Technical note supporting the 2018 River Murray: floodplain trees (Tree condition index) Trend and Condition Report Card

DEW Technical note 2018/14

Government of South Australia
Department for Environment and Water

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Government of South Australia
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GPO Box 1047, Adelaide SA 5001

Telephone National (08) 8463 6946

International +61 8 8463 6946

Fax National (08) 8463 6999

International +61 8 8463 6999

Website www.environment.sa.gov.au

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Summary

The condition of the trees of the River Murray is one of the key indicators of the health of the River Murray ecosystem. Trees are a critical part of the riverine ecosystem as they provide habitat and structure to the environment that is used by many of the fauna that inhabit the area. Trees are considered to be a key habitat feature, and as such are a target of the South Australian *River Murray Act 2003* and should be reported against for the State of the Environment Report, produced by the Environment Protection Agency (EPA).

South Australia invests in many monitoring programs across the South Australian River Murray (SARM), many of which include tree condition monitoring. Tree condition monitoring is undertaken using a standardised method developed for the Murray–Darling Basin, the Tree Condition Index (TCI). In order to assess the current trend and condition of trees across the SARM, TCI data was collated from all of the various monitoring programs that are undertaken. These programs cover both managed and unmanaged wetlands, three different species (River red gum, Black box and River cooba) and different heights on the floodplain. The majority of the data came from larger monitoring programs associated with larger infrastructure programs such as Chowilla Regulator and South Australian Riverland Infrastructure Improvement Program (covering Pike and Katarapko floodplains) while other smaller wetlands and floodplains were also represented.

The analysis showed that the trend for all trees assessed across the SARM was **stable**. For each of the three species assessed, the trend was also stable. The condition across all trees assessed was shown to be fair. This was the same for each of the species assessed. A **fair** condition is associated with a TCI score of poor to moderate. Trees in these classes will likely visibly respond to single watering events, while trees in lower condition will require multiple watering events to show a response, or may not respond. The assessment of fair condition reflects that while they are in lower condition, they are still capable of responding positively in a short time frame.

The assessment of the trend as stable reflects an overall picture and may not be reflective of the condition of individual wetlands, or areas within a wetland. To be classed as ‘getting better’ or ‘getting worse’, 90% of the data need to show this response. This is a high threshold, however it means that we are confident in the result. The median score for the three species does show a slight downward trajectory, but this is mixed with some strong positives resulting in an overall stable result.

1 Introduction

The *Natural Resources Management Act (2004)* has a requirement ''to keep the state and condition of the natural resources of the State under review.' In order to consolidate data collected around the state into a simple, easy to interpret information source, the Department for Environment and Water (DEW) produces report cards for the state's natural resources. Previous rounds of report cards have reported against the targets in the South Australian Natural Resources Management Plan (Government of South Australia, 2012). However, for the next round of reporting, the report cards will not only seek to report on the state of the natural resources of South Australia, but will also form the main source of data for the State of the Environment Report.

The State of the Environment Report (SOER) is a legislated requirement under the *Environment Protection Act (1993)*. The SOER has several key assessments that need to be undertaken including:

- Include an assessment of the condition of the major environmental resources of South Australia 112(3(a))
- Include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003* 112(3(ab))
- Identify significant trends in environmental quality based on an analysis of indicators of environmental quality 112(3(b))

The River Murray has previously been part of the reporting process as it is a focal point of the state's natural resources. See the 2014 River Murray report cards here. However, the way that the river health has been assessed has continuously been adapted to reflect reporting needs within the constraints of the available data and information. For the 2018 report cards, the River Murray report cards will be adapted to reflect the requirements of the SOER.

The *Environment Protection Act 1993* specifically refers to the *River Murray Act (2003)* for the assessment of the health of the River Murray. Under the River Murray Act there is a series of objectives known as the Objectives for a Healthy River Murray (*River Murray Act 2003* 7(1-5)). These objectives cover a range of issues including:

- River health
- Environmental flows
- Water quality
- Human dimensions.

The suite of River Murray report cards for 2018 was developed with specific line of sight to the objectives for a healthy River Murray to facilitate both adequate reporting on the condition of the state's natural resources as well as the requirements of the SOER.

