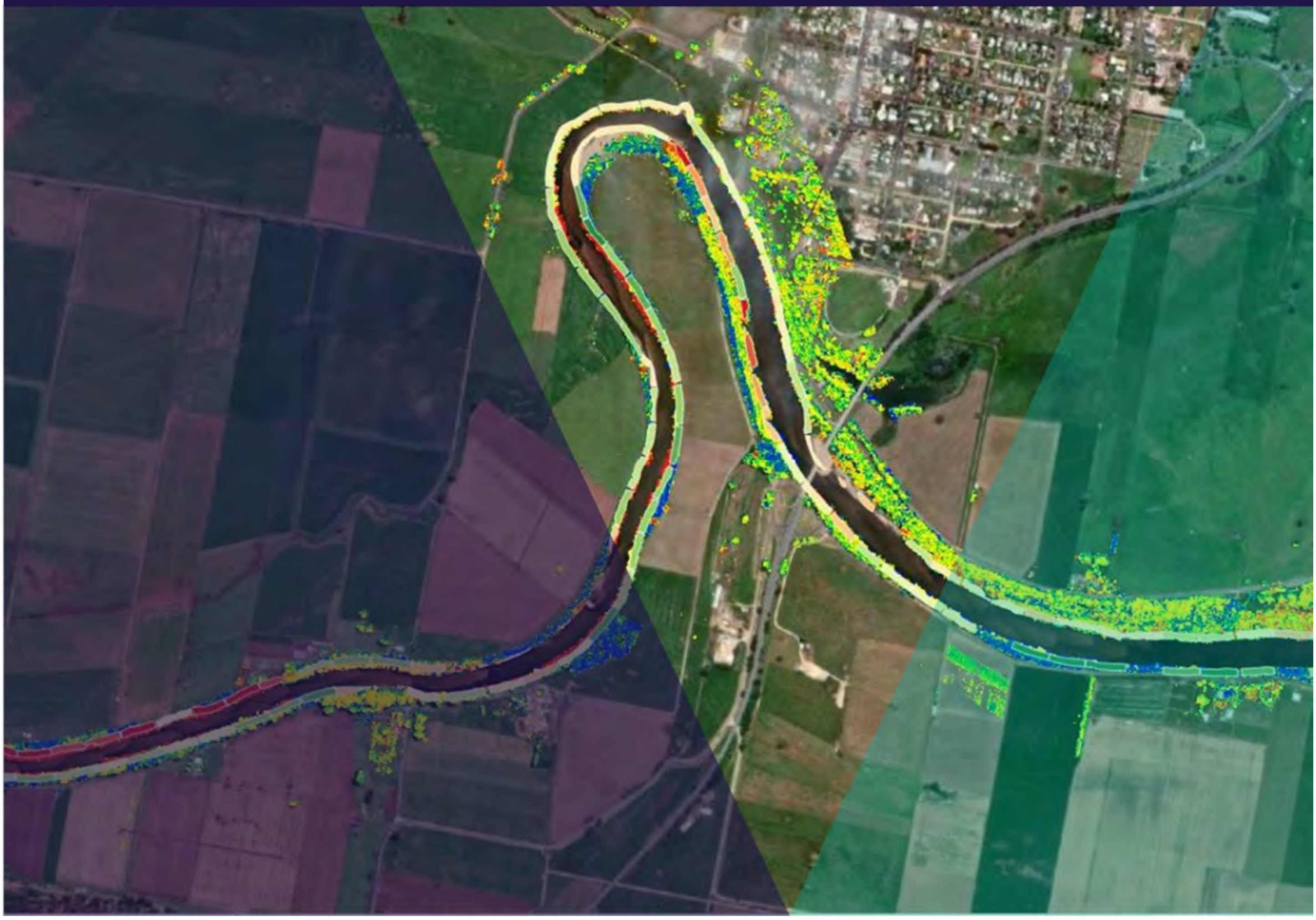
Stream Change Assessment: detecting change in riparian woody vegetation using LiDAR derived data

April 2022



VICTORIA State Government
Environment, Land, Water and Planning

OFFICIAL

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

ISBN 978-1-76105-923-0

Stream Change Assessment: detecting change in riparian woody vegetation using LiDAR derived data

April 2022

Catchments, Waterways, Cities and Towns, Waterway Programs Branch

Acknowledgements

Many thanks to all the Victorian Catchment Management Authorities for their assistance with this work, particularly the inclusion of case studies. We also thank and acknowledge staff in the Coordinated Imagery Program within Land Use Victoria, DELWP for their efforts in facilitating the procurement, capture and analyses of data products that contributed to this report. Shane Brooks (Ecology & Technology) developed the work-flow and generated the subsequent data products to enable these analyses.

