs, in a sustainable way. The plan sets an environmentally sustainable level of water take for consumptive use (sustainable diversion limit) and secures a share of available water for the environment. This 'environmental water' allows managers to restore some of the critical elements of the flow regime so that plant and animal species can complete their lifecycles and help build population resilience in healthy habitats.

The Basin Plan sets out three overall environmental objectives for water-dependent ecosystems. These are to:

a. protect and restore water-dependent ecosystems of the Murray–Darling Basin
b. protect and restore the ecosystem functions of water-dependent ecosystems
c. ensure that water-dependent ecosystems are resilient to climate change and other risks and threats.

These are long-term objectives; and implementation of the plan and environmental recovery will take time. Therefore, the plan aims to achieve "no net loss or degradation in the recruitment and populations of native water-dependent species including vegetation, birds, fish and macroinvertebrates" (Schedule 7, Basin Plan) up to 2019, and looks for improvement beyond 2019.

Basin-wide Environmental Watering Strategy

The Basin-wide Environmental Watering Strategy (the strategy), released in 2014, expands on the Basin Plan. It guides the management of water for the environment at a Basin scale over the longer term with the aim of halting the decline and then improving the condition of key water-dependent ecosystems.

The strategy describes how waterbirds, fish, vegetation and flows are expected to respond to environmental water delivery over the next decade, given current operating rules and procedures. It lists quantified environmental expected outcomes (expected outcomes) for flows, native fish, waterbirds and native vegetation beyond 2019, and further expected outcomes to be achieved beyond 2024. This acknowledges that populations will take time to respond to mechanisms of the Basin Plan. The expected outcomes set out in the strategy describe how the plan should work to: maintain and improve the ways rivers flow and connect on to floodplains; improve species diversity, extend population distributions, and improve successful completion of critical stages of lifecycles.

The strategy describes the expected outcomes to maintain the extent and to improve the condition of water-dependent vegetation in the Murray–Darling Basin's floodplain (MDBA, 2014). For the strategy and hence the 2017 Evaluation, this vegetation has been classified into three 'structural groups': forests and woodlands, shrublands and non-woody vegetation (Figure 1).

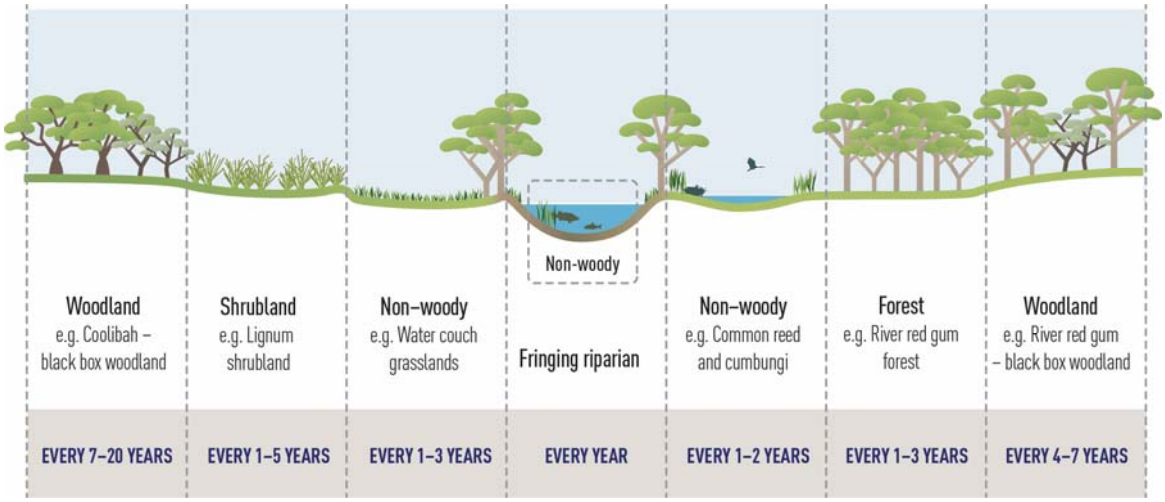

Figure 1 A stylised example of structural groups of vegetation, their position on the floodplain and their required watering frequency (MDBA, 2014)

The MDBA modelled the floodplain vegetation area which can be influenced with environmental water, with constraints (MDBA, 2014). This modelling showed that there are areas where flows are actively managed on the floodplain areas (e.g. areas with large headwater storages such as Macquarie, Murrumbidgee and Murray regions) and areas that are managed more passively (such as through flow rules in water resource plans or via natural events).

The areas on the managed floodplain can receive environmental water within operational constraints, for example through flow rules in water resource plans or via The Living Murray 'environmental works' sites on the River Murray floodplain. The expected outcomes for vegetation discussed in this report represent the areas that are, or may be able to be, inundated on the managed floodplain with 2750 GL of environmental water. The managed floodplain is 25% of the area inundated in a 1 in 100 year flood. It is important to note that environmental water recovery is not yet complete and that constraints may change in the future.

Other parts of the floodplain (i.e. unmanaged floodplain areas) support diverse vegetation communities but are influenced by factors outside of the Basin Plan (e.g. natural flooding, climatic conditions, land use and fire). They will continue to decline if they do not receive enough water and they may transition from flood-dependent vegetation communities into other types.

2017 Basin Plan Evaluation measures of success

The decline in the condition of the Basin's water-dependent ecosystems has occurred over many decades. Redressing this decline is a long-term process and improvements in the Basin's environment will take some time to secure and measure. Some responses, such as improving water connections across floodplains and

along rivers, will occur sooner in response to delivering water for the environment, while other responses, like restoring populations of plant and animal species, will take longer to respond to an improved flow regime and water quality. Critical life-cycle functions must be restored before there are comprehensive signs of improved Basin-scale health and resilience. This 'ecological lag' was recognised in the strategy, as shown below in Figure 2 Illustrative environmental response to Basin Plan implementation. More information on this figure is on the MDBA web site <www.mdba.gov.au/sites/default/files/pubs/Final-BWS-Nov14.pdf>.

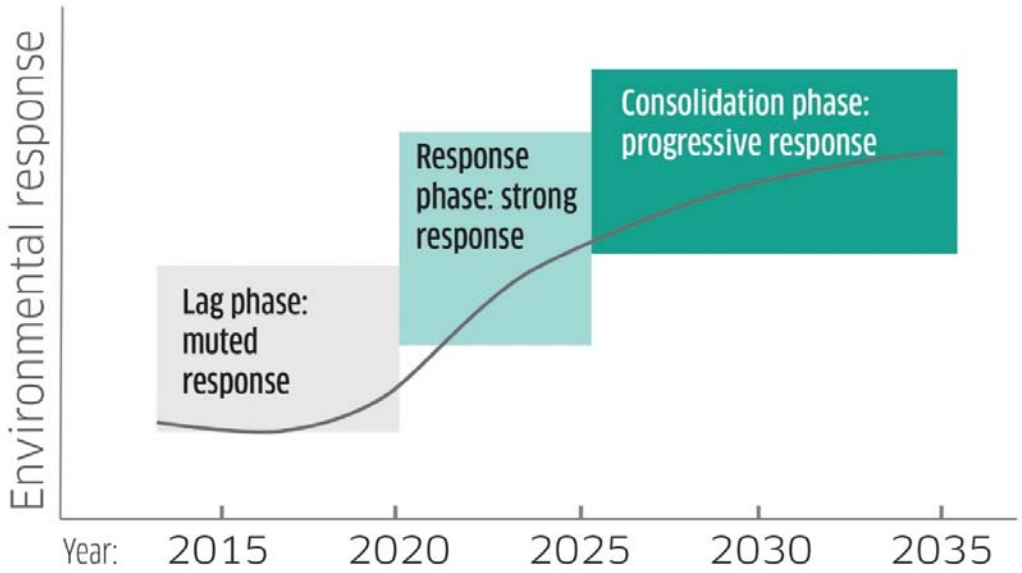

Figure 2 Illustrative environmental response to Basin Plan implementation

Evaluating progress in 2017 poses a challenge as most expected outcomes in the strategy are based on expected outcomes after 2017 (i.e. 2019 and 2024). Similarly, the targets in the Basin Plan are also longer-term than 2017. Therefore, to assess whether the Basin Plan implementation is on track a mix of interim measures of success are required.

The measures of success for native vegetation are based on our best scientific understanding of longer term healthy population-cycle trajectories. In forests and woodlands dominated by river red gum (*Eucalyptus camaldulensis*), black box (*Eucalyptus largiflorens*) and coolibah (*Eucalyptus coolabah*), changes in response to water availability are expected to be slow. Condition can improve over seasons and discrete events can result in recruitment. However, overall changes in composition, extent and condition of these communities can take years to decades. Across the Basin, tree condition is likely to be naturally highly variable in response to cycles of drought and flood, as well as environmental watering opportunities. For example, river red gums are less drought tolerant than black box; they need to be flooded more frequently and require fresher groundwater sources to maintain good condition.

Plants can withstand extended periods without inundation, but sequential inundation events are needed to improve plant health, growth and reproduction. Lignum (*Duma florulenta*) that experience extended periods of drought tend to be smaller shrubs, with fewer stems. After a prolonged dry period, lignum can enter a dormant stage where the plant looks dead. Lignum can regenerate from dormancy, but the likelihood of

successful regeneration decreases with increasing dormancy period, changing the services and functions the plants provide in the landscape.

For non-woody water-dependent vegetation such as water couch (*Paspalum distichum*), Moira grass (*Pseudoraphis spinescens*), common reed (*Phragmites australis*), marsh club-rush (*Bolboschoenus caldwellii, Bolboschoenus medianus or Bolboschoenus fluviatilis*) and *Ruppia tuberosa*, changes occur relatively quickly in response to watering events, providing there is a sustainable population that includes rhizomes and seedbanks at the site scale. In areas where seedbanks or existing vegetation are lacking, native water-dependent vegetation may take much longer to re-establish which will influence the structure and contiguousness of these vegetation communities.

At this early stage of implementation, we expect to see Basin Plan mechanisms supporting the short-term life cycle requirements of native vegetation, as shown conceptually in Figure 3 below. Evidence that these life cycle components are improving will provide confidence that improved condition and increased extent will be seen in the future.

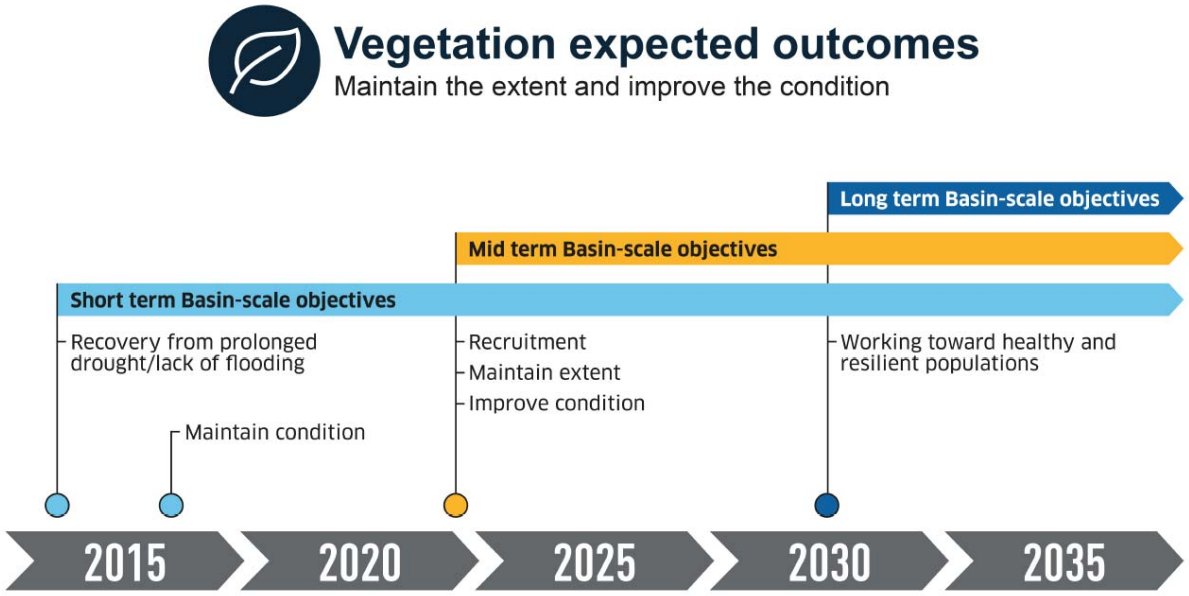

Figure 3 Expected recovery time for native vegetation in response to the implementation of the Basin Plan

The measures of success (and their links to the expected outcomes from the strategy) evaluated for native vegetation in this report, are shown in Figure 4 below.