The six report cards for the River Murray are:

- River Murray: floodplain trees (Tree condition index) Trend and Condition Report Card
- River Murray: Coorong and Lower Lakes vegetation (Vegetation target success) Trend and Condition Report Card
- River Murray: high value wetlands (Achievement of ecological targets) Trend and Condition Report Card
- River Murray: Murray Mouth (Days open) Trend and Condition Report Card
- River Murray: fish passage (Permanently wet area accessible) Trend and Condition Report Card
- River Murray: water (quantity and quality) Trend and Condition Report Card

This report provides the background information, methodology and results that underpins the 2018 River Murray Tree Condition Report Card. The river health objectives of the River Murray Act state that "the key habitat features in the River Murray system are to be maintained, protected and restored in order to enhance ecological processes" (Section 7(2)a). The overstory trees of the River Murray have been identified as a key habitat feature as the trees form a very important part of the riverine ecosystem providing habitat for the diverse fauna, contributing to vegetation community structure and riverbank stability as well as being culturally significant and valued for their aesthetics.

River red gum (*Eucalyptus camaldulensis*), black box (*Eucalyptus largiflorins*), and river cooba (*Acacia stenophylla*) are iconic species which support ecological process. The tree condition of the River Murray floodplain and channel assets is vital to the ongoing ecological functioning of the region as it provides structure, stability, nutrient cycling and habitat. The tree condition is determined principally by the water regime of the River Murray. This water regime has been significantly altered through the development of the River Murray as a water resource. The natural variability in the water level has been reduced to provide a stable water level for boating, recreation and water extraction. The lack of variable water levels results in some trees being permanently inundated while others are inundated less frequently. Over time this watering regime leads to the decline in condition of the trees and if it persists for prolonged periods of time, it will lead to the death of the tree.

A visible response in the condition of a tree to environmental watering is contingent on the condition of the tree/s prior to inundation (Casanova, 2015). Trees in good condition are more likely to respond rapidly to environmental watering than stressed trees and very much more likely to respond than defoliated trees in the lowest condition classes which may take multiple watering events to show a visible response (Souter et al., 2013). If trees are in moderate condition, a 2–3 year interval between watering events is likely to be adequate to maintain condition, but not be sufficient to consistently meet the ecological target. Consecutive watering events are likely to be required to restore condition (Wallace, 2015).

In order to improve the condition of the vegetation of the riverine ecosystem of the River Murray, both the South Australian and Australian Government have committed to programs across the Murray–Darling Basin. The overarching plan for the Murray-Darling Basin, the Basin Plan, seeks to increase the amount of environmental water through a series of water recovery and efficiency measures. This is complemented by major infrastructure projects designed to allow for the managed inundation of River Murray floodplains and wetlands, such as the Living Murray and South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP).

Several monitoring programs monitor tree condition across the SARM. These include monitoring programs associated with the Living Murray, SARFIIP as well as other programs such as the Riverine Recovery Project. These monitoring programs have been run for the past decade and cover several major ecological components including and tree condition (Nicol et al. 2017). These programs provide data for trees in areas that are currently actively managed, areas that will be managed in the future and areas that are not and will not be managed.

This report card will assess the condition of trees in the floodplain and channel against targets identified in Kilsby and Steggles (2015). These are principally to maintain viable functioning populations of river red gum, black box and river cooba. Definitions are provided in Kilsby and Steggles (2015).

2 Methods

2.1 Data sources

Data was sourced from a number of different projects and programs. The largest sources of data were from Chowilla (The Living Murray Initiative), Pike and Katarapko (SARFIIP), however, there was also considerable data from some of the smaller wetlands along the length of the South Australian River Murray (SARM) collected through monitoring programs such as the Riverine Recovery Project. All of the data used for the assessment is available through the Biological Databases of South Australia (BDBSA, accessible online here).

As the data comes from many different programs and projects it covered both managed and unmanaged sites as well as different heights on the floodplain.