Report produced by:

Catchments, Waterways, Cities and Towns, Waterway Programs Branch
Department of Environment, Land, Water and Planning
Website: www.delwp.vic.gov.au

Citation
DELWP (2022) **Stream Change Assessment: detecting change in riparian woody vegetation using LiDAR derived data**
Department of Environment, Land, Water and Planning, East Melbourne, Victoria

Contents

1. Executive summary 1

2. Introduction 6

2.1 Developing a repeatable method to assess change through time at scales relevant for management 8

2.2 Purpose and scope of this report 9

3. Methods 10

3.1 Aerial LiDAR Survey 10

3.2 LiDAR Data Sets 11

3.2.1 Modifications made to the 2010 ISC3 LiDAR data sets required to support a reliable baseline for change assessment 13

3.3 Vector maps 16

3.3.1 New riparian buffer assessment area boundaries to support change assessment 18

3.4 Calculated metrics and ISC Streamside Zone scores 19

3.4.1 Differences compared to the 2010 ISC3 Streamside Zone metrics 22

3.5 Do differences in processing change the 2010 ISC3 Streamside Zone scores? 22

3.6 Describing changes in riparian vegetation 24

4. Results 28

4.1 State-wide summary 28

4.2 Regional summary 30

4.3 Individual CMA regional summaries 36

4.3.1 Corangamite Region 36

4.3.2 East Gippsland Region 43

4.3.3 Goulburn-Broken Region 47

4.3.4 Glenelg-Hopkins Region 55

4.3.5 Mallee Region 61

4.3.6 North-East Region 67

4.3.7 North Central Region 72

4.3.8 Wimmera Region 78

4.3.9 West Gippsland Region 82

4.4 Examining the potential influence of buffer width on assessments of riparian change 88

4.5 Using fractional canopy cover at different height strata to interpret vegetation change 91

5. Next steps 92

6. References 94

OFFICIAL

List of tables

Table 1 River length resampled by LiDAR in 2018–2020 as a percentage of the river length in each CMA region. 8

Table 2 Comparison of vector data products that were generated for the ISC3 Streamside Zone and the SCA project 18

Table 3 Outline and brief description of riparian metrics used in the ISC3 assessment. For full methods description of these see Fugro (2013). Metrics were calculated from the bank toe outwards. Results are presented in this report for fractional canopy cover, canopy height, vegetation width and fragmentation; other metrics were used in the calculation of ISC Streamside Zone scores but not presented. 20

Table 4 Example of presentation of data showing percentage of sections that decreased, increased or did not change. 25

Table 5 Example of presentation of data showing % change in sections above different vegetation width thresholds 26

Table 6 Summary of changes in Streamside Zone ISC scores for nine catchments. The percentage of ISC reaches in each CMA that increased, did not change, or decreased is show, along with the average change across all ISC reaches in each CMA are shown. 30

Table 7 Summary of changes in riparian vegetation for nine CMA regions. The percentage of 100m sections in each CMA that increased, did not change, or decreased is shown for the fractional canopy cover, canopy height, fragmentation and vegetation width. The average percent change across all surveyed sections in each CMA is also shown. 31

Table 8 Summary of canopy cover (%) at Cann River 14 and Chalka Creek 39 across the two time periods and at three buffer widths. 90

Table 9 Summary showing the length of reaches, number of sections where LiDAR was captured, the number of sections included in our summaries (based on overlap between capture areas of greater than 50%), the percentage of captured sections that were included, and the dates of LiDAR capture in 2010 and 2018. LiDAR was captured at 150 ISC reaches but fewer than 40 sections were sampled at 9 reaches which were excluded from this report. 95

Table 10 Summary of changes in riparian vegetation for ISC reaches. The percentage of sections at each reach that increased, did not change, or decreased is shown for the ISC Streamside Zone score, along with the mean change (“Change”). 101

Table 11 Summary of changes in riparian vegetation for ISC reaches. The percentage of sections at each reach that increased (“INC”), did not change (“NC”), or decreased (“DEC”) is shown for fractional canopy cover, canopy height, fragmentation and vegetation width, along with the mean change (“Change”). 105

Table 12 Summary of changes in riparian vegetation at ISC reaches in each CMA. For fractional canopy cover, canopy height and vegetation width, values greater than zero (i.e. an increase in 2018 versus 2010) are highlighted in green, and values less than zero highlighted in red. For fragmentation, values lower than zero are highlighted in green, and values greater than zero in red. 113

List of figures

Figure 1 Subset of ISC streams resampled by LiDAR in 2018–2020 7

Figure 2 Steps for using LiDAR to map and quantify riparian vegetation 10

Figure 3 Example of LiDAR scan point cloud showing the stream channel and adjacent vegetation. 11

Figure 4 Example showing an aerial photo from a short section of King Parrot Creek (top) along with the associated 1m resolution Digital Elevation Model (DEM) and 2m resolution vegetation Fractional Canopy Cover model (FCC) and Canopy Height Model (CHM) that are derived from the LiDAR point cloud. 12

Figure 5 Duplicate counting of vegetation in overlapping passes of the aircraft (left) compared to corrected data (right). Higher vegetation cover is represented by blue colours and red rectangles in the background are the flight path of the aerial LiDAR aircraft. 13

Figure 6 Illustration of fractional canopy cover in the six different height interval classes (left panel), and example showing the distribution of different height classes at the Ovens River (right panel). 15

Figure 7 Example showing the river bed mapped from the DEM (photo shown in Figure 4). 16

Figure 8 Triangular artefacts in the river channel in the DEM are caused by interpolation across the water from artificially high points on the bank where LiDAR is measuring the canopy of dense vegetation and not the ground. 17

Figure 9 Vector data products for a section of an ISC sub-reach, derived from the streambed (blue) include the centreline divided into 100m sections, with buffers of different width extending from the toe of the bank. 17

Figure 10 The woody riparian vegetation FCC (green) is used in combination with the vector line mapping to generate metrics. Vegetation width is shown in red. Vegetation overlapping the streambed maps overhang, vegetation overlapping the area for riparian vegetation assessment is used to map cover, height and structure, and the gaps between the vegetation map fragmentation. 21