Table 1 2017 Measures of Success associated with the native vegetation Expected outcomes in the Basin-wide environmental watering strategy (MDBA, 2014)

Forests and Woodlands

Expected outcomes	2017 Measures of Success
Maintain the current extent of forest and woodland vegetation, including approximately: • **360,000 ha of river red gum** • **409,000 ha of black box** • **310,000 ha of coolibah.**	Maintain current extent of river red gums, black box and coolibah.
No decline in the condition of river red gum, black box and coolibah across the Basin.	Maintain condition of river red gums, black box and coolibah.
By 2024, improve condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca.	Maintain condition of river red gums in key catchments.
By 2024, improve recruitment of trees within river red gum, black box and coolibah communities, in the long term achieving a greater range of tree ages.	Provide opportunities for the recruitment of river red gums, black box and coolibah trees.

Shrublands

Expected outcomes	2017 Measures of Success
Maintain the current extent of extensive lignum shrubland areas within the Basin. **These outcomes apply to lignum communities across the following regions (at a minimum): Lower Lachlan, Lower Murrumbidgee, Lower Darling, Lower Condamine–Balonne (including Narran Lakes), Lower Gwydir, Macquarie Marshes, Lower Border Rivers and the River Murray from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes).** **By 2024, improve the condition of lignum shrublands.** **These outcomes apply to lignum communities across the following regions (at a minimum): Lower Lachlan, Lower Murrumbidgee, Lower Darling, Lower Condamine–Balonne (including Narran Lakes), Lower Gwydir, Macquarie Marshes, Lower Border Rivers and the River Murray from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes).**	Maintain lignum shrublands in nominated regions.

Non-woody vegetation

Expected outcomes	2017 Measures of Success
Maintain the current extent of non-woody vegetation. **By 2024, increased periods of growth for communities that closely fringe or occur within the main river corridors.**	Provide periods of growth for non-woody vegetation closely fringing the main river corridors.
Maintain the current extent of non-woody vegetation.	Provide periods of growth for specific community types at specified locations.
By 2024, increased periods of growth for communities that form extensive stands within wetlands and low-lying floodplains including; • **Moira grasslands in Barmah–Millewa Forest** • **Common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes** • **Water couch on the floodplains of the Macquarie Marshes and Gwydir River** • **Marsh club-rush sedgelands in the Gwydir.**	Provide periods of growth for specific community types at specified locations.

Ruppia tuberosa

Expected outcomes	2017 Measures of Success
By 2019, *Ruppia tuberosa* to occur in at least 80% of sites across at least a 50 km extent.	*Ruppia tuberosa* occurring in at least 80% of sites across at least 50 km of southern Coorong.
By 2029, seed bank to be sufficient for the population to be resilient to major disturbances.	Maintain the seedbank of *Ruppia tuberosa* in the southern Coorong.

Contribution of the Plan to the Basin environment

Healthy rivers and floodplains of the Basin rely on a healthy flow regime and good water quality, which in turn support the water-dependent ecology of the system (e.g. birds, fish, vegetation etc.).

Water for the environment, delivered through the Basin Plan, is expected to provide tangible benefits for vegetation by restoring flow regimes along the riparian corridor, as well as out onto the floodplains and into wetlands. The most common approach to achieving the expected outcomes for native vegetation is to mimic

ecologically-significant parts of the natural flow regime. A range of opportunities and mechanisms are available to environmental water managers and planners. These may include providing appropriate flow regimes that support the water-dependent vegetation (MDBA, 2014), such as:

Creating and augmenting lateral connectivity by increasing bankfull and, where possible, over-bank events into low-lying wetlands and small over-bank events to inundate water-dependent vegetation
Extending flow durations and protecting flow peaks (including by limiting extraction) to support floodplain vegetation communities
Delivering water to support recruitment and improve condition of forest and woodland vegetation, including allowing for drying periods

Many potential threats that must be managed to achieve the native vegetation objectives fall outside the remit of the Basin Plan. These include:

- climate change including a change in local rainfall and intensity, seasonality and temperature
- habitat fragmentation caused by land use change, cropping or clearing
- change in land management such as overgrazing, fire management and changed nutrient input
- change in river regulation, such as storages, barriers, extraction, flow seasonality and flow variability.

The Basin Plan is one management lever able to improve flow regimes, but an integrated catchment management approach is important to manage other threats and support the expected outcomes for native vegetation.

Figure 4 below identifies some of the key needs and potential threats to achieving native vegetation objectives. This figure shows the importance of the Basin Plan, as well as highlighting the importance of broader catchment management measures needed to achieve the most efficient and effective use of environmental water.

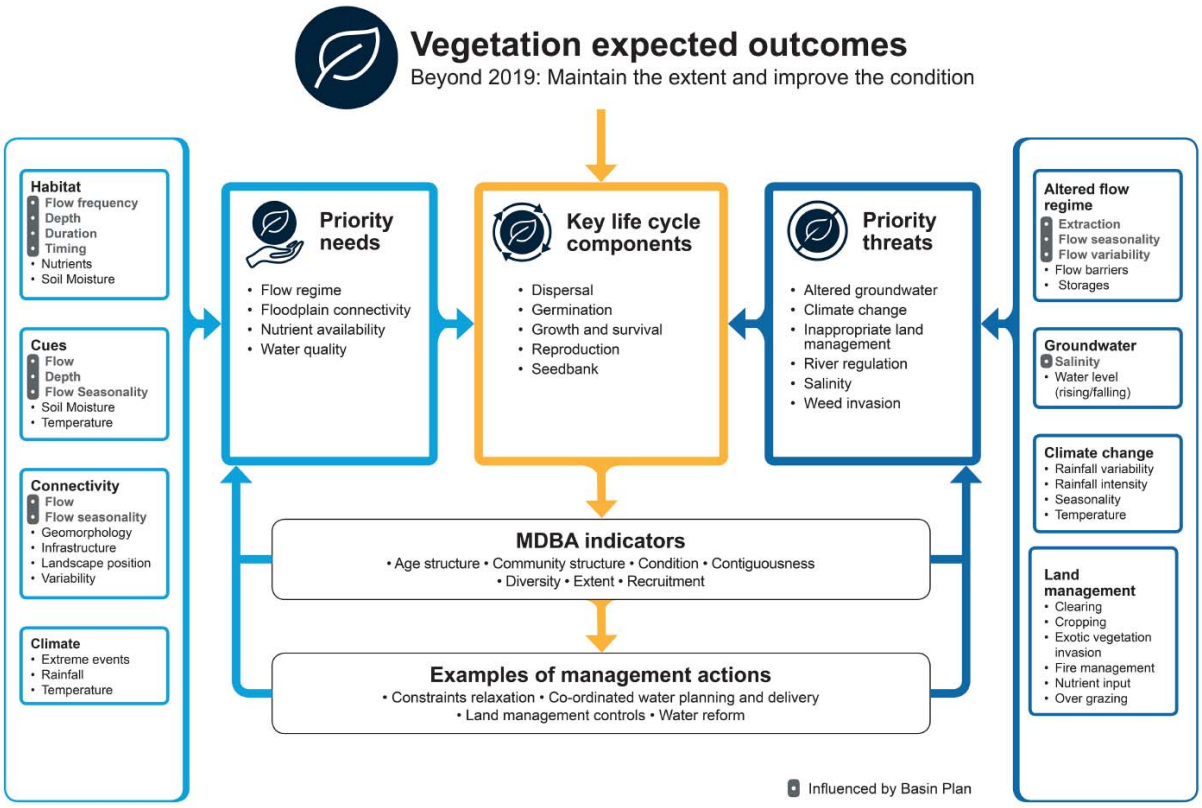

Figure 4 Drivers that influence the achievement of the native vegetation expected outcomes in the Murray–Darling Basin

One of the biggest factors influencing the environmental condition of the Basin is the climate (long term) and the weather (shorter term). The Basin climate is highly variable and extreme weather events (such as prolonged drought and floods) have a significant on its environmental condition. Climatic conditions also significantly influence environmental outcomes as they play a critical role in determining the volume of environmental water available for delivery within a season and the types of outcomes that may be targeted in any given year.

The climate over the implementation period has been variable, commencing with near average conditions in 2012–13, steadily becoming drier and hot from 2013–14 to mid-2015–16 and then closing the period with above average rainfall and inflows across much of the Basin. Areas of Queensland, New South Wales and Victoria entered drought at various points through the reporting period (2012-2017) and maximum and minimum temperatures exceeded the highest on record in some areas.

The amount of water in the rivers of the Murray–Darling Basin is expected to be affected by climate change (CSIRO 2008). Under a median climate change scenario, water in the northern Basin rivers' is predicted to decline by 8% by 2030, and in the southern Basin rivers by 12%. Under a dry climate change scenario, those reductions increase to 26% in the northern Basin and 37% in the southern Basin. Under these changing and variable conditions, the use of resource availability scenarios will become increasingly important and relevant in determining the provision of water for the environment.

Method

Multiple lines of evidence

Many people and organisations contributed to this evaluation. This included Government agencies across the Basin (QLD, NSW, ACT, VIC and SA), research institutions, and community groups and individuals, who contributed regional and local knowledge.

The key scientific data that was used in this evaluation is shown below in Table 2 (see References section for the full citations).

Table 2 Information that contributed to the native vegetation 2017 Basin Plan Evaluation

Information	Description	Application
Basin State & Commonwealth watering outcome reports	Annual States and Commonwealth Environmental Water Holder reports on the ecological outcomes of water delivered from site monitoring (i.e. individual wetlands, river systems or wetland complexes). See References Section for the full list of reports.	A meta-data analysis approach was taken with these reports. Environmental water outcomes were collated and organised to provide Basin-scale and regional insights on environmental water use.
Basin Plan Reporting Requirements (Schedule 12 Item 9.3)	Each water year environmental water holders report to the MDBA on the purpose, volume and use of environmental water.	Environmental water outcomes were mapped to watering events which took place since 2013–14 to determine the contribution of environmental water at a Basin scale.
Stand Condition Assessment tool	The Murray–Darling Basin spatial mapping tool was commissioned in 2013 and updated in 2017. It uses Landsat 8 imagery, field data and machine learning to predict the condition of forest and woodland trees (river red gums, black box and coolibah). See Appendix A - Murray–Darling Basin Stand Condition Assessment Tool for further information.	The outputs provide an annual snap shot of condition of river red gum, black box and coolibah across the Murray–Darling Basin by using tree canopy density as a surrogate for "health". The tool also calculated river red gum, black box and coolibah extent (MDBA, 2014).
Coorong *Ruppia tuberosa* monitoring	*Ruppia tuberosa* monitoring in the Coorong since 1998 (winter) and since 2007 (summer) until 2017.	Data was used to form the quantitative environmental expected outcomes in the strategy for *Ruppia tuberos*a. This

Information	Description	Application
	See References Section for the full list of reports and the raw data is available on Data.gov.au.	data was used to identify trends in *Ruppia tuberosa* extent and resilience.
Murray–Darling Basin Environmental Water Knowledge Research Project	This project aims to improve information about how key forest and woodland trees, understorey and wetland plants respond to environmental water and key threats. This study incorporates analysis of existing information, field work at four sites in the Murray–Darling Basin and laboratory experiments.	Insights from this research were applied to inform the interpretation of native vegetation data.