2.2 Condition assessment

Surveys were undertaken using the standardised 'The Living Murray' tree condition method (Souter et al., 2010). At each transect, the condition of 30 trees (with a diameter at breast height of ≥ 10 cm) was assessed visually for crown extent and crown density. The Tree Condition Index (TCI) is calculated by summing the scores for crown extent and crown density for each individual tree (Souter et al., 2010) (Table 1). A tree with a TCI score of 10 or above (Table 3) represents a tree in "good" condition (Wallace, 2015). Trees with TCI scores between 5 and 7, and between 8 and 9 (Table 3) are considered to be trees in "poor" and "moderate" condition respectively (Wallace, 2015).

A tree with a TCI score of 4 or below (Table 2) is considered to have a "minimal" crown extent with "sparse" crown density and be in "very poor" condition. Trees with TCI scores ≥ 5 are expected to respond positively to watering and those ≥ 8 to increase to the next condition class. The strength of the response from a tree to increased soil moisture availability decreases as the TCI score decrease (Wallace, 2015). Trees with low TCI scores have a lengthy response time and would require multiple, consecutive watering in order to achieve a viable, functioning floodplain tree populations and attain some degree of resilience. Trees with a TCI score = 0 are either (i) dead or unlikely to respond to watering, or (ii) be very near to the critical point of 'loss'. Maintaining woodland areas as functioning habitat requires trees to be in moderate to good condition (Wallace, 2015).

Table 1: Tree Condition Index score descriptions and condition classes for trees of the River Murray used for the condition assessment, adapted from Souter et al. 2010.

TCI score	Condition description		Condition classes
0	Non-viable	Tree may be dead or very near to the critical point of loss. A small proportion of trees may respond to delivery of water, but are likely to be in a precarious position i.e. response may not be sustained and tree may not recover	Poor
2-4	Very poor	Tree viable but in very poor condition and in a precarious position i.e. continuation of dry conditions is likely to lead to death. Trees with low TCI scores have a slow response. A single watering may stabilise condition. Multiple, back to back watering will be required to achieve "good" condition	Poor
5-7	Poor	Most trees would be expected to respond positively to watering. Inundation may stabilise condition or result in an improvement. Trees may be at the edge of the resilience period, i.e. continuation of dry conditions is likely to lead to a marked loss of condition. Multiple, back to back watering is likely to be required to achieve "good" condition	Fair
8-9	Moderate	Most trees with TCI scores ≥ 8 would be expected to respond positively to watering and increase to the next condition class	Fair
10-12	Good	Trees are expected to have a moderate degree of resilience and should be able to withstand a short dry period with minimal loss of condition	Good

13-14	Excellent	Trees are expected to have a high degree of resilience and should be able to withstand a short period with minimal loss of condition	Very Good

The tree condition score through time was modelled using Bayesian statistics. This modelling approach was used as it provides more information surrounding the results and allows for a more detailed assessment of trend and condition based on variability inherent in the data. Bayesian modelling also provides confidence intervals allowing for an objective and transparent assessment of trend and condition. It provides an estimate of the likelihood of the trend or condition assessed. Modelling was undertaken using a binomial model looking at the condition score. Analysis was undertaken in R Studio (version 1.1.383, running R version 3.4.2, R Core Team, 2013) using Bayesian Generalized Linear Models (using the stan-glm function in the rstanarm package, Stan Development Team 2016, 4000 runs). Assessment occurred for each tree species separately. Location was included as a random factor to account for the difference in spatial location of the trees. The lower elevations (i.e. the channel) was considered to be the lower part of the floodplain rather than an additional spatial divider, i.e. the channel and floodplain sites were analysed together. The current condition was estimated from the posterior distribution resulting from the Bayesian analysis. A 70% threshold was used to characterise the condition (Wallace 2017), i.e. 70% of the data needed to reflect a condition of good to be classed as good.

2.3 Trend assessment

The time series data was analysed using the same Bayesian modelling approach as the condition assessment. The following values were estimated from the posterior distribution resulting from the Bayesian analysis:

- Slope (trend)
- Change between 2008 and 2016 (magnitude of any change)

Generic definitions for trend are provided in Table 2, including the specific values used here as thresholds to define the classes.