Figure 11 Large Trees are shown as hashed areas over the LiDAR CHM. This area of King Parrot Creek is Floodplain Riparian Woodland (EVC 56) where large trees are defined as having a minimum height of 20m and minimum crown area of 400m^2.(20m x 20m). 21

Figure 12 The Structure 2 metric is the count of 5m height classes present with FCC > 20%. 21

Figure 13 Illustration of how differences in calculation of metrics (at 141 ISC reaches sampled for the SCA) have altered Index of Stream Condition Streamside Zone Scores (Scores_diff) and seven metrics (Vegetation width, Vegetation overhang, Fragmentation, Tree cover, Shrub cover, Vegetation structure, Large trees; see Table 3 for details). The x-axis shows the difference as re-processed value – original ISC 2010 value; the y-axis shows the count of number of ISC reaches. 23

Figure 14 Percent overlap in sections between 2010 (blue) and 2018 (red) for a section of King Parrot Creek shown in Figure 4. 24

Figure 15 Histograms showing summary of vegetation width at 1000 hypothetical sections in two times. 25

Figure 16 Histograms showing summary of vegetation width at 1000 hypothetical sections at Time 1 and Time 2. The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above these thresholds. 26

Figure 17 Changes in Streamside Zone ISC scores and the five riparian vegetation metrics at CMAs sampled across the state. The count on the y-axis is the number of ISC reaches for the ISC Streamside Zone score panel and the number of sections for all other panels. 29

Figure 18 Summary of changes in vegetation metrics across the state. The change in each vegetation metric was calculated (i.e. metric value in Time 2 – metric value in Time 1) at each section, and then the averages of these sections taken at each ISC reach. 29

Figure 19 Changes in ISC Streamside Zone ISC scores across CMA regions. The count on the y-axis is the number of ISC reaches. 32

Figure 20 Changes in fractional canopy cover across CMA regions. The count on the y-axis is the number of sections. 32

Figure 21 Changes in fragmentation across CMA regions. The count on the y-axis is the number of sections. 33

Figure 22 Changes in canopy height across CMA regions. The count on the y-axis is the number of sections. 33
Figure 23 Summary of changes in vegetation metrics in each CMA region. The change in each vegetation metric was calculated (i.e. metric value in Time 2 – metric value in Time 1) at each section, and then the averages of these sections taken at each ISC reach. 34
Figure 24 Relationship between increases in fractional canopy cover and rainfall at ISC reaches. Blue line and grey shading are mean and 95% confidence interval from a generalised additive model. Each point represents the mean increase in canopy cover at an ISC reach, with 95% confidence intervals. Only sections where 5% increase or greater were included in results. 35
Figure 25 Streamside ISC scores for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections. 38
Figure 26 Fractional canopy cover for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections. 39
Figure 27 Canopy height for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections. 40
Figure 28 Vegetation width for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections. 41
Figure 29 Fragmentation for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections. 42
Figure 30 Streamside Zone ISC score for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections. 44
Figure 31 Fractional canopy cover for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections. 44
Figure 32 Canopy height for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections. 45
Figure 33 Vegetation width for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections. 45
Figure 34 Histograms showing summary of vegetation width at Snowy River reach 3 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above those thresholds. 46
Figure 35 Fragmentation for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections. 46
Figure 36 ISC Streamside Zone scores for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections. 49
Figure 37 Fractional canopy cover for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections. 50
Figure 38 Canopy height for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections. 51
Figure 39 Vegetation width for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections. 52
Figure 40 Fragmentation for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections. 53
Figure 41 Histograms and aerial imagery showing vegetation width at Faithfuls Creek reach 21 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above those thresholds. Green lines on photographs are transects perpendicular to the stream used to measure vegetation width. 54
Figure 42 Streamside Zone ISC scores for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections. 56

Figure 43 Canopy cover for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections. 57
Figure 44 Canopy height for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections. 58
Figure 45 Vegetation width for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections. 59
Figure 46 Fragmentation for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections. 60
Figure 47 ISC Streamside Zone scores for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections. 64
Figure 48 Canopy cover for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections. 64
Figure 49 Canopy height for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections. 65
Figure 50 Vegetation width for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections. 65
Figure 51 Histograms showing summary of vegetation width at Lindsay River reach 68 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 30m in the two periods and the % change in the proportion of sections above those thresholds. 66
Figure 52 Fragmentation for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections 66
Figure 53 Streamside Zone ISC scores for locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections. 69
Figure 54 Fractional canopy cover for locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections. 69
Figure 55 Canopy height locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections. 70
Figure 56 Vegetation width locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections 70
Figure 57 Fragmentation locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections. 71
Figure 58 Streamside Zone ISC scores for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections. 75
Figure 59 Fractional canopy cover for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections. 75
Figure 60 Canopy height for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections. 76
Figure 61 Vegetation width for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections. 76
Figure 62 Fragmentation for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections. 77
Figure 63 Streamside Zone ISC scores for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections. 79
Figure 64 Fractional canopy cover for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections. 79
Figure 65 Canopy height for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections. 80
Figure 66 Vegetation width for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections. 80
Figure 67 Fragmentation for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections. 81