Results and Discussion

Native vegetation monitoring that aims to understand the influence of environmental water and progress towards achieving expected outcomes is predominately undertaken at the site scale (i.e. specific location within wetlands, river systems or wetland complexes). This is appropriate for native vegetation as ecological responses will be observed at the individual tree or vegetation community scale. Basin-wide expected outcomes that combine the site-scale monitoring, a conceptual understanding of the processes that drive vegetation response, and a flow history are then inferred from these site-scale responses.

Forests and woodlands

River red gum forests and woodlands growing near rivers, creeks, wetlands and lakes are widespread throughout the Basin. They are an important component of the Basin ecology as they stabilise the soil and river banks and provide habitat for native animals (e.g. birds' nests in hollows and reptiles that live under fallen branches).

Regular flooding is vital to maintain river red gum forests and woodlands. Black box is a common drought-tolerant and flood-responsive vegetation community that grows throughout the Basin. Black box generally occurs higher on the floodplain than river red gums and can source water from rainfall, floods, rivers and groundwater. Coolibah grows in the northern part of the Basin in riverine habitats and on floodplains, sourcing its water from rainfall, floods and groundwater.

The forest and woodland areas considered as part of this evaluation are located on the managed floodplain only.

Extent

The extent of forests and woodlands within the managed floodplain has been defined by the Stand Condition Assessment Tool as 360,000 ha of river red gums, 409,000 ha of black box and 310,000 ha of coolibah (plus or minus 10%), see Appendix A - Murray–Darling Basin Stand Condition Assessment Tool for further information and MDBA, 2014).

This evaluation assessed one expected outcome for river red gum, black box and coolibah extent (Table 3).

Table 3 Expected outcome and 2017 Measures of Success for river red gum, black box and coolibah extent

Expected outcome	2017 Measure of Success
Maintain the current extent of forest and woodland vegetation including approximately: • **360,000 ha of river red gum** • **409,000 ha of black box** • **310,000 ha of coolibah**	Maintain extent of river red gums, black box and coolibah.

Basin Plan contribution

Changes to extent due to the Basin Plan are expected to occur at local scales (i.e. the tree or community scale), and the degree of such change in the short term is likely to be small. For example, environmental water will improve condition and promote successful recruitment over several years, and if this recruitment occurs on the edges it might increase the extent of the forest or woodland. An absence of environmental water will cause tree death and a decrease in extent over an extended period.

Changes in vegetation extent due to the Basin Plan will take some time to see. For example, environmental water will improve condition and promote successful recruitment over several years, thereby increasing the extent. An absence of environmental water will cause tree death and a decrease in extent will occur over an extended period.

Evaluation findings

At this early stage of implementation, it is difficult to determine if the Basin Plan has met the 2017 Measure of Success or if it is on track to achieve this expected outcome.

To improve the expected outcomes for the extent of floodplain forests and woodland, it is important to progress the removal of constraints in the system, protect environmental water and use floodplain regulators and other works. Coordinating the planning and delivery of environmental water with environmental managers and planners, and where relevant with river operators is also needed to maximise vegetation outcomes using the delivery of consumptive water. Management of immediate interventions that reduce the extent of forest and woodland vegetation such as land clearing and revegetation are beyond the remit of the Basin Plan.

In addition to using site specific monitoring information, the MDBA will continue to investigate options in consultation with state and commonwealth agencies to monitor and evaluate extent of woodland and floodplain vegetation at the Basin scale.

Table 4 2017 Measure of Success, expected outcome and the evaluation finding for river red gum, black box and coolibah extent

Metrics	Results
2017 Measure of success Maintain extent of river red gums, black box and coolibah.	**Too early to tell** It was not possible to evaluate the maintenance of river red gum, black box and coolibah extent at the Basin-scale in 2017 due to the lag time expected to detect a change in extent and the lack of information.
Expected outcome Maintain the current extent of forest and woodland vegetation including approximately: • 360,000 ha of river red gum • 409,000 ha of black box	**Too early to tell** At this stage it is unclear if Basin Plan implementation is on track to achieve the expected outcomes due to the lag time expected to detect a change in extent and lack of information.

Metrics	Results
• 310,000 ha of coolibah.	

Condition

The condition of flood-dependent woody vegetation commonly improves in response to flooding that occurs at the correct time of year, for an appropriate duration and at an appropriate frequency over time. These flows maintain and encourage the growth of woody vegetation and recharge and refresh the surrounding groundwater. An improvement in condition can indicate the presence of an appropriate flow regime and conversely a decline in condition can indicate the lack of appropriate flows. Environmental water planners and managers have a good understanding of how some vegetation responds to flows and can deliver water to get these outcomes, for example river red gums. Less is known about the watering requirements of black box and coolibah and research is underway to better understand these needs.

The 2017 Evaluation assessed two expected outcomes for woody vegetation condition on the managed floodplain (Table 5) using the Stand Condition Assessment (see Appendix A - Murray–Darling Basin Stand Condition Assessment Tool for further information) and monitoring results.

Table 5 Expected outcomes and 2017 Measures of Success for the condition of river red gums, black box and coolibah

Expected outcomes	2017 Measures of Success
No decline in the condition of river red gum, black box and coolibah across the Basin	Maintain condition of key woody species.
By 2024, improve condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca	Maintain condition of river red gums in key catchments.

The Stand Condition Assessment Tool found that the river red gum condition on the managed floodplain has been maintained since 2009 with most communities categorised as being in moderate condition (Figure 5). There has been a slight improvement in condition in the Murrumbidgee, Lachlan, Macquarie-Castlereagh and Murray Basin regions, reflecting a somewhat stable watering history in these areas. A very slight decline was observed in the Murray and Wimmera-Avoca (see Figure 9).

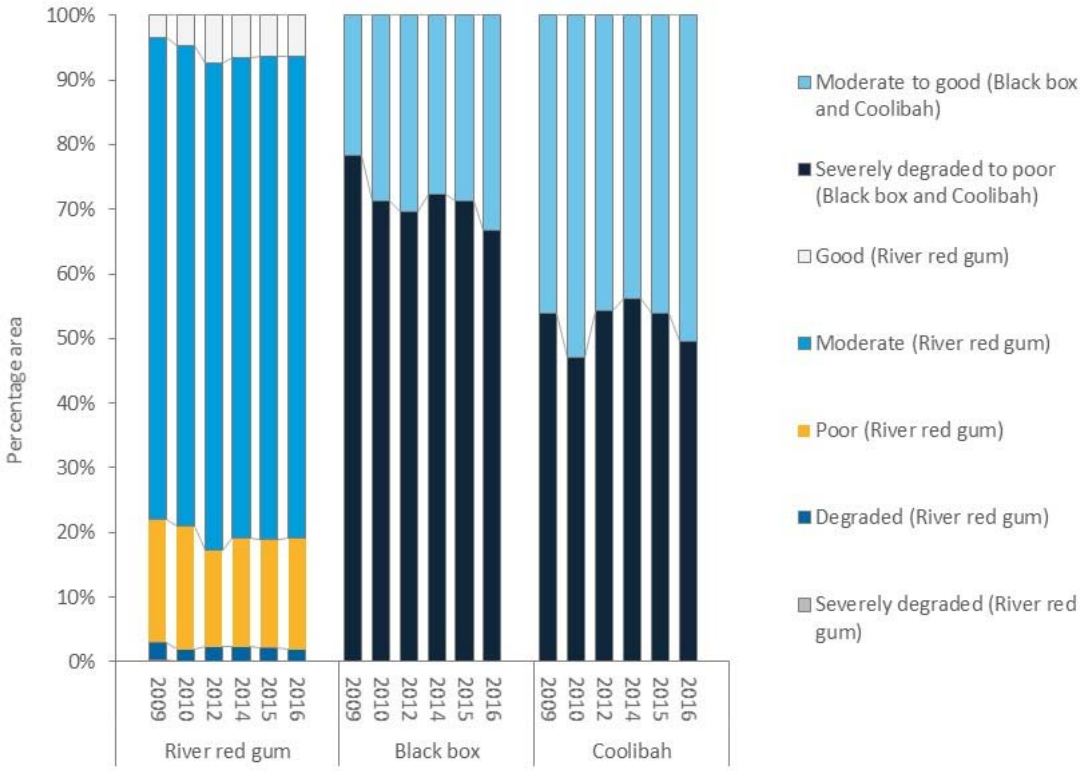

Figure 5 The percentage area of river red gum (area is 363,180ha), black box (area is 409,603ha) and coolibah (area is 311,844 ha) across the Murray–Darling Basin on the managed floodplain in each condition category over the survey years from 2009 to 2016 (exluding 2011 and 2013).

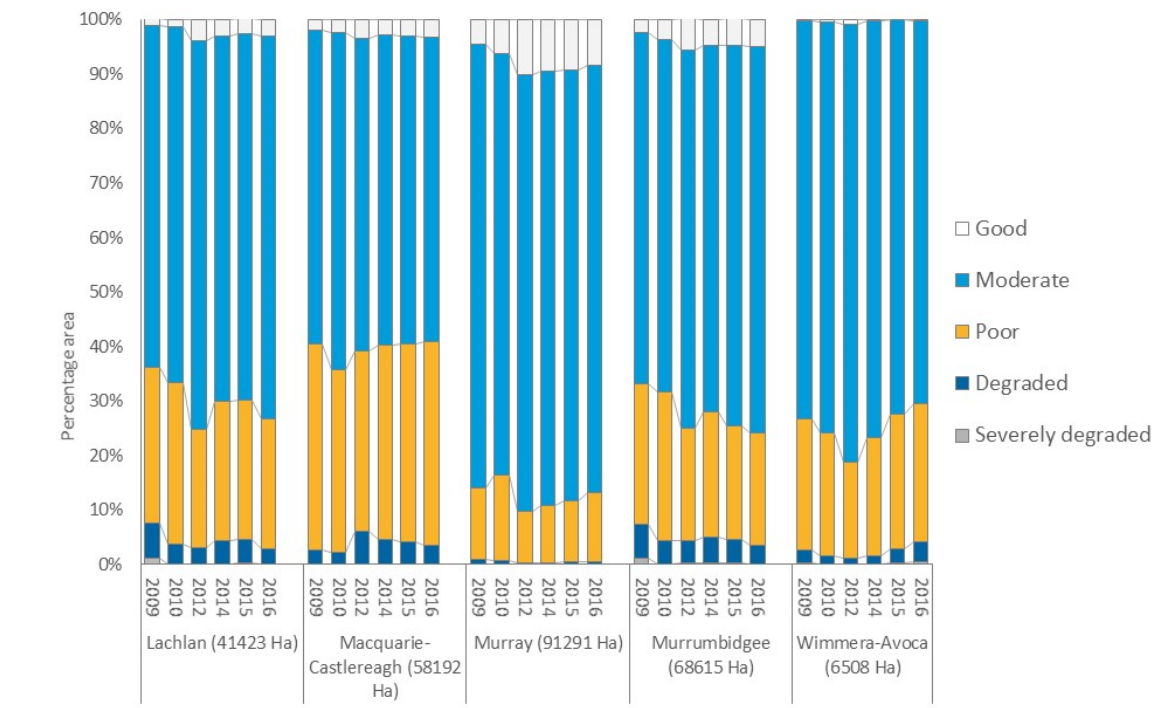

Figure 6 River red gum condition in the Lachlan, Macquarie-Castlereagh, Murray, Murrumbidgee and Wimmera-Avoca Basin region from 2009 to 2016 (exluding 2011 and 2013)

The condition of black box on the managed floodplain has been varied from 2009 to 2016 (Figure 5), with most of the Murray–Darling Basin categorised as 'severely degraded to poor'. There is a slight improvement in black box condition in the Murrumbidgee, Barwon-Darling and Border Rivers (see Figure 7). Black box condition in the other Basin regions has generally been maintained, with some variation between years.