Table 2: Trend descriptions and thresholds applied to the Bayesian modelling output for the TCI scores.

Trend	Description	Threshold
Getting better	Over a scale relevant to tracking change in the indicator it is improving in status with good confidence	Greater than 90% likelihood that target achievement trends are positive
Stable	Over a scale relevant to tracking change in the indicator it is neither improving or declining in status	Less than 90% likelihood that target achievement trends are positive or negative
Getting worse	Over a scale relevant to tracking change in the indicator it is declining in status with good confidence	Greater than 90% likelihood that target achievement trends are negative
Unknown	Data are not available, or are not available at relevant temporal scales, to determine any trend in the status of this resource	Not applicable
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above trend classes	Not applicable

2.4 Reliability

The reliability of the data was scored using the scoring system developed for the 2018 Report Cards. This scoring system uses four scores to assess different aspects of the data used to underpin the report card. Scores for all four are then averaged to determine the final score. The four scores are:

- Information currency
- Information applicability
- Spatial representation
- Information accuracy

Scoring was undertaken according to Table 2.

Table 3: Scoring system for the reliability of the information used to underpin the analysis for River Murray: floodplain trees Trend and Condition Report Card.

Score given	Information currency	Information applicability	Spatial representation	Information accuracy
5	Information >10 years old	Data are based on expert opinion of the measure	From an area that represents less than 5% the spatial distribution of the asset within the region/state or spatial representation unknown	Better than could be expected by chance
4	Information up to 10 years old	All data based on indirect indicators of the measure	From an area that represents less than 25% the spatial distribution of the asset within the region/state	> 60% better than could be expected by chance
3	Information up to 7 years old	Most data based on indirect indicators of the measure	From an area that represents less than half the spatial distribution of the asset within the region/state	> 70 % better than could be expected by chance
2	Information up to 5 years old	Most data based on direct indicators of the measure	From across the whole region/state (or whole distribution of asset within the region/state) using a sampling design that is not stratified	> 80 % better than could be expected by chance
1	Information up to 3 years old	All data based on direct indicators of the measure	From across the whole region/state (or whole distribution of asset within the region/state) using a stratified sampling design	> 90 % better than could be expected by chance

3 Results

3.1 Data sources

A total of 24,199 trees were used for the assessment of trend and condition, 15,447 river red gum, 6,921 black box and 1,831 river cooba. These data were sourced from 29 different areas across the South Australian River Murray (SARM) (Table 4).

Table 4: Summary of trees used for the River Murray: floodplain trees Trend and Condition Report Card including location and species.

Location	River red gum	Black box	River cooba	Grand Total
Arlunga	12	2		14
Big Bend	25	9		34
Bookmark Creek	148			148
Brenda Park and Morphett Flat	105	7	28	140
Chowilla Complex	13288	4911	1562	19761
Graignook	16			16
Cumbunga Creek	8	1		9
Donald Flat Lagoon	11	4		15
Goat Island And Paringa Paddock	14	5		19
Irwin Flat	14	3		17
Katarapko	180	1170	180	1530
Loveday Complex	120			120
Marks Landing	10	1		11
McBean Pound Complex	25	3		28
Murbko Flat Complex	13	1		14
Murtho Park Complex	360			360
Nigra Creek Complex	126	12	41	179
North Caurnamont	8	5		13
Pike/Mundic Complex	472	695	15	1182
Pilby Complex	14	15		29
Portee Complex	41	2		43
Pyap Complex	21	11		32
Ral Ral Complex	33	35		68
Sinclair Flat	27	1		28
Swan Reach Complex	131	5		136
Swan Reach Ferry	30			30
Teal Flat Complex	22	11		33
Walker Flat Lakes Complex	7	4		11
Woolenook Bend Complex	21	8		29
Yatco Lagoon	145		5	150
Total	**15447**	**6921**	**1831**	**24199**

Across all of the trees, the majority of trees were located within permanent wetlands (56%). This was followed by trees areas that have a combination of permanent and temporary water (30%). The remaining trees were evenly split across temporary wetlands (6%) and runoff/seepage areas (5%). The majority of trees came from three areas; Chowilla (81%), Katarapko (6%) and Pike (5%). All three of these areas are reported against separately and in far greater detail than will be covered in this report. For a more detailed evaluation of the tree condition of these areas see Wallace (2017), Green and Suitor (2017) and Walters (2017) respectively.