Figure 68 Streamside Zone ISC scores for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections. 83
Figure 69 Fractional canopy cover for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections. 84
Figure 70 Canopy height for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections. 85
Figure 71 Vegetation width for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections. 86
Figure 72 Fragmentation for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections. 87
Figure 73 Two examples, from Cann River in the East Gippsland CMA (left) and Chalka Creek in the Mallee CMA (right), showing multiple buffer widths from the stream bed out laterally to 10m (purple line), 20m (yellow line) and 40m (white line). 89
Figure 74 Canopy cover at Cann River 14 and Chalka Creek 30 across the two time periods and at three buffer widths 90
Figure 75 (a) overall canopy cover and (b) canopy cover at different height strata at Acheron River reach 62 in Time 1 (2010) and Time 2 (2018). 91
Figure 76 (a) overall canopy cover and (b) canopy cover at different height strata at Snowy River reach 4 in Time 1 (2010) and Time 2 (2018). 91

1. Executive summary

Background and methods

Riparian lands provide social, cultural, environmental and economic benefits, but are threatened by vehicle and livestock access, feral pests, agricultural run-off and invasive weeds. To maintain and improve the values that riparian land supports, management actions, especially livestock management via fencing, revegetation, weed control and willow removal, are undertaken across Victoria. Much of this work is funded by the Victorian government and undertaken by catchment management authorities (CMAs) in partnership with landholders.

Information about the status and trend of riparian condition is critical to inform state and regional waterway planning, evaluation and reporting. It is vital to demonstrate and evaluate the outcomes of investment into riparian management in order to track progress towards objectives and guide improved practice.

The objectives of the Stream Change Assessment (SCA) project were to:

i. develop an efficient and repeatable approach to assess changes in riparian woody vegetation across broad spatial extents drawing on existing data sets and methods; and
ii. using this method, provide an assessment of woody vegetation change at a subset of Victoria's river and stream reaches. The assessment uses Light Detection and Ranging (LiDAR) data to assess characteristics of woody vegetation in the riparian zone. The outcomes of this work can be used to assist planning, guide management, evaluate management outcomes and document change.

In Victoria, LiDAR was first used to assess the condition of riparian vegetation at broad spatial scales for the 2010 Index of Stream Condition (ISC). The ISC has provided important snapshots of the condition of Victoria's rivers in 1999, 2004 and 2010. In 2010, technological developments in remote sensing meant aerial LiDAR could be used instead of on-ground sampling to assess the Streamside Zone ISC sub-index across the state. This aerial LiDAR method provided a more consistent and comprehensive data collection method.

The SCA re-sampled a subset of ISC river reaches (n = 141) using aerial LiDAR from 2018 to 2020, to assess changes in woody vegetation since the 2010 ISC3 capture. These reaches represent ~3,424 km of stream length, or ~13% of the ISC river network, and were selected in consultation with CMAs based on their needs for new information to evaluate change due to management and/or to guide their planning.

The SCA project developed a repeatable and semi-automated work-flow for processing raw LiDAR data into maps and derived metrics to assess change between 2010 and 2018-2020 at a range of spatial scales. Importantly, the SCA project also revised and re-purposed the LiDAR data collected in 2010 to provide a reliable baseline and support a repeatable assessment of change going forward. This work was needed because the approaches used to generate metrics for the 2010 ISC3 assessment were not suitable to support an assessment of change through time and modifications were required.

This report summarises the key components of work undertaken during the SCA to date:

- Description of a workflow for efficient data processing
- Re-processing of the entire 2010 LiDAR capture to provide a reliable baseline for future change assessments
- Processing of 2018-2020 captured data for key vegetation metrics and ISC Streamside Zone scores
- Summary of changes in ISC Streamside Zone scores and vegetation metrics between the two assessment periods (2010 and 2018-2020) at the state, regional and ISC reach scales
- Outline of conclusions and next steps.

The metrics described and summarised in this report are fractional canopy cover, canopy height, vegetation width and fragmentation; these represent a subset of the full set of vegetation metrics that were derived as part of the SCA project. Other vegetation metrics, as well as information on channel form, will be explored as part of future work. ISC Streamside Zone scores were also calculated so these could also be compared between the two assessment periods. Notably the woody weeds component of the Streamside Zone score was not updated for the second assessment period so results do not account for any changes due to woody weed management or expansion. An update would involve manual interpretation of aerial imagery and interrogation of CMA woody weed management data, which was beyond the scope of this project and will be covered in subsequent work.

The minimum unit of measurement where metrics and scores were calculated was the 'section' which comprises ~100m of stream length on one side of the stream bank. The SCA outputs will enable vegetation metrics to be calculated at riparian widths ranging from 10m to 200m (noting that results will be sensitive to the width chosen for the assessment – see section 4.4). For this report, a buffer width of 40m was used to summarise vegetation metrics, which aligns with the width used in the 2010 ISC3 assessment.

Sections can be aggregated to calculate metrics at a range of scales. For each section, the difference between assessment periods was calculated for each vegetation metric i.e. metric value in period 2 – metric value in period 1. The percentage of sections that increased (i.e. difference over time > 0), decreased (i.e. difference over time < 0) and did not change (i.e. difference over time = 0) was then calculated at the state- CMA-region and ISC reach- scale.

To be consistent with the ISC3 methodology, Streamside Zone scores needed to be compared at the ISC reach scale. For each section, the difference in score over time was calculated as for vegetation metrics (i.e. Score in assessment period 2 – Score in assessment period 1). The mean at the ISC reach scale was derived from the total sections within a reach. Each reach was then categorised as having increased (difference in score between assessment periods > 0), decreased (difference in score between assessment periods < 0) or remaining unchanged.