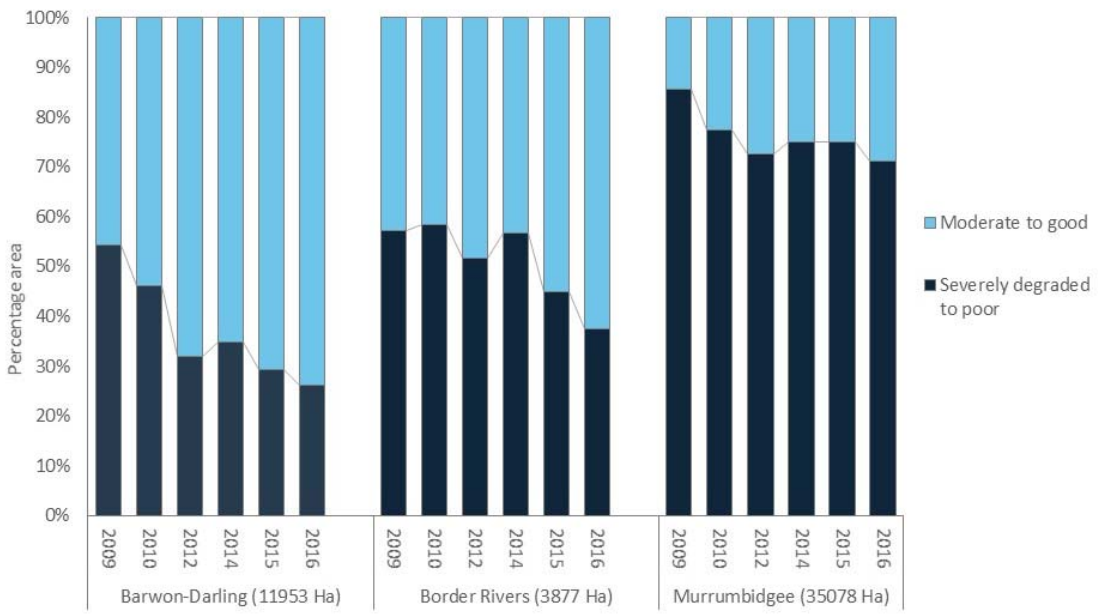

Figure 7 Black box condition in the Barwon-Darling, Border Rivers and Murray Basin regions from 2009 to 2016 (exluding 2011 and 2013)

The condition of coolibah on the managed floodplain from 2009 to 2016 has been mixed (Figure 5) with half of the area categorised as 'severely degraded to poor' and half categorised as 'moderate to good'. This was expected as these areas generally occur higher on the managed floodplain and receive environmental water only periodically. The Stand Condition Assessment Tool has not been as extensively validated for coolibah as for river red gums and black box. As a result, the model produces an assessment of coolibah condition on the managed floodplain that is a more variable result than is likely to be occurring (see Figure 8). The results indicate that most coolibah communities in good condition are found in the Gwydir, Namoi, Moonie, Condamine-Balonne and Barwon-Darling Basin regions.

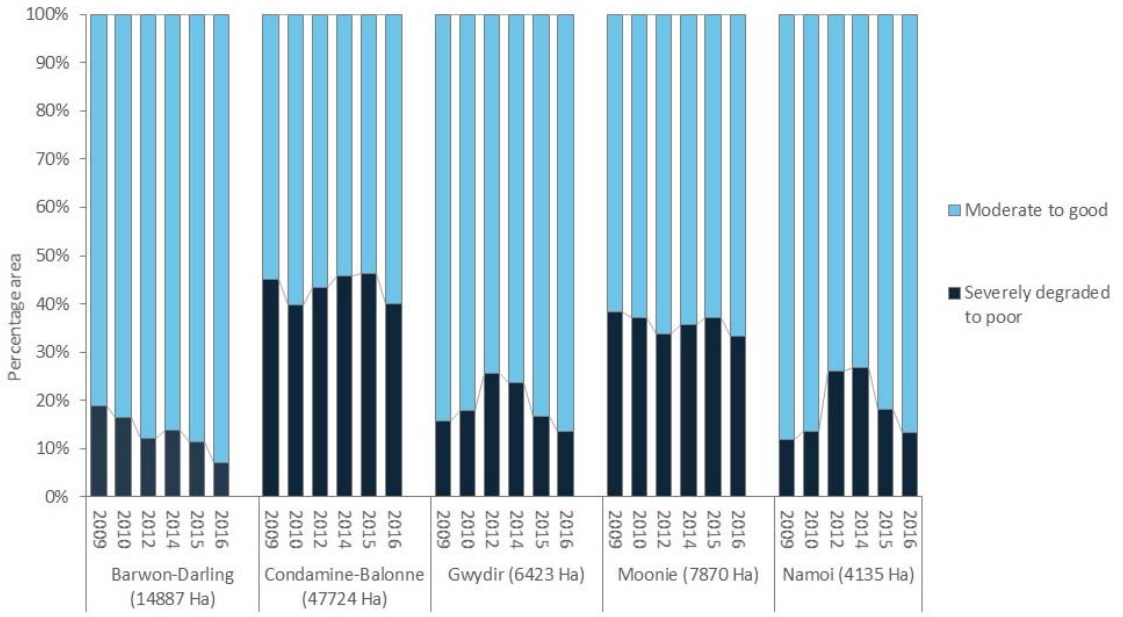

Figure 8. Coolibah condition in the Barwon Darling, Condamine-Balonne, Gwydir, Moonie and Namoi from 2009 to 2016 (exluding 2011 and 2013).

Basin Plan contribution

There has been some improvement in river red gums condition in response to environmental water under the Basin Plan. The progress and achievements up to 2017 in Table 6 relate to the Murray, Lachlan, Murrumbidgee, Lower Daring, Goulburn Broken and Wimmera-Avoca Basin regions as specified in the expected outcomes (Table 6 and Table 5).

Table 6 Progress and achievements up to 2017 of river red gum condition growing on the managed floodplain in the Murray, Lachlan, Murrumbidgee, Lower Darling, Goulburn Broken and Wimmera-Avoca Basin regions

Basin region	Progress and achievements up to 2017
Murray	Environmental water has been delivered to support and improve the condition of river red gum vegetation at sites along the River Murray. In these areas, there has been evidence of improvement in tree condition, with increases in growth and tree vigour observed through monitoring programs (MDFRC, 2016; Wood F. , 2016; DEWNR, 2016). Where environmental water has not been delivered with sufficient frequency or duration, the condition of river red gums has declined. This has occurred in areas on the floodplain where constraints have limited environmental water delivery.

Basin region	Progress and achievements up to 2017
Lachlan	In areas of the Lower Lachlan, environmental water made a small improvement to the condition of individual river red gums. However, a change in the condition of the river red gum communities was not detected (Dyer, et al., 2016).
Murrumbidgee	Environmental water has maintained and improved the condition of river red gum communities along the Murrumbidgee. Where environmental water has not been delivered in sufficient frequency or duration, the condition of river red gums has declined (Wassens, et al., 2016). This decline has occurred in areas higher on the floodplain where constraints have limited environmental water delivery.
Lower Darling	Environmental water has not been used in the Lower Darling to improve river red gum condition (CEWO, 2017).
Goulburn-Broken	Due to constraints, environmental water has not been used to improve river red gum condition in the Goulburn-Broken (CEWO, 2017).
Wimmera-Avoca	Due to the low reliability of the Commonwealth holdings and the highly variable nature of flows in the Wimmera-Avoca, environmental water is not available in most years. The small volume of available environmental water was used to contribute to instream base flows rather than to support river red gums growing on the adjacent floodplains (CEWO, 2017).

Evaluation findings

Maintaining the condition of river red gums, black box and coolibah requires successive environmental watering events across the managed floodplain. The 2017 Evaluation has shown that the condition of river red gum, black box and coolibah has generally been maintained. In some areas, environmental water has improved the river red gum condition. In other areas higher on the managed floodplain, vegetation condition has declined.

The 2017 Measures of Success have been met (Table 7). The Basin Plan implementation is on track to achieve the expected outcomes on the managed floodplain (Table 7) provided the following actions occur: continued coordination of environmental water (where appropriate); operation of existing 'environmental works' at TLM sites; protection of environmental water; and implementation of an integrated catchment approach.

There are instances where a conservative approach to delivering water for the environment has limited the achievement of the 2017 Measure of Success and expected outcome. This has occurred where water stays within the river channel rather than flowing onto the floodplain, for example in the Goulburn-Broken region. There are other instances where high flows are required to ensure water can flow overbank and onto the adjacent floodplain, for example the along the River Murray in South Australian.

The Murray–Darling Basin Authority will develop the Stand Condition Assessment tool, including doing more model runs, analysis, correlation with environmental water outcomes to understand the trends and change

in condition over time and coordinating the collection of additional field data in partnership with Basin states.

Table 7 2017 Measures of Success, Expected outcomes and the evaluation findings for the condition of river red gums, black box and coolibah

Metrics	Results
2017 Measure of success Maintain condition of key woody species.	**Met** River red gum, black box and coolibah condition has generally been maintained across the Basin with some variation observed at specific locations and for a particular species.
Expected outcome No decline in the condition of river red gum, black box and coolibah across the Basin.	**On track** River red gum, black box and coolibah condition has generally been maintained across the Basin with some variation observed at specific locations and for a particular species.
2017 Measure of success Maintain condition of river red gums in key catchments.	**Met** Basin Plan implementation has maintained and improved the condition of river red gums in some locations, notably at sites along the River Murray.
Expected outcome By 2024, improve condition of river red gum in the Lachlan, Murrumbidgee, Lower Darling, Murray, Goulburn–Broken and Wimmera–Avoca.	**On track** River red gum condition has been maintained and improved in response to environmental watering under the Basin Plan. However, this has not occurred in the Goulbourn-Broken where environmental water has not flowed over the river channels onto the floodplain or in the Lower Darling where environmental water has not been delivered to target river red gums. Therefore, a decline in the condition of river red gums in areas might be seen over a period of years.

Recruitment

Achieving successful recruitment events (or reproduction) of river red gums, black box and coolibah is important to improve the age structure of these vegetation communities and ensure that populations are replenished. Success will take many years. Early signs of success include the presence of seedlings and saplings. To achieve this, river red gums, black box and coolibah require a sequence of environmental watering events, appropriate soil moisture and temperatures for seedling and saplings to grow.

The strategy lists one expected outcome to improve the recruitment of river red gum, black box and coolibah by 2024 on the managed floodplain (Table 8).

Table 8 Expected outcome and 2017 Measure of Success for recruitment of river red gums, black box and coolibah

Expected outcome	2017 Measure of Success
By 2024, improve recruitment of trees within river red gum, black box and coolibah communities—in the long term achieving a greater range of tree ages.	Provide opportunities for the recruitment of river red gums, black box and coolibah trees.

Basin Plan contribution

Due to limited data availability, or a lack of a Basin-wide program, the 2017 Evaluation relies on discreet examples from the Lower Lachlan, Macquarie Marshes and Hattah Lakes where monitoring the outcomes from environmental water has found to promote recruitment of trees within river red gum and black box forest and woodland communities.

High rainfall and the delivery of environmental water in the Lower Lachlan river system during spring 2015 resulted in the growth of river red gum seedlings and saplings. However, grazing in these areas reduced the proportion of seedlings and saplings that survived (Dyer, et al., 2016).

Recruitment of seedlings and saplings has been observed every year from 2010 to 2017 in the Macquarie Marshes but has been more abundant in the northern Macquarie Marshes where environmental water has been delivered, compared to the southern region (S. Bowen pers. comm.).

In 2010-11 and 2013-14 natural flooding and environmental regulators and pumps have delivered environmental water across a larger area of the Hattah Lakes managed floodplain to enable river red gum germination to reach the sapling stage, i.e. trees 0cm to 15cm Diameter at Breast Height (Figure 9). A large number of these river red gum seedlings (at a density of approximately 2000 seedlings m^{-1}) have germinated around the edge of waterbodies forming thick strands (Wood, Freestone, Brown, Campbell, & Huntley, 2016). Some seedlings will perish over time and reduce in density, for example, seedlings that are two years old are found at a density of 1000 seedlings m^{-1}. Environmental water delivered in 2013-14 stimulated high rates of river red gum germination (Figure 9) in drier and less frequently flooded areas of river red gum forest (Wood, Freestone, Brown, Campbell, & Huntley, 2016).