Spatially, the data covers wetlands from Old Teal Flat to the SA border, however, it does not represent a complete record of all the wetlands of the SARM, nor does the data represent a complete record for the wetlands that are sampled, the various monitoring programs have their own questions which may mean their sampling design is not intended to provide an estimate of condition for the area, but for the area under active management Given the nature of the dataset, there is a bias towards wetlands that are the focus of management, or proposed management as well as a bias towards trees that are lower on the floodplain.

It should also be noted that there is a substantial increase in the survey effort through time. The majority of the survey effort has occurred in the last few years. The effect of this is that the condition in the more recent surveys will be over represented in the models and bias them towards the current condition. While this will not affect the current condition assessments, the effect on the trend may result in optimistic results.

3.2 Condition

In 2016, river red gum, black box and river cooba all received a condition rating of fair (Table 4). The condition assessment shows that the median TCI score across all tress was seven with a credible interval (90% of results) between five and twelve. The results of each of the species are shown in table 4. The distribution of counts from the 4,000 model runs across all species are shown in Figure 1. Figure 2 shows the results separated by species.

Table 5: Summary results from the Bayesian analysis of TCI scores for tress of the South Australian River Murray for 2016 including median TCI scores, 90% credible intervals and overall condition assessment.

Measure	Predicted (median) TCI Score	Credible interval (90% of results)	Condition
River red gum	8	6 to 12	Fair
Black box	8	5 to 12	Fair
River cooba	5	3 to 10	Fair
Combined	7	4 to 12	Fair

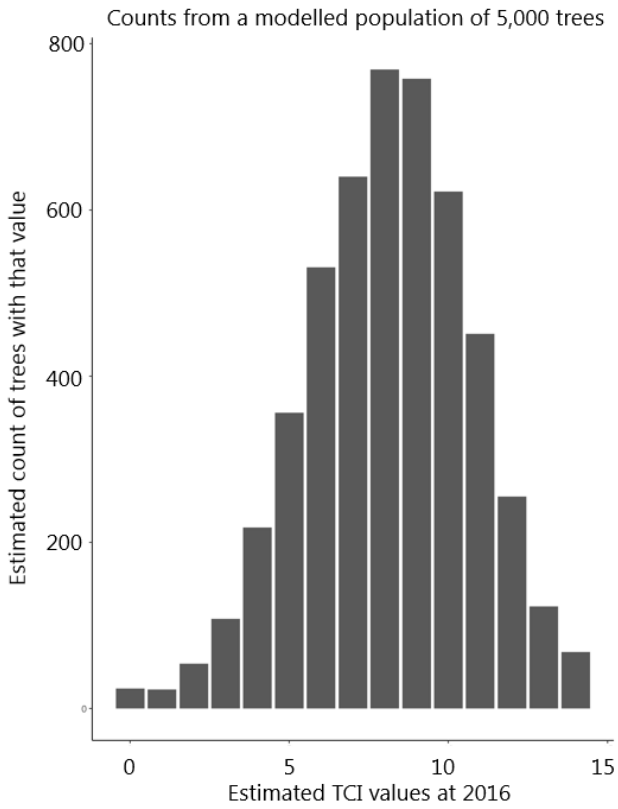

Figure 1: Distribution of tree condition index for all trees analysed for 2016 as produced by the Bayesian analysis (5000 model runs).