Results

State-wide scale

At the state-wide scale, the key results were:

- Of the 141 reaches assessed, the Streamside Zone ISC sub-index score remained unchanged at 114 (81%), increased by one unit at 26 (18%), and increased by two units at one reach.
- Fractional canopy cover (FCC) increased at 69% of sections by 3% on average.
- Canopy height increased at 76% of sections by ~1m on average.
- Fragmentation decreased at 68% of sections by 4% on average.
- Vegetation width increased at 60% of sections by 4m on average.

The relatively small changes between the two assessment periods at this large spatial extent was not unforeseen for several reasons:

- Substantial changes in riparian vegetation due to management are likely to occur over longer time-intervals than the 8-10 years between assessment periods. Changes over larger extents and of larger magnitude may be observed if future comparisons are undertaken over longer time frames.
- Not updating the woody weeds (i.e. willows) component of the ISC Streamside Zone score for the second assessment period (as noted above) would have influenced ISC score comparisons. In cases where woody weeds were removed, decreases in canopy height and cover may represent beneficial outcomes, so caution and local context should be applied when interpreting results.
- Riparian vegetation can vary at a range of spatial scales, from the very small (i.e. plant growth at scales of less than metres) to very large (e.g. in relation to physiography or weather conditions). This means that when data are aggregated, increases at some locations are

likely to be masked by decreases at others, so substantial changes will only be observed if they occur systematically in the same direction.

- LiDAR was recaptured at reaches for a range of reasons, so results should be viewed through expectations of change in a local context, based on whether or not management was undertaken along a reach (its timing extent and quality) or the influence of disturbances such as floods, drought and bushfire.

CMA-region scale

CMA regions differ broadly in terms of vegetation type, environmental context (e.g. rainfall, slope) and amount and types of riparian management. These differences mean that the magnitude and extent of changes in riparian vegetation are likely to vary among CMA regions.

Streamside Zone ISC scores generally did not change at the CMA region scale (see Table E1). The lack of significant changes in ISC Streamside Zone scores reinforces that the ISC reach-scale assessments are insensitive to change over the medium-term (8-10 years), and supports the reduced frequency of ISC benchmarking assessments (previously undertaken every ~5 years)

Table E1 Summary of changes in Streamside Zone ISC scores for nine catchments. The percentage of ISC reaches in each CMA that increased, did not change, or decreased is shown, along with the average change across all ISC reaches in each CMA.

Catchment Management Authority Region	Shift in ISC Streamside Zone score between assessment periods (% of ISC reaches)			Average change in ISC Streamside Zone score
	Increase	No change	Decrease	
Corangamite	4	96	0	0.04
East Gippsland	54	46	0	0.53
Goulburn-Broken	21	79	0	0.21
Glenelg-Hopkins	0	100	0	0.0
Mallee	31	69	0	0.3
North Central	7	93	0	0.10
North East	0	100	0	0.0
Wimmera	8	92	0	0.10
West Gippsland	48	52	0	0.53

Key findings for individual vegetation metrics (see Table E2 below) among CMA regions were:

- Fractional canopy increases were widespread with the largest changes in regions with high rainfall (East and West Gippsland) or where flooding and/or water management occurred between assessments (Mallee).
- Widespread increases in canopy height were observed but these were generally of a small magnitude (<2m).
- Fragmentation decreased at more than 50% of sections at all CMAs, with the largest decreases in West and East Gippsland.
- Vegetation was wider at more than 50% of sections at all CMA regions except for Glenelg-Hopkins where a small decrease was observed.

While more detailed analyses are needed to explore the drivers of riparian change, preliminary work suggested a strong influence of rainfall on vegetation changes. Canopy cover increased by more than 10% at only one of 18 ISC reaches with less than 500mm annual rainfall, whereas it increased by more than 10% at all ISC reaches with more than 800mm rainfall.

Table E2 Summary of changes in riparian vegetation for nine regions. The percentage of 100m sections in each CMA that increased, did not change, or decreased is shown for the fractional canopy cover, canopy height, fragmentation and vegetation width. The average percent change across all surveyed sections in each CMA is also shown.

CMA Region	Shift in fractional canopy cover (% of sections)			Average change in sections	Shift in canopy height (% of sections)			Average change in sections
	Increase	No change	Decrease		Increase	No change	Decrease	
Corangamite	58	3	39	1.2	67	3	30	0.4
East Gippsland	71	1	29	4.8	83	1	16	1.2
Goulburn-Broken	77	0	23	5.1	83	0	17	1.2
Glenelg-Hopkins	57	6	37	0.6	66	5	29	0.3
Mallee	91	1	8	6	82	1	17	1.1
North Central	73	2	26	2.5	77	2	21	0.7
North East	56	0	44	0.7	77	0	23	1.2
Wimmera	77	3	20	2.3	80	3	17	0.6
West Gippsland	74	1	25	7.3	85	1	14	1.6

CMA Region	Shift in fragmentation (% of sections)			Average change in sections	Shift in vegetation width (% of sections)			Average change in sections
	Increase	No change	Decrease		Increase	No change	Decrease	
Corangamite	39	5	56	-1.9	53	9	38	0.7
East Gippsland	25	0	75	-7.9	69	4	27	3.8
Goulburn-Broken	23	0	77	-6.3	67	2	31	6.8
Glenelg-Hopkins	48	0	52	0.1	45	15	40	-0.6
Mallee	21	0	79	-5.4	64	2	34	8.2
North Central	29	2	69	-2.8	58	7	35	2.8
North East	37	1	62	-2.2	59	1	40	4.8
Wimmera	22	1	77	-3.4	59	11	30	1.4
West Gippsland	18	5	77	-9.5	72	3	25	7.9

ISC-reach scale

While changes in riparian woody vegetation were relatively minor at state- and regional-scales, within most regions there were ISC reaches where more substantial changes were observed.