Black box in Hattah Lakes have germinated in areas that flooded naturally or received high rainfall since 2009-10. Many of these plants have reached sapling stage i.e. trees from 0cm to 15cm Diameter at Breast Height (Figure 10). A high number of black box seedlings germinated in response to inundation in 2014 (Wood, Freestone, Brown, Campbell, & Huntley, 2016).

Some areas that are higher on the floodplain have had limited recruitment as they received water only during 2014 when there were significant floods (Wood, Freestone, Brown, Campbell, & Huntley, 2016).

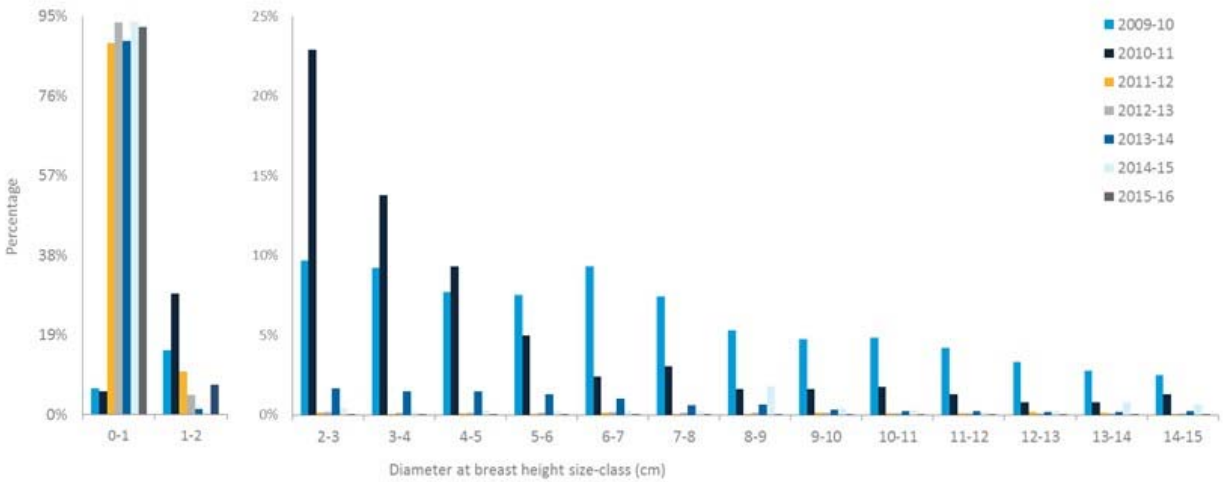

Figure 9 Percentage of river red gum forest samplings from 0 to 15 cm Diameter at Breast Height (DBH) at Hattah Lakes from 2009 to 2016; n(2009–10) = 709, n(2010–2011) = 624, n(2011–2012) = 3,946, n(2012–13) = 65,753, n(2013–2014) = 4,563, n(2014–2015) = 1,707 and n(2015–16) = 326,127

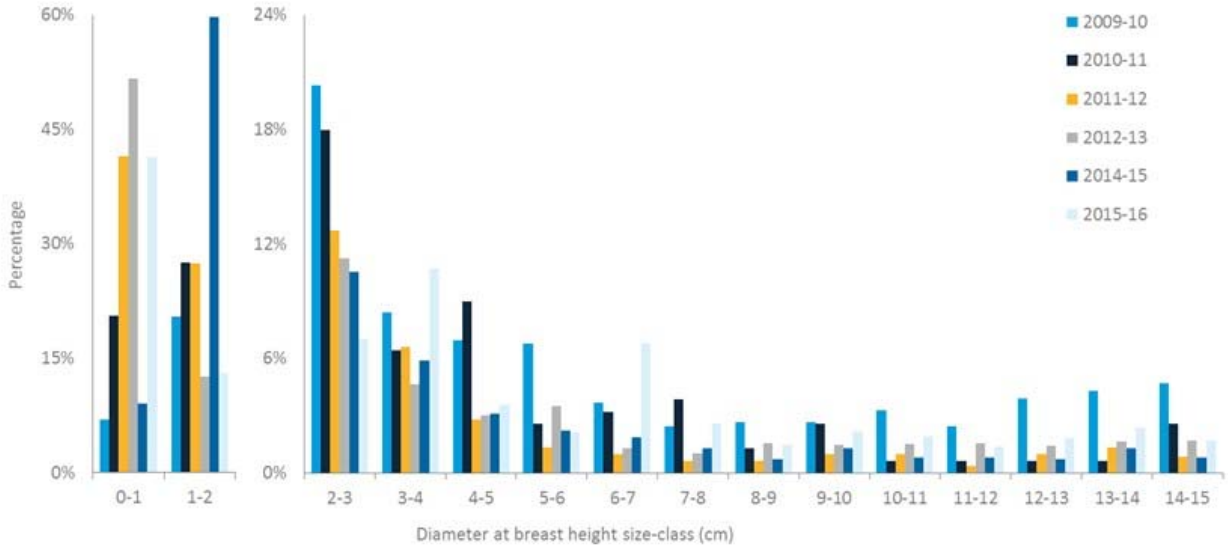

Figure 10 Percentage of black box saplings from 0 to 15 cm Diameter at Breast Height (DBH) at Hattah Lakes from 2009 to 2016 (execpt 2013-14); n(2009–10) = 488, n(2010–2011) = 156, n(2011–2012) = 818, n(2012–13) = 2,227, n(2014–2015) = 865 and n(2015–16) = 1,828

Evaluation findings

The Lower Lachlan and Hattah Lakes examples above show that river red gum and black box recruitment events have occurred where environmental water has been delivered and threats, such as grazing, are

managed. There have been instances where the recruitment of river red gums have occurred in undesirable locations, so this outcome also needs to be managed. For example, there has been river red gum encroachment at the McKenna's and Sunshower Lagoons in the mid-Murrumbidgee. In addition, river red gum recruitment has caused dense thickets or strands in some areas which also need to be managed, such as in Hattah Lakes and Barmah Forest.

Changes to extent due to the Basin Plan are expected to occur at local scales, and the degree of such change in the short term is likely to be minor and is not monitored. Due to limited data and information, it is unclear if Basin Plan implementation has met the 2017 Measure of Success and if it is on track to meet the expected outcome for river red gums, black box and coolibah recruitment (Table 9).

It is important to continue to invest in, coordinate and fill these information gaps to better understand vegetation recruitment and community structure across the Basin and how to deliver environmental water to achieve the best possible outcome.

Table 9 2017 Measure of Success, expected outcome and the evaluation findings for recruitment in forests and woodlands

Metrics	Results
2017 Measure of success Maintain recruitment of river red gums, black box and coolibah. **Expected outcome** By 2024, improve recruitment of trees within river red gum, black box and coolibah communities—in the long term achieving a greater range of tree ages.	**Insufficient evidence** Early signs of recruitment in the form of successful reproduction include the presence of seedlings and saplings. These have been observed at sites where water has been delivered and monitoring has been undertaken, such as at the Lower Lachlan, Macquarie Marshes and Hattah Lakes. A monitoring program across the Basin has not been undertaken. Therefore, determining progress towards maintaining recruitment of river red gums, black box or coolibah is difficult due to the lack of information at the Basin scale.

Lignum shrublands

Lignum grows along riverbanks, on floodplains and in wetlands across the Basin. It requires periodic flooding to maintain good condition to grow new leaves, stems and flowers and therefore allow for reproduction. Lignum can grow in woodlands under trees or as the dominant overstorey species in shrublands, with small plants growing among the shrubs. Lignum shrublands provide important habitat for a range of animal species, and dense, tall shrublands can be ideal nesting and nursery habitat for many waterbird species.

The quantified environmental outcomes in the strategy apply to the lignum shrublands growing on the managed floodplain across the following regions Lower Lachlan, Lower Murrumbidgee, Lower Darling, Lower Condamine–Balonne (including Narran Lakes), Lower Gwydir, Macquarie Marshes, Lower Border Rivers and

the River Murray from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes) (MDBA, 2014).

The 2017 Evaluation assessed two lignum shrubland expected outcomes relating to their extent and condition (Table 10). These outcomes apply to lignum communities across the following regions (at a minimum): Lower Lachlan, Lower Murrumbidgee, Lower Darling, Lower Condamine–Balonne (including Narran Lakes), Lower Gwydir, Macquarie Marshes, Lower Border Rivers and the River Murray from the junction of Wakool River to downstream of Lock 3 (including Chowilla and Hattah Lakes).

Table 10 Expected outcomes and 2017 Measures of Success for lignum shrublands in nominated Basin regions

Expected outcomes	2017 Measures of Success
Maintain the current extent of extensive lignum shrubland areas within the Basin. **By 2024, improve the condition of lignum shrublands**	Maintain lignum shrublands in nominated Basin regions.

Basin Plan contribution

Data is not being collected to quantify changes in extent of lignum shrublands at a Basin scale, nor in most cases at a site scale. Instead, commentary is provided in Table 11 below on where water has or has not been delivered under the Basin Plan to maintain the extent and improve the condition of lignum shrublands within the Basin regions specified in the expected outcomes.

Table 11 Progress and achievements up to 2017 for the extent and condition of lignum shrublands at nominated Basin regions

Basin region	Location	Progress and achievements up to 2017
Murray	Wetlands along the River Murray from the junction of Wakool to lock 3 (including Chowilla and Hattah Lakes)	Environmental water delivered under the Basin Plan to sites along the River Murray has improved the health of individual lignum shrubs, particularly where a series of events have been delivered in recent years. Some examples are provided from monitoring programs in the region. On the Chowilla floodplain, the condition of lignum shrublands has improved in areas where environmental water has been consistently delivered (DEWNR, 2016). At Hattah Lakes, the condition of lignum shrublands in areas that have been watered has improved; however, the overall condition of lignum shrublands across the site has declined (Wood F. , 2016). Decline in lignum shrubland condition has been recorded at the Lindsay-Mulcra-Wallpolla Forest with lignum shrublands on the higher parts of the floodplain experiencing dry periods for between 20 and 40 years. Lignum shrublands that have received water through the environmental works at Mulcra Island have improved in condition (MDFRC, 2016). Lignum shrublands at Bottle Bend, near Buronga, have responded well to environmental water by producing new growth and improving in condition. In parts of this floodplain where environmental water has not been delivered, lignum shrublands have continued to decline in condition (Freestone, Campbell, & Healy, 2017). The extent of lignum shrublands is not mapped or monitored in the Murray Basin region.
Lachlan	Lower Lachlan	In the Lower Lachlan the core wetland areas of lignum shrublands in the Great Cumbung Swamp have been supported with environmental watering and natural flooding. The waterings have resulted in flushes of new growth and improved the condition of lignum shrublands. However, lignum shrubland condition is declining where frequent inundation has not occurred, either naturally or augmented by environmental water, such as the Lignum swamp (Dyer, et al., 2016). Extent of lignum shrublands has not been mapped or monitored in the Lower Lachlan.

Basin region	Location	Progress and achievements up to 2017
Murrumbidgee	Lower Murrumbidgee	Environmental water has been delivered at many wetlands in the Lower Murrumbidgee, including wetlands in the Redbank, Nimmie-Caira and mid-Murrumbidgee regions. Lignum shrublands have been supported in core areas of these wetlands and have responded to inundation events with increased growth (Wassens, et al., 2016). Extent of lignum shrublands is not mapped or monitored in the Lower Murrumbidgee.
Darling	Lower Darling	Monitoring of lignum shrubland condition or extent is not undertaken in the Lower Darling.
Condamine-Balonne	Lower Condamine-Balonne (including Narran Lakes)	Lignum shrublands in the northern section of Narran Lakes and near channels are more frequently inundated and are in good condition. In contrast, lignum shrublands in areas of Narran Lakes requiring large floods for inundation have experienced infrequent inundation, are in poor condition and plants are sparsely distributed (Thomas, Karunaratne, Heath, & Kuo, 2016).
Gwydir	Lower Gwydir Wetlands	Environmental water has maintained the condition and extent of key areas of lignum shrublands in the Gwydir wetlands in areas that can receive environmental water (DECCW, Gwydir Wetlands Adaptable Environmental Management Plan, 2011). Where constraints have limited environmental water delivery, the condition of lignum shrublands has declined (DECCW, 2011; Frazier, et al., 2016).
Macquarie–Castlereagh	Macquarie Marshes	Where environmental water can be delivered within constraints, lignum shrublands have improved in condition and maintained their extent. Where constraints limit environmental water delivery, lignum shrublands have declined in condition except in response to natural flooding and rainfall events in 2012–13. (DECCW, 2010; Sharon Bowen, pers. comms.; Bowen, Simpson, Hosking, & Shelly, 2017).
Border Rivers	Lower Border Rivers	Lignum shrublands are found within the floodplain wetlands and riparian region of the Lower Border Rivers. Environmental water has not been used to target areas outside the river channels, including lignum shrublands (CEWO, Restoring and Protecting the Border Rivers 2016-17, 2016). Monitoring of lignum condition or extent is not undertaken in the Lower Border Rivers.