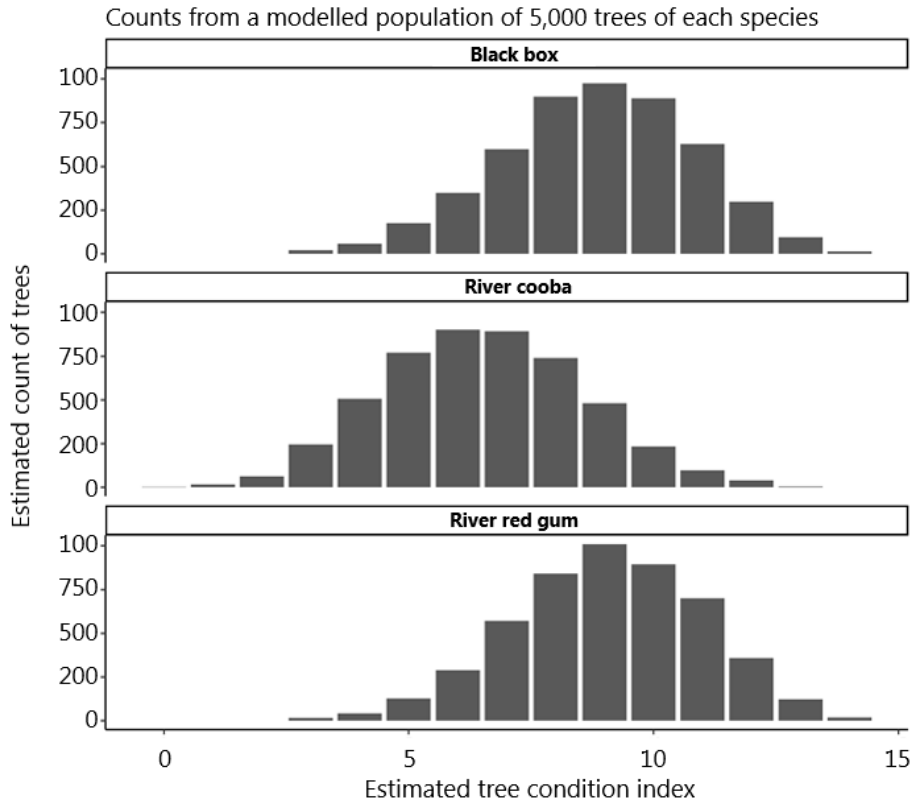

Figure 2: Distribution of tree condition index for black box, river cooba and river red gum for 2016 as produced by the Bayesian analysis (5,000 model runs).

3.3 Trend

The regional level trend assessment, incorporating all three species, showed that condition is stable. In order to be classed as either getting better or worse, 90% of the results need to demonstrate a positive or negative slope respectively. As can be seen in Figure 3, the median value is slightly negative, however, the distribution covers both positive and negative and was, therefore, classed as stable.

The three species showed similar results when assessed individually. All median slope values were negative, however, none of the three species achieved the 90% threshold to be classed as getting worse (Figure 4). This data was presented in a linear graph for the report card itself (Figure 5). This figure highlights the average negative slope of the modelling results. The river cooba appears to be declining, however, only approximately 80% of the modelling results show a decline and therefore, it is classed as stable.

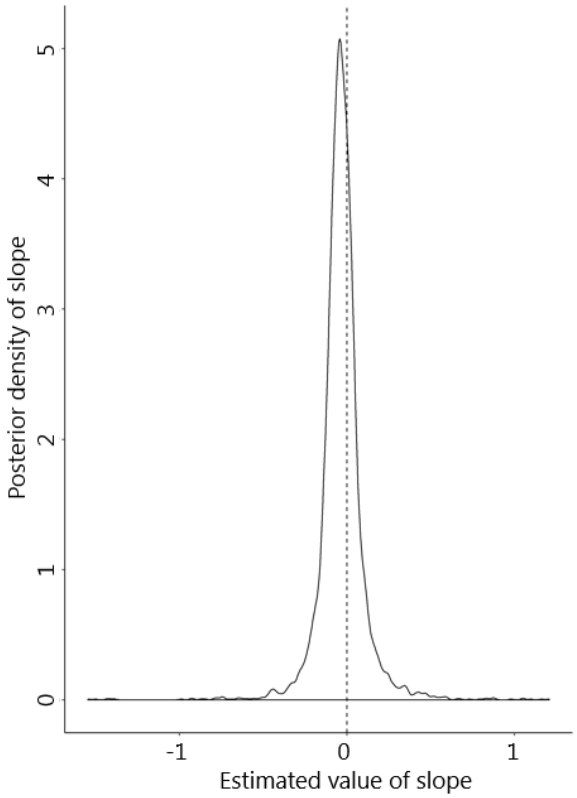

Figure 3: Summary of the slopes generated from the Bayesian modelling for all species of floodplain trees assessed.