Key results at the ISC reach scale include:

- Fractional canopy cover increased by >10% at nine reaches, five of which were in West Gippsland, two in East Gippsland, and one each in the Goulburn-Broken and the Mallee.
- Canopy height increased at 129 of 141 reaches by ~1m on average. The most substantial changes (increases of more than 2m) were observed most commonly in the East and West Gippsland regions.
- Fragmentation decreased at 86% of reaches (121 of 141) reaches, which were spread across all CMAs.
- Vegetation width increased at 82% of reaches (115 of 141), and at more than 10 reaches within all regions except the North-East (5 reaches).

The most substantial changes were observed at sub-reaches within ISC reaches. These were usually sub-reaches of stream length of several kilometres where substantial and/or sustained riparian management had been undertaken. Representative examples of these are presented throughout the regional summaries, and illustrate some of the potential drivers of change, notably riparian management (e.g. fencing, revegetation, woody weed removal) and environmental water management.

Conclusions and next steps

The SCA project successfully developed a semi-automated process to assess and track woody riparian vegetation change using LiDAR derived data. The work-flow can now be efficiently applied to any new LiDAR capture along rivers and streams to produce a standard set of comparable metrics that can be used to assess change.

The results of the first investigation of riparian woody vegetation change between the two assessment periods showed that changes due to riparian management were evident over an 8 to 10-year timeframe. However, these changes were rarely manifested at the waterway asset scale (i.e. ISC reach) and rarely resulted in shifts in the Streamside Zone sub-index used to characterise condition of an ISC reach as used in an ISC assessment. This latter result emphasises the limitations of the ISC when attempting to apply the method to assess change rather than the spatial benchmarking assessment that it was originally design for. Given the relatively minor changes observed at broad spatial scales in this assessment, it is reasonable to be confident that the ISC3 2010 benchmark continues to provide a contemporary estimate of riparian condition at the ISC reach scale. Where data weren't recaptured in 2018-20, the ISC3 2010 Streamside Zone score and underlying metrics, coupled with information on management effort, will provide DELWP and CMA regions with reliable information to inform their plans and strategies.

Significant changes in riparian woody vegetation occurred almost exclusively along shorter sections (sub-ISC reach) of stream length (1-10km), where significant and/or sustained management effort was undertaken. Nonetheless the magnitude of these changes varied substantially within and among environmental contexts. This underlines the importance of:

- Reliable and comprehensive spatial information on management effort (type, timing and quantity, i.e. DELWP standard outputs) to interpret these responses and
- Realistic spatial and temporal scales over which to set management objectives and assess change.

High priority further work includes:

- Incorporating woody weeds into the new data set and derived scores to facilitate improved interpretation of any observed changes in woody vegetation. This will rely on a combination of CMA woody weed management data as well as manual interpretation of aerial imagery.
- Analyses to attribute changes in riparian vegetation to potential causes, such as riparian management, and environmental factors like rainfall, temperature and hydrology. This will greatly improve current understanding of the drivers of riparian woody vegetation change and can help managers set realistic targets for the timing and magnitude of changes following riparian management.
- Comparing the performance and utility of alternative remotely-sensed methods for detecting changes in riparian woody vegetation to meet a range of evaluation and reporting purposes. Sentinel and Landsat datasets are freely available and more frequently collected and so they may offer a more cost-effective alternative to LiDAR in some circumstance to detect change in riparian vegetation. However, these data sets are gathered at coarser spatial resolutions than LiDAR so there is a need to examine and compare their relative sensitivities for detecting change. Such comparisons will help inform and rationalise future efforts to measure and track changes in riparian woody vegetation.

2. Introduction

Riparian lands are valued for providing habitat, food and shade and buffering riverine ecosystems from impacts of adjacent human land use. They are important natural refuges in agricultural and urban landscapes, supporting biodiversity. Riparian corridors facilitate wildlife movement along waterways, connecting patches of remnant native vegetation and are popular destinations for recreational activities including camping, fishing and bushwalking.

Riparian land is threatened by vehicle and livestock access, feral pests, agricultural runoff and invasive weeds (including blackberry, hawthorn and willows). To maintain and improve the values that riparian land supports, management actions such as livestock management via fencing, revegetation, weed control and willow removal are undertaken across Victoria.

Information about the status and trend of riparian condition is critical to inform state and regional waterway planning, evaluation and reporting. An ongoing challenge is to demonstrate and evaluate the outcomes of investment into riparian management in order to track progress towards objectives and guide improved practice.