Evaluation findings

Where environmental water under the Basin Plan and natural floods have watered lignum shrublands their condition has improved (Table 11). Lignum shrublands, often requiring several subsequent waterings to improve condition. In areas that have not received adequate water the condition of lignum shrublands are likely to have declined.

In some Basin regions lignum shrublands will continue to decline in areas outside of the managed floodplain and may transition into flood tolerant vegetation. Therefore, it is important to continue to implement all the Basin Plan mechanisms to ensure the condition and extent of lignum shrublands in key Basin regions do not decline.

There is no widespread mapping, monitoring or reporting of lignum shrublands vegetation in the Basin. Without monitoring and established baselines, it is difficult to determine if the implementation of the Basin Plan has met the 2017 Measures of Success or if the Basin Plan is on track to achieve the expected outcomes for lignum shrublands at all the nominated Basin regions. Some progress has been made with monitoring, and this will help to refine the expected outcomes in the future (Brooks, 2017).

Further investigation is warranted of the potential to refine the expected outcomes, improve information, objectives, monitoring and reporting of lignum shrublands. It is also important to develop state long-term watering plans that specify relevant important areas, objectives and environmental water requirements for lignum shrublands.

Table 12 2017 Measures of Success, Expected Outcomes and the evaluation findings for lignum shrublands

Metrics	Results
2017 Measure of Success Maintain lignum shrublands in nominated Basin regions. **Expected outcome** Maintain the current extent of extensive lignum shrubland areas within the Basin (in specified regions).	**Insufficient evidence** In some locations, such as northern section of Narran Lakes, northern Macquarie Marshes and lower Murrumbidgee lignum shrublands have been maintained. Determining if this has occurred across the nominated Basin regions is difficult as not all the lignum shrubland areas have not been defined or monitored.
Expected outcome By 2024, improve the condition of lignum shrublands (in specified regions).	**Insufficient evidence** Without monitoring of condition at all the specified Basin regions it is not possible to determine if the Basin Plan implementation is on track to achieve the expected outcome for lignum condition by 2024.

Non-woody vegetation

Non-woody native vegetation is the water dependent vegetation growing along river channels and wetlands. It includes grasslands, sedgelands, rushlands, herblands and fully-submerged species (such as *Ruppia tuberosa*). These water-dependent non-woody plants require flooding for some or all of their life cycles in order to grow and reproduce. They can form extensive grasslands or reed beds in wetlands, river banks and frequently-inundated floodplains.

Some non-woody species have an annual life cycle, and depend on the presence or absence of water in the wetlands. Maintaining the current extent of non-woody vegetation requires inundation of wetlands at sufficient frequencies to provide suitable conditions for these species.

Vegetation fringing main river corridors

Non-woody native vegetation found along or within the river channels of the Basin provides habitat and food for fish, invertebrates, frogs and birds, and is important for instream productivity and stabilising river banks.

The 2017 Evaluation reports on two expected outcomes relating to vegetation closely fringing main river corridors (Table 13).

Table 13 Expected outcomes and 2017 Measure of Success for vegetation closely fringing main river corridors

Expected outcome	2017 Measure of Success
Maintain the current extent of non-woody vegetation. **By 2024, increased periods of growth for communities that closely fringe or occur within the main river corridors**	Provide periods of growth for non-woody vegetation closely fringing the main river corridors.

Basin Plan contribution

The Basin-wide environmental watering strategy specifies expected outcomes for maintaining the extent and providing for increased periods of growth for non-woody vegetation closely fringing the main river channels (MDBA, 2014). In the absence of a monitoring program to assess progress against these expected outcomes, this report provides two examples where water delivery has improved vegetation closely fringing the main river corridors in the Edward-Wakool system and Goulburn River.

Environmental water has been delivered with the objective to improve the condition of riverbank vegetation in the Edward-Wakool river system. Vegetation fringing the river banks has responded positively to the flows and, recovering and re-establishing along the riverbank. (Watts, et al., 2016; Watts, et al., 2016).

Vegetation monitoring in Goulburn River showed that environmental water promoted the growth of non-woody fringing vegetation where freshes occurred during spring 2014–-15. However, limited growth was

recorded in 2015–16 because of the dry antecedent conditions (Webb, 2016). Site-specific monitoring suggests that freshes are likely to contribute to the growth of non-woody vegetation closely fringing main river corridors.

Evaluation findings

In the absence of Basin-wide information and monitoring it can be assumed that the extent and periods of growth of vegetation closely fringing the main river corridor will be maintained if environmental water has been delivered at the appropriate time of year and for long enough. When operationally feasible the volume of consumptive water fluctuates throughout the River Murray system, its effluents and anabranches to benefit closely fringing vegetation. These areas are often negatively impacted by pest animals, grazing and clearing. So even if water has been delivered appropriately these threats need to be managed if the vegetation is to benefit from improved water flows.

Limited monitoring information makes it difficult to determine if Basin Plan implementation is on track to achieve the expected outcomes for vegetation closely fringing main river corridors across the Basin. There is not widespread, consistent monitoring or reporting of non-woody vegetation extent in the Basin. Some progress has been made (Brooks, 2017) to map riparian vegetation that can help refine the expected outcomes and identify areas for monitoring against this expected outcome.

Table 14 2017 Measures of Success, Expected Outcomes and the evaluation findings for vegetation closely fringing main river corridors

Metrics	Results
2017 Measure of success Provide periods of growth for non-woody vegetation closely fringing the main river corridors. **Expected outcome** By 2024, increased periods of growth for communities that closely fringe or occur within the main river corridors	**Insufficient evidence** In some locations, such as the Edward-Wakool System and Goulburn River, water has been delivered to provide vegetation fringing the rivers with increased periods of growth. Determining if there have been periods of growth of vegetation that closely fringe the main river corridors of the Murray–Darling Basin is difficult at this point due to information gaps.
Expected outcome By 2024, increased periods of growth for communities that closely fringe or occur within the main river corridors.	**Insufficient evidence** Locations, types and extent of non-woody vegetation along the main river corridor has not been defined. Therefore, it is unclear if Basin Plan implementation is on track to achieve the expected outcomes.

Wetland and low-lying floodplain vegetation

Non-woody vegetation found in wetlands and low-lying floodplain regions include reeds, rushes and grasses that can form extensive reed beds or grasslands. These are a foundational component of the wetland system and provide essential food and habitat resources for a range of animals.

The wetlands experience different wetting and drying cycles that are important for maintaining the key vegetation types and supporting a diverse and resilient wetland vegetation community. When water is delivered to these wetland areas there are opportunities for the water-dependent vegetation species to grow, flower and produce seeds.

The 2017 Evaluation assessed two expected outcomes for wetland and low-lying floodplain non-woody vegetation (Table 15).

Table 15 Expected outcome and 2017 Measure of Success for periods of growth of wetland and low-lying floodplain non-woody vegetation

Expected outcomes	2017 Measures of Success
Maintain the current extent of non-woody vegetation (at specified locations). **By 2024, increased periods of growth for communities that form extensive stands within wetlands and low-lying floodplains including;** **Moira grasslands in Barmah–Millewa Forest** **Common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes** **Water couch on the floodplains of the Macquarie Marshes and Gwydir River** **Marsh club-rush sedgelands in the Gwydir**	Provide periods of growth for specific community types at specified locations.

Basin Plan contribution

The strategy specifies expected outcomes for Moira grasslands in the Barmah–Millewa Forest, common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes, water couch on the floodplains of the Macquarie Marshes and Gwydir rivers and marsh club-rush sedgelands in the Gwydir. Examples of where the Basin Plan has contributed to outcomes for non-woody vegetation at these sites are in Table 16.

Table 16 Progress and achievements up to 2017 for periods of growth of wetland and low-lying floodplain non-woody vegetation

Basin region	Location	Non–woody water-dependent vegetation	Progress and achievements up to 2017
Murray	Barmah-Millewa Forest	Moira grass	Environmental watering has facilitated the growth of Moira grass and enabled the plant to flower and disperse seed. However, the extent of Moira grass has not improved due to a depleted seedbank and the difficulty of delivering water of sufficient depth and duration during spring and summer to promote growth (Ward, 2016).
Lachlan	Great Cumbung Swamp	Common reed and cumbungi	Common reed and cumbungi communities in the Great Cumbung Swamp have experienced periods of growth and maintained extent in response to environmental water delivery (Dyer, et al., 2016).
Macquarie–Castlereagh	Macquarie Marshes	Common reed, cumbungi and water couch	In the Macquarie Marshes, where environmental water has been delivered over successive years, common reed, cumbungi and water couch communities have been supported with increased periods of growth and the extent has been maintained (Sharon Bowen pers. comms. Bowen, Simpson, Hosking, & Shelly, 2017).
Gwydir	Gwydir Wetlands	Marsh club-rush and water couch	In the Gwydir wetlands, water couch and marsh club-rush vegetation communities have been maintained in the core areas and have experienced periods of growth in response to environmental water delivery, (Frazier, et al., 2016). The condition has been improved and the extent has been increased (Bowen 2017).

Evaluation findings

Evidence suggests there have been periods of growth of non-woody wetland and floodplain vegetation in some areas in response to environmental watering under Basin Plan. Therefore, it can be inferred that Basin Plan implementation is mostly on track to achieve the expected outcomes. Without monitoring or the establishment of baseline extents at the specified locations it is not possible to determine if Basin Plan implementation is on track to achieve this expected outcome.

The likelihood of achieving the outcomes could be further improved by implementing an integrated catchment approach that considers external threats, such as pest animals, grazing and clearing. Removing constraints in some areas and delivering environmental water across the floodplain also would help achieve these outcomes.

Table 17 2017 Measure of Success, expected outcomes and the evaluation findings for periods of growth of non-woody and low-lying floodplain vegetation

Metrics	Results
2017 Measure of success Provide periods of growth for specific community types at specified locations.	**Met** Environmental water has been applied to provide increased periods of growth for wetland and low-lying floodplain vegetation in the extensive stands of Moira grasslands in Barmah–Millewa Forest, common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes, water couch on the floodplains of the Macquarie Marshes and Gwydir River and marsh club-rush sedgelands in the Gwydir.
Expected outcome Maintain the current extent of non-woody vegetation (at specified locations).	**Insufficient evidence** Without monitoring or the establishment of baseline extents at the specified at all locations it is not possible to determine if Basin Plan implementation is on track to achieve this expected outcome.
Expected outcome By 2024, increased periods of growth for communities that form extensive stands within wetlands and low-lying floodplains including; • Moira grasslands in Barmah–Millewa Forest • Common reed and cumbungi in the Great Cumbung Swamp and Macquarie Marshes • Water couch on the floodplains of the Macquarie Marshes and Gwydir River	**Insufficient evidence** Determining if there have been periods of growth of non-woody and low-lying floodplain vegetation at all locations is difficult at this point due to information gaps.

Metrics	Results
• Marsh club-rush sedgelands in the Gwydir.	

Ruppia tuberosa in the Coorong

Ruppia tuberosa plays an important role in the Coorong's ecosystem and is a key indicator of the health of the system. Many species in the Coorong, such as waterfowl and migratory waders, rely on the plant as a food resource. *Ruppia tuberosa* also provides habitat for other species in the southern Coorong, such as Murray hardyhead and chironomid larvae.