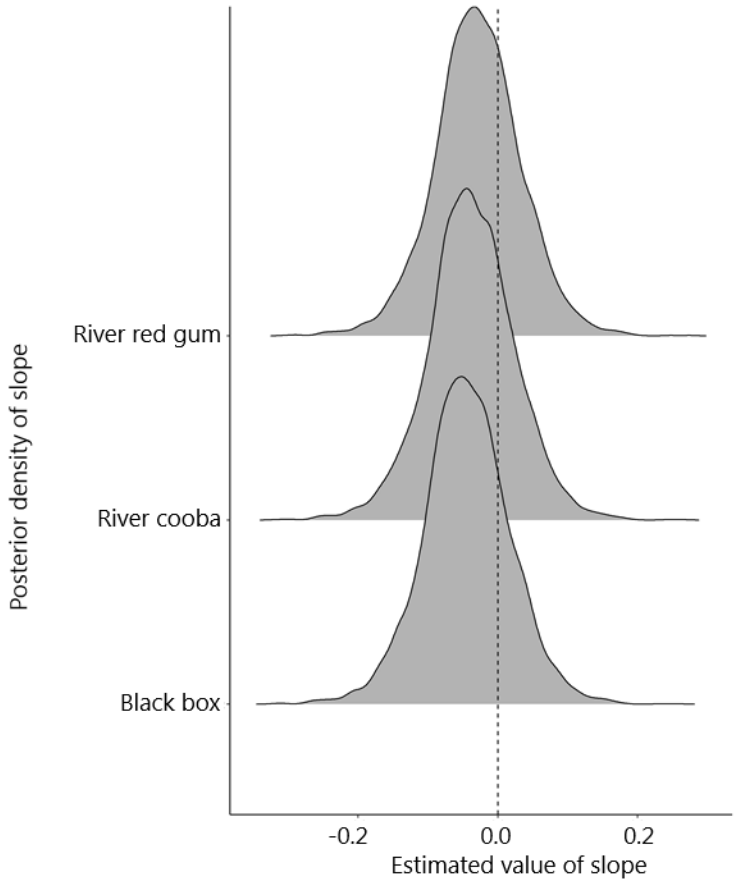

Figure 4: Estimated values for the slope for River red gum, River cooba and Black box respectively.

While the purpose of this report is to look at the overall condition of trees across the SARM, it was also noted that across the different areas that were assessed the trends varied considerably, ultimately leading to the stable trend score.

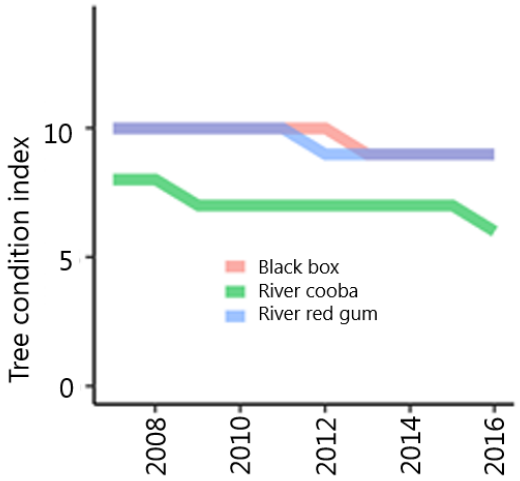

Figure 5: Estimated tree condition scores for the three species of tree based on the modelling results. This figure was developed for the report card.

3.4 Reliability

The scores for each of the four guides along with justification is provided in Table 2.