The Index of Stream Condition (ISC) has been fundamental in providing snapshots of river condition in 1999, 2004, and 2010. Technological developments in remote sensing enabled the Department of Environment, Land, Water and Planning (DELWP) to replace on-ground sampling with LiDAR to measure riparian woody vegetation attributes across the entire stream network for the 2010 ISC3 assessment. LiDAR, which stands for Light Detection and Ranging, uses reflections of a laser scanner mounted below light aircraft to measure the height of the ground surface, vegetation, and other structures. This aerial survey method provided a more consistent and comprehensive collection of data compared with previous field-based sub-samples of river reaches. The ISC Streamside Zone scores and underlying metrics have subsequently been used as the predominant source of information about the broad scale status of riparian condition, typically reported at the reach scale. However, the data and underlying methods used to generate the ISC assessment were not designed to track riparian change.

This “Stream Change Assessment Project” (SCA) aimed to develop an approach to document changes in Victoria’s woody riparian vegetation and channel form over time. Changes may have occurred in response to riparian management, changes in threats, or natural disturbances including floods, droughts, and fires. The SCA project recaptured LiDAR at a subset of ISC reaches to map the physical structure of the river channel and woody vegetation. These reaches represent 3,474km of stream length, or ~13% of the ISC river network (Figure 1, Table 1). Resampled reaches were nominated by catchment management authorities (CMAs) based on their priorities for new information to evaluate change due to management and/or to guide their planning. The scope of this work included nine CMA regions across Victoria, with Melbourne Water undertaking their own LiDAR-based assessment (Port Phillip and Westernport region). The project then developed a range of methods and data products to assess and document magnitudes of change in riparian woody vegetation since 2010. More specifically, it has:

- Generated a reliable baseline from the 2010 ISC3 LiDAR capture for the entire ISC stream network to support ongoing change assessment for Streamside Zone vegetation metrics - the approaches used to generate metrics for the 2010 ISC3 assessment were not intended to support an assessment of change through time and modifications were required.
- Developed semi-automated analytical tools and workflows to map the riverbed and banks from high resolution digital terrain models that are derived from aerial LiDAR surveys. Automated tools maximise consistency of the mapping over manual processes to ensure that observed changes through time were not due to differences in the mapping methods.
- Defined individually identifiable vegetation and channel sampling units aligned to the 2010 ISC river network.
- Calculated metrics for riparian woody vegetation for reaches recaptured during the second assessment period (2018 - 2020)

- Quantified changes that have occurred at between the two assessment periods (2010 and 2018–2020)
- Provided the data products and tools to DELWP and CMAs for use in regional evaluation, reporting and planning.

While this project draws upon many of the 2010 ISC3 underlying data and measurement techniques to enable the change assessment, it is not intended as a new state condition benchmark for reporting the current condition of Victorian ISC waterways. The metrics used in this study are limited to the Streamside Zone sub-index of the ISC and no information on hydrology, aquatic life or water quality was collected as required to derive a contemporary Index of Stream Condition. The geospatial models created from the resampled LiDAR may be used to contribute to assessment of changes in channel physical form at some time in the future but were not included as part of this study.

Ultimately, the outcomes of this work will generate comprehensive and up to date information about Victoria's rivers that DELWP and CMAs can use to inform the development of state policy and regional waterway management programs and guide management to protect and improve river health.

Figure 1 Subset of ISC streams resampled by LiDAR in 2018–2020

Table 1 River length resampled by LiDAR in 2018–2020 as a percentage of the river length in each CMA region.

CMA Region	Total ISC Stream Length 2010 (km)	ISC Stream Length Sampled 2018–20 (km)	Percent re-sampled of total ISC Stream Length
Corangamite	2635	489	19%
East Gippsland	3231	175	5%
Goulburn-Broken	3668	518	14%
Glenelg-Hopkins	3378	534	16%
Mallee	1523	273	18%
North Central	3950	540	14%
North East	3710	237	6%
Wimmera	1716	255	15%
West Gippsland	2823	403	14%
Total	**26,634**	**3424**	**13%**

2.1 Developing a repeatable method to assess change through time at scales relevant for management

Examining temporal changes in riparian vegetation requires methods that can be repeated reliably over time. This was not the original purpose of the ISC, which was designed as a snapshot of river condition at one point in time, not to examine trends (DSE 2005). To be able to assess change through time, it was necessary to ensure that the data and metrics derived from the 2010 LiDAR capture would support this approach.

While the ISC3 2010 approach was suitable for its intended purpose of comparing vegetation condition spatially for the ISC assessment, several limitations (explored in more detail in the methods below) were identified which would have meant that comparisons over time would have been unreliable. Consequently, erroneous conclusions would have been drawn about the magnitude and extent of observed change in riparian vegetation through time. A substantial component of the SCA was therefore directed at developing repeatable methods that could be used to assess change through time, which necessarily involved regenerating a reliable 2010 baseline from which change could be assessed. These data are the baseline metrics against which any future LiDAR surveys can be compared to quantify the magnitude and rate of change.

The major focus of this project is on metrics that describe riparian vegetation change, not to recreate an ISC assessment. However, ISC Streamside Zone scores were recalculated from the reprocessed 2010 baseline and also from data captured in 2018-2020. They are presented in this report for two purposes:

- ISC Streamside Zone scores (and any relative changes in time between the two assessment periods) are likely to be of interest to management agencies given the widespread use of the ISC score to characterise waterway assets, and
- to explore whether methodological changes in the re-calculation of the 2010 metrics that underpin the scores manifest in changes in the derived scores.