Ruppia tuberosa is a submerged aquatic plant that was once widespread along the length of the South Lagoon of the Coorong. By late summer, *R. tuberosa* persists as seeds and turions on the ephemeral mudflats on the shores of the southern Coorong. These seeds and turions then germinate or sprout when the water levels rise during late autumn and the plants continue to grow through winter. If the water levels in the southern Coorong remain adequate, the plant reproduces sexually (producing seeds) and asexually (producing turions) during spring and early summer.

The 2017 Evaluation assessed two expected outcomes for *R. tuberosa* relating to its extent and resilience (Table 18). For the purposes of this evaluation the southern Coorong is defined as length of the South Lagoon and the southern section of the North Lagoon.

Table 18 Expected outcomes and 2017 Measures of Success for *Ruppia tuberosa* in the Coorong

Expected outcomes	2017 Measures of Success
By 2019, *Ruppia tuberosa* to occur in at least 80% of sites across at least a 50 km extent	*Ruppia tuberosa* occurring in at least 80% of sites across at least 50 km of the southern Coorong.
By 2029, the seed bank to be sufficient for the population to be resilient to major disturbances.[1]	Maintain the seedbank of *Ruppia tuberosa* in the southern Coorong.

Long-term monitoring of the extent and abundance of *R. tuberosa* in the Coorong shows that its area of occupation has increased (Figure 11). The *R. tuberosa* summer monitoring program began in 2007 and the 2016–17 monitoring period was the first time that *R. tuberosa* occurred in at least 80% of sites across at least 50 km of the southern Coorong. Given that increased extent is so recent, it's difficult to determine if this outcome will be consistently met from 2019 onwards. Meeting this outcome each year relies on maintaining appropriate water and salinity levels in the Coorong through each stage of the species life cycle, as well as identifying and controlling the influence of

[1] This requires at least 10,000 seeds/m^2 within the bed of the core population of *Ruppia tuberosa*

other external factors such as filamentous algae that can smother the plant, limiting growth and preventing recruitment.

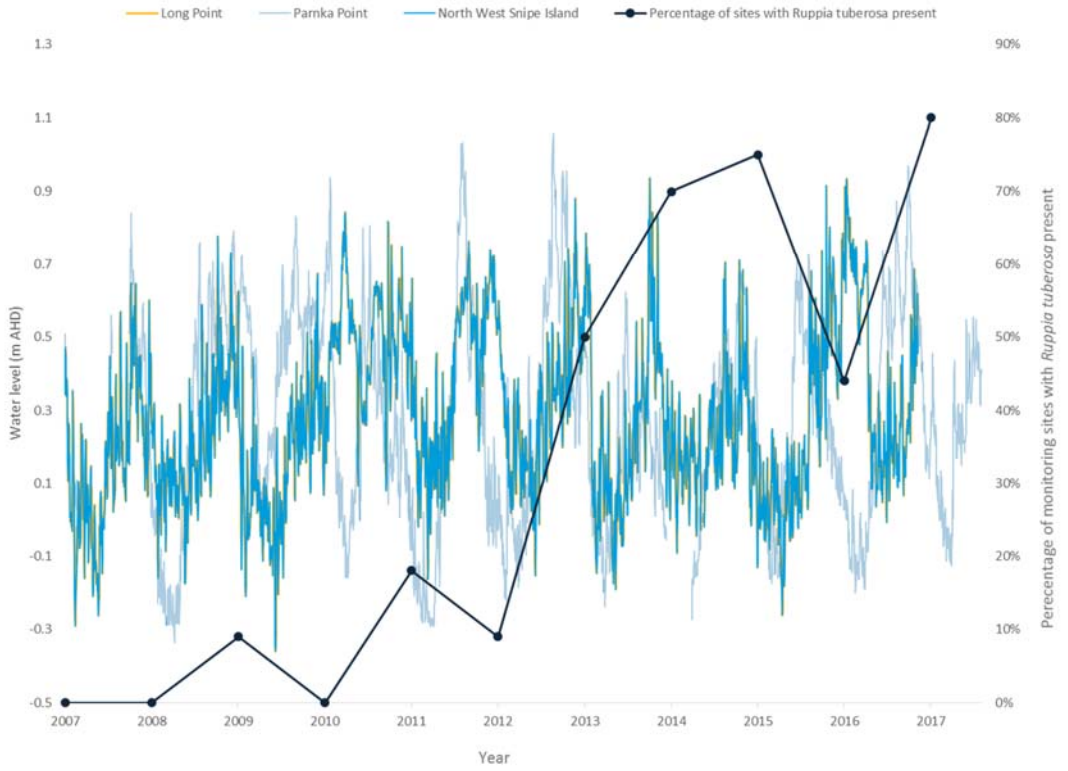

Figure 11 Area of occurrence of Ruppia tuberosa in the southern Coorong and the average seasonal water levels for each year (m AHD) from 2007 to 2017.

Although the area of extent has improved, the vigour of plants at most sites was poor until the high flow event in 2016–17. Since 2012, less than 40% of monitoring sites met the criteria to be classed as a vigorous population. In the 2016–17 water year, 75% of populations within monitoring sites were classed as vigorous (Paton, Paton, & Bailey, 2017).

It is difficult to determine if *R. tuberosas* seedbank will be resilient to major disturbances by 2029. At least 10,000 seeds per m2 within the bed of the core population are needed for the *R. tuberosa* seed bank to be resilient to major disturbance (MDBA, 2014). Long-term monitoring of *R. tuberosa* in the Coorong has found that the seedbank is still greatly diminished, with average seed densities only a fraction of what is required for a resilient population (Paton, Paton, & Bailey, 2017). For example, even though there was an improvement in flowering during 2016–17, *R. tuberosa* reproduction was hampered by the presence of filamentous algae. High levels of productivity were expected to result in around 1,130 seeds per m2 but fewer than 226 seeds per m2 were found at most sites.

Expert advice suggests that the slow recovery of *R. tuberosa* in the Coorong after the millennium drought could be attributed to the inability to maintain adequate water levels during spring and early summer (Paton, Paton, & Bailey, 2017). This has resulted in a failure to sustain plant growth, promote the production of flowers and ensure the successful completion of the reproductive cycle.

As seen in Figure 11, from 2012 to 2015 *R. tuberosa* increased in the area of occupation. In 2015, the water levels in the Coorong during spring were the lowest in five years, which led to the desiccation of plants and a decrease in the area of extent and occupation. However, this level of abundance was similar to abundance levels observed in the previous two years (Paton, Paton, & Bailey, 2016). In 2017, the strategy outcome for *R. tuberosa* to occur in at least 80% of sites across at least a 50 km extent in the Coorong was met, with *R. tuberosa* found at 80% of monitoring sites along a 53 km stretch in the southern Coorong.

Salinity levels may also impede the successful completion of various life stages of *R. tuberosa.* Salinity affects *R. tuberosa* directly when salinity levels exceed 100 g/L and indirectly by creating an optimal environment for algae (Kim, 2013; Paton, Paton, & Bailey, 2017). From 2007 to 2010, *R. tuberosa* populations declined in the southern Coorong due to increased salinity and low water levels (Figure 12). When salinity levels decreased in 2010 and 2011 *R. tuberosa* recolonised some parts of the southern Coorong. Although average spring and summer salinity levels increased from 2013 to 2015, average winter salinity levels remained low compared to 2009. This is critical for *R. tuberosa* seed germination and shoot establishment (Kim, 2013; Paton, Paton, & Bailey, 2017). In 2016, salinity levels in winter were low enough to promote *R. tuberosa* germination and growth. However, salinities in the southern Coorong also fell low enough to provide optimal conditions for algal growth which then hampered the growth and reproduction of *R. tuberosa*.

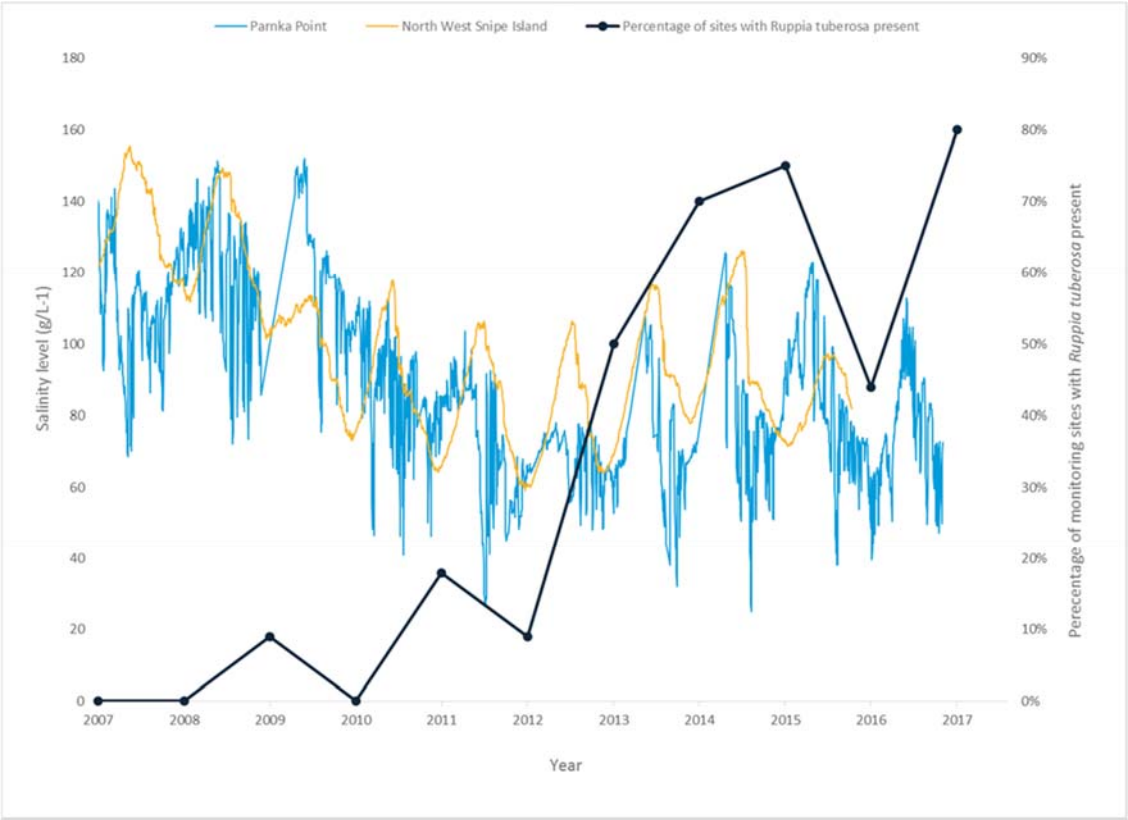

Figure 12 Area of occurrence of *Ruppia tuberosa* in the southern Coorong and seasonal average salinity levels (g/L) from 2007 to 2017.

Basin Plan contribution

The strategy specifies expected outcomes for maintaining the extent and increasing seedbank abundance (MDBA, 2014). Environmental water has been delivered to the Coorong, Lower Lakes and Murray Mouth every year since the Basin Plan took effect, however there is little data available about how much was actually delivered across the barrages to the Coorong.

There have been some studies conducted to determine *R.tuberosa* outcomes after environmental water delivery, both *in situ* and through modelling programs. *In situ* studies found that while environmental water contributed to maintaining water levels in the Coorong in early spring and dampened water level drawdown, not enough environmental water was delivered to maintain adequate water levels from late spring into early summer. As a result*, R. tuberosa* often failed to complete its reproductive cycle.

Evaluation findings

Maintaining adequate water levels and salinity for *R. tuberosa* to complete its life cycle will be critical to meeting the extent outcome by 2019. Over the past decade, water levels have been suitable to stimulate *R. tuberosa* seed germination over winter due to annual patterns of sea level rise and high inflows. However, water levels have not been maintained through to early summer due to insufficient barrage flows. This drop in water level fails to support the plant to complete its life cycle.