Table 6: Results of the reliability assessment of the CLLMM Vegetation data

Guide	Score	Justification
Currency	5	Data available up to date
Applicability	5	Data is a direct measure of the indicator
Spatial representation	2	Spatial coverage is dominated by a few key areas that are the focus of management activities (e.g. Chowilla, Pike and Katarapko). The analysis also includes both areas that have and have not been actively managed or subject to future management. There may also be a bias towards trees lower on the floodplain than trees higher up. This may result in optimistic results as trees higher up are generally in poorer condition.
Accuracy	5	Data is collected by trained staff in the manner described in Souter et al. (2010).

4 Discussion

4.1 Data

The data that has been used in this report card has been collected through multiple programs across multiple spatial scales. The method used, the TCI (Souter et al. 2010), has been consistently applied, however, there may be slight variations and personal biases within the observations that cannot be accounted for in the data. However, given that the methodology is the same, these differences were considered minimal and, at the spatial scale of interest, of little consequence.

The spatial representation of trees in the data set may also have a result on the overall results. It is important to note that the dataset is not complete and there are areas that are under or not represented. The datasets are dominated by the larger datasets of managed wetlands. Given the focus on the effect of management activities, the trees selected for monitoring are biased towards those that are receiving environmental water, i.e. lower down on the floodplain. Trees higher up on the floodplain are less likely to receive environmental water due to the volumes of water required to reach them, which generally leads trees at these higher elevations to be in poorer condition.

4.2 Condition

River red gum, black box and river cooba are three of the most iconic species of floodplain tree in South Australia. They are highly valued for their provision of many ecosystem services, role in riverine foodwebs and they also contribute to the river's aesthetic values. They provide key habitats for birds, reptiles, bats, insects and amphibians. The current (2016) condition of all three species, across all floodplain and channel sites was recorded as fair. A fair condition score is associated with trees with reduced canopy cover and general health but would be expected to respond positively to watering.

Tree condition was also highly variable along the South Australian River Murray (SARM). The water regime that the trees across the SARM are subjected to varies over time and in locations is decoupled from flow events in the river itself through the use of regulators and weirs. This analysis did not separate out trees that are subjected to managed inundations to provide an overall picture of tree health. As more of the large infrastructure programs are implemented (e.g. Pike and Katarapko floodplains) it could be expected that the overall condition will improve and separating out managed and not managed areas may become more prudent.

River cooba recorded a lower TCI scores than either river red gum or black box. River cooba is predominantly found higher on the floodplain and, therefore, higher water levels are required to inundate these trees. These higher water levels require higher flow volumes and are less likely under the management of the River Murray.

4.3 Trend

Across all three species the trend from 2008 to 2016 was recorded as stable. Given the broad scale of these analyses there are likely to be areas that are improving and those that are declining within the areas sampled. The Bayesian model identified that across the all the trees sampled it was slightly more likely that there was a decline rather than an improvement in overall condition but the 90% credible interval was not reached to be classed as getting better or worse. Based on these results, the added sampling effort in the past few years does not appear to have had an effect on the results.

The same trend was seen for each of the individual species analysed. The median trend for River red gum, Black box and River cooba was consistently slightly negative but the distribution of results covered both positive and negative results. The results were very consistent across the three species. The overall condition of trees across the

SARM was fair, which suggests that these trees will respond positively to watering events. Given the intentions of the Basin Plan to return more environmental water to the system along with the investment in infrastructure at key locations along the SARM it is expected that the frequency of watering events will increase, leading to an increase in tree condition.

This overall assessment may not reflect the trend at individual locations. This assessment is designed to provide a high level assessment of tree condition across the whole of the SARM. The data that this assessment used comes from various monitoring programs across the SARM and the majority of these are analysed separately and in more detail. These detailed assessments show that there are areas across the SARM that are showing improvements in the TCI scores. These areas are predominantly areas where infrastructure has been constructed to allow for the managed inundation of floodplain habitat. Detailed discussions on different areas can be in site specific reports (Chowilla: Wallace (2017), Katarapko: Green and Suitor (2017), Pike: Walters (2017).

The increases in condition at these locations offset the declines that have been seen in others. The efforts to improve the condition of trees across the SARM are not uniform. While some large scale programs to manage flooding of trees (i.e. not individual sites) are happening, such as the weir pool manipulation program (here), the general consensus is to focus on key habitat areas.

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