Assessing the progress of *R. tuberosa* against the expected outcomes for area of extent and seedbank resilience is difficult due to significant knowledge gaps such as the uncertainty around how interactions between environmental factors influence *R. tuberosa* outcomes, what triggers the presence of filamentous algae and how water can be delivered to support *R. tuberosa* requirements.

Results of monitoring and an increase in the understanding of *R. tuberosa's* requirements have indicated that expected outcomes for this species in the southern Coorong need to be refined. Expert advice suggests that extent expected outcomes could be refined to align with historical extent and include measures of vigour and seedbank viability (Paton, Paton, & Bailey, 2017; Paton, Paton, & Bailey, 2016). Refining the expected outcomes may assist water managers to work towards consistently achievable outcomes and promote the resilience of *R. tuberosa* into the future.

Table 19 2017 Measures of Success, Quanitfied Environmental Expected Outcomes and the evaluation findings for *Ruppia tuberosa* in the Coorong

Metrics	Results
2017 Measure of success *Ruppia tuberosa* occurring in at least 80% of sites across at least 50 km of the southern Coorong.	**Met** *Ruppia tuberosa* was present at 80% of sites across 53 km in the southern Coorong in 2016–17.
Expected outcome By 2019, *Ruppia tuberosa* to occur in at least 80% of sites across at least a 50 km extent.	**Insufficient evidence** As 2016–17 was the first year that *R. tuberosa* occurrence was met since the *R. tuberosa* summer monitoring program began in 2007 it is difficult to determine if this trend will continue. Maintaining adequate water and salinity levels for *R. tuberosa* to complete its life cycle will be critical to meeting the extent outcome by 2019.
2017 Measures of Success Maintain the seed bank of *Ruppia tuberosa* in the southern Coorong.	**Not met** *Ruppia tuberosa's* seed bank has failed to recover since the millennium drought and remains extremely depleted.
Expected outcome By 2029, the seed bank to be sufficient for the population to be resilient to major disturbances.	**Too early to tell** The complexity of the Coorong ecosystem and uncertainty around maintaining adequate water levels in the southern Coorong during spring and early summer mean it is unclear if the expected outcome will be met in 2029.

Are we on track?

The evaluation shows some of the 2017 measures of success, or elements of them, have been met, with others are yet to be determined at this early stage of Basin Plan implementation or there is insufficient evidence. Consequently that, Basin Plan implementation is on track to achieve some of the expected outcomes for native vegetation but at this early stage it is not possible to determine if implementation is on track to meet the, the Basin Plan's intermediate (up to 2019) and long-term targets (from 2019) and in turn the Basin Plan's overall environmental objectives for native vegetation.

The 2017 Evaluation has identified early positive signs that native vegetation on the managed floodplain has responded to environmental water delivered under the Basin Plan. In addition to the 2017 Measures of Success, native vegetation diversity (the number of different native species) has improved and the extent of exotic species at sites across the Basin has declined (Capon & Campbell, 2017).

A total of 1,703 GL of environmental water delivered in 301 watering events between 2013 and 2016 has targeted native vegetation objectives across the Basin. Most of these watering events occurred in the southern Basin, where the majority of held environmental water is used compared to the northern Basin, which has more planned environmental water.

Environmental water delivery has been coordinated to improve timing, depth and duration of flows, such as achieving a slow flood recession, thereby maintaining soil moisture levels and enhancing opportunities for native vegetation to germinate and grow (Gawne, et al., 2017). To achieve native vegetation outcomes, it is vital to continue Basin Plan implementation, coordination, planning and delivery of environmental water.

Some threats outside the scope of the Basin Plan, such as grazing, cropping and land clearing, needto be managed to ensure native vegetation communities can benefit from Basin Plan implementation. These external threats will influence whether the expected outcome for 2024 can be met.

Summary of Evaluation Findings

Environmental flows could better achieve vegetation outcomes if key Basin Plan mechanisms were implemented. For example, the removal of current constraints, implementation of the Sustainable Adjustment Mechanism and protection of environmental water are critical to increase the frequency and extent of floodplain inundation. This will improve the condition and extent outcomes of floodplain vegetation, especially higher on the floodplain.

Even with the limitations outlined above, environmental water holders are using water effectively to support native vegetation within the managed floodplain.

Positive environmental responses have been observed at the site scale where environmental water has been delivered in consecutive years or where environmental water has been delivered at the

right time and for the right duration. There are likely to be noticeable improvements in native vegetation at the Basin scale in the long term – though climate and local weather condition will also play a significant role.

Conservative water delivery has limited lateral connectivity and vegetation has declined, especially vegetation further out on the floodplain where environmental water is irregularly received.

The Living Murray 'environmental works' sites on the River Murray floodplain have contributed to improvements in native vegetation condition.

Forest and woodland vegetation can take several years to respond to successive environmental watering events and, for example, detect a change in vegetation structure, whereas non-woody vegetation responds more quickly. Therefore, the period between improved water supplies and detection of positive changes in vegetation condition, growth and extent will vary depending on vegetation type (i.e. site scale or Basin scale).

Vegetation outside of the managed floodplain will continue to decline in the absence of sufficient water and may transition into a less water-dependent type.

Adaptive management should continue in the planning, delivery and monitoring of environmental outcomes as specified in the following sub-findings:

- Coordinate State and Australian government investment into monitoring across the Basin.
- Update and create baseline information for vegetation condition and extent, for example lignum shrublands.
- Continue to coordinate collaborative investment into key knowledge gaps.
- Ensure long-term funding, and well designed and coordinated effort to provide better insights on vegetation change to address data gaps.
- Use the existing data that is collected and investigate options to analyse it against different parameters (e.g. flow duration and magnitude).
- Develop long-term environmental watering plans that focus on outcomes in priority areas that are not specified in the strategy.

Expected outcomes in the Basin-wide environmental watering strategy could be reviewed based on outcomes from the 2017 Evaluation.

Environmental water planners, managers and river operators should continue to coordinate planning and delivery through the use all available water (i.e. both environmental and consumptive water).

The Native Fish Strategy was highly effective in promoting cooperative research to inform management efforts and a similar strategy for native vegetation may facilitate knowledge building. The establishment of a strong community of practice, including planners, researchers and managers, to advise on the best way to achieve the expected outcomes for native vegetation will help to ensure environmental water use and monitoring is strategic.

Consider how to implement an integrated catchment management approach to mitigate non-flow related threats (e.g. land management, salinity, weed invasion and climate change), and undertake revegetation and translocating threatened species.

Our understanding of native vegetation condition, extent and growth has improved over the past few decades. However, there remain many unanswered questions and gaps in monitoring and knowledge that, if addressed, would enable environmental water to be delivered more efficiently and effectively. Additional research and monitoring is needed to establish baselines of the current extent of native vegetation and to understand patterns of change in forest and woodland condition, recruitment and growth of vegetation across the Basin.

Appendixes

Appendix A - Murray–Darling Basin Stand Condition Assessment Tool

The Murray–Darling Basin Authority commissioned a spatial stand condition assessment tool of river red gums, black box and coolibah for the development of the strategy in 2014. The tool defined the extent of these communities in the managed floodplain using a predictive model based on existing vegetation mapping and an analysis of satellite images (Figure 13).

The condition assessment involves a combination of quantitative ground surveys, remote sensing and modelling using machine learning. The ground surveys record the percentage of live leaf area, plant area index and crown extent. These parameters have been identified as being reliable and objective indicators of stand condition in floodplain forests.

The tool was backdated to 2009, and then updated every year up to 2016 using Landsat 8 imagery. The assessment was not completed for 2011 and 2013 due to corrupt Landsat 7 imagery and flooding preventing completion of fieldwork.

At the time of the November 2014 strategy publication the assessment provided high confidence condition scores for river red gums and black box in the Lachlan, Murrumbidgee, Lower Darling, Murray, Wimmera-Avoca and Goulburn-Broken Basin regions. Due to data limitations in 2014 many areas of the Basin, particularly in the north, meant that it was not possible to specify the condition of coolibah. Since 2014 further field surveys in the northern Basin have been used to validate and improve the tool. Therefore, the 2017 Evaluation will include coolibah condition in the northern Basin.

The Basin Plan objectives and targets were set in 2012 and the expected outcomes in the strategy were set in 2014. The Living Murray program has recovered water for the environment in the River Murray between 2007 and 2011 and a larger volume of water across the Basin has been recovered by the Commonwealth Environmental Water Holder since 2012 under the Basin Plan. In addition to flow volume, vegetation communities require a sequence of environmental waterings across multiple years for them to improve in condition. Therefore, the 2017 Evaluation assessed the condition of river red gum, black box and coolibah from 2009 (i.e. the baseline of current condition), rather than from 2014. The assessment determines the percentage area in each condition score category for the Basin regions within the managed floodplain (Figure 13). It is understood and accepted that there is variation between condition assessment findings at this scale compared to what is observed at the site scale (i.e. at the Chowilla Floodplain) from on ground monitoring.

The Murray–Darling Basin Authority will publish the outputs of the tool on Data.Gov.au in early 2018.

The condition of river red gums across five categories[2] and the condition of black box and coolibah were assessed against two categories[3]. As data capture and validation improves five categories of condition will be used across the Basin.

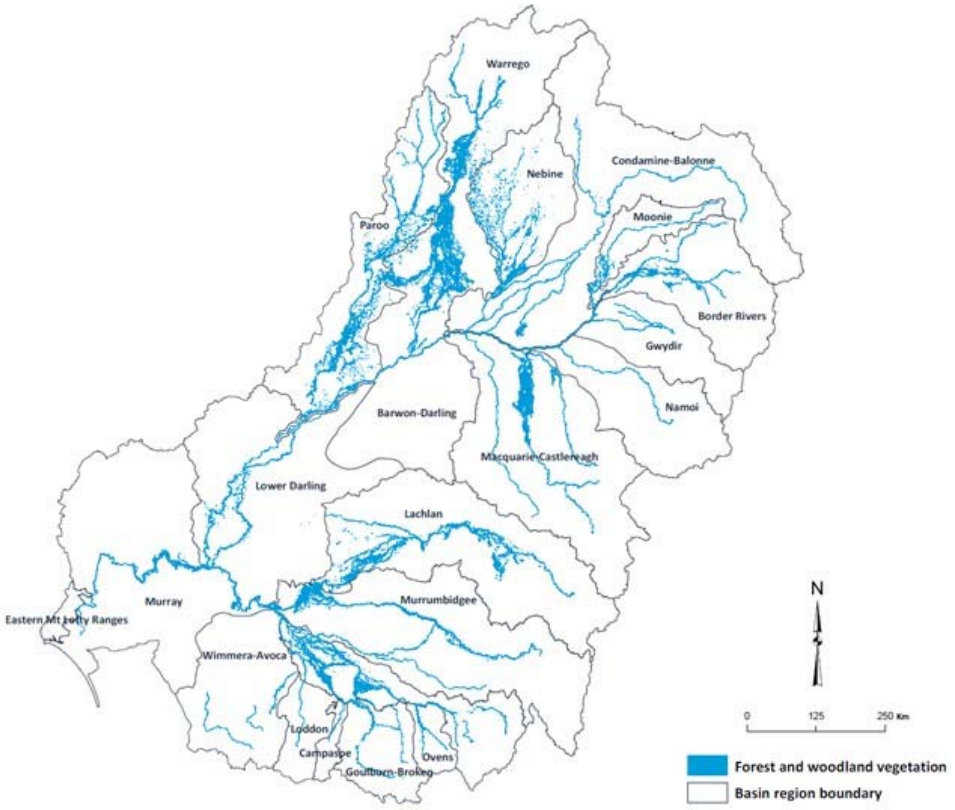

Figure 13 Basin Plan regions and the stand condition assesment area for the forest and woodland vegetation within the Murray–Darling Basin on the managed floodplain

[2] scores between 0–2 are categorised as 'severely degraded'; >2–4 are 'degraded'; >4–6 are 'poor'; >6–8 are 'moderate'; >8–10 are 'good' condition

[3] scores between 0–6 are categorised as 'severely degraded to poor' and >6–10 are 'moderate to good' condition

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