2.2 Purpose and scope of this report

The main purpose of this report is to present summaries of changes observed at the subset of ISC reaches sampled in both 2010 and 2018–2020. The focus is limited to riparian woody vegetation because methods and metrics to assess channel form are being finalised. The results are an examination of LiDAR captured along ~3474 km of stream length from 9 CMA regions (Table 1) and 141 ISC reaches (see Appendix Table 9 for details). This represents ~13% of the Victorian ISC stream network.

This report does not present a detailed examination of the potential drivers of this change (e.g. riparian management, threats or other environmental factors), although some representative examples from selected CMAs are included to illustrate some candidates. Preliminary explorations of the effects of rainfall and selection of buffer width on changes in riparian woody vegetation are also presented. More detailed analysis is likely to be conducted in the future, with some of the possibilities for analysis outlined in Section 5 (“Next Steps”).

The approach used to assess woody vegetation change has several limitations that should be considered when interpreting the results:

- The LiDAR data measures vegetation structure but does not distinguish between species, and thus nativeness.
- While most of the LiDAR capture occurred in summer and autumn months, there are some instances where sampling was undertaken during other seasons. As such, there are cases where the results reflect seasonal differences in canopy cover – for example reduced canopy cover associated with winter leaf fall by deciduous species (i.e. willows). The dates of LiDAR capture allow this to be considered when interpreting the results (Table 9).
- In some instances, there were difficulties with delineating the stream channel and river banks which are used to generate the riparian vegetation assessment areas. In these cases, the bank lines that were generated in 2010 by manually interpreting aerial imagery and the 2010 LiDAR digital elevation model were re-used to delineate both the 2010 and 2018 assessments.
- Riparian vegetation was measured adjacent to the stream channel referenced from the toe of the bank. Lateral movement of the channel or changes in water depth between the two capture times will influence the degree of overlap in the sampling areas used to measure vegetation measured on each date. Areas where the overlap between assessments periods was low were therefore excluded to maximise the likelihood that measured differences represent changes in the riparian vegetation rather than differences in the area sampled. The data summaries presented in this report are limited to areas where there was a >50% overlap in the area sampled between the two time periods. This represented >98% sections. The small number of sections with <50% overlap between sample dates were almost entirely confined to high energy rivers.

3. Methods

Airborne LiDAR scanning was used to create 3D models of vegetation structure and digital terrain models from which to measure the physical form and Streamside Zone sub-indexes of the state-wide 2010 ISC3 assessment (Figure 2). This foundation data set covers nearly 30,000 km of Victorian waterways providing baseline measurement of the riparian vegetation for a 200 m swathe either side of the river channels. In 2018-2020, ~3474 km of ISC stream network was re-sampled across a subset of ISC reaches that were nominated by CMAs according to their priorities for new information to evaluate change due to management or to guide their planning. An outline of the key steps involved in the data capture and processing are provided below with emphasis on aligning the methods and data processing to ensure the two LiDAR surveys conducted nearly a decade apart were comparable. The 2010 baseline needed to be updated by applying the 2018-20 algorithms for quantifying fractional cover of vegetation to the archived LiDAR point cloud data. The revised LIDAR data was then processed into riparian metrics and scores following the approaches documented for the ISC3 in Fugro (2013) except where noted in the methods described below. The construction of a new 2010 baseline that is aligned to contemporary LiDAR survey methods is a fundamental step forward providing capacity to measure riparian change into the future.

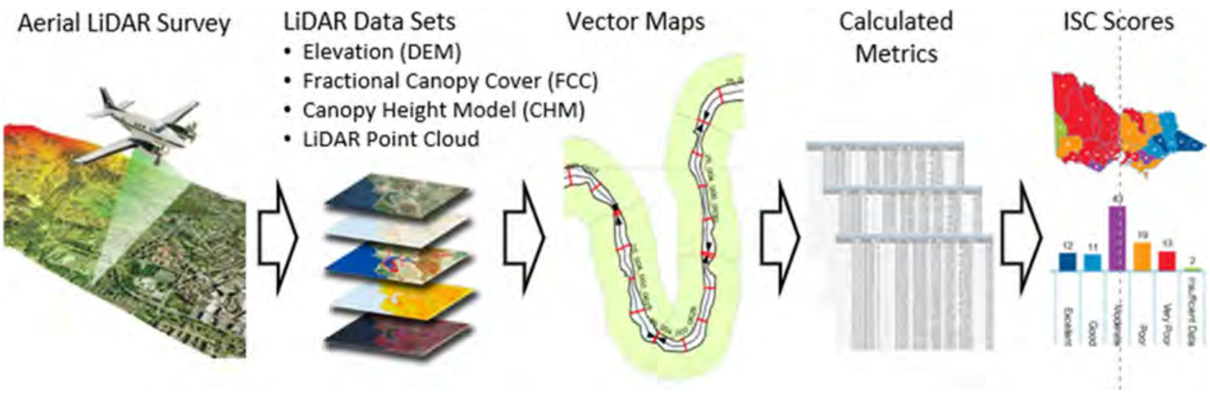


Figure 2 Steps for using LiDAR to map and quantify riparian vegetation

3.1 Aerial LiDAR Survey

Airborne LiDAR uses reflected laser pulses from a light aircraft to measure the distance to the ground. Each laser pulse can also be reflected from other surfaces including vegetation and buildings but not from water which absorbs the laser light. For the 2010 ISC3 and this project, the scan density was a grid with approximately 4 laser pulses for every m^2 of land surface, with multiple heights being recorded from each pulse due to partial reflections from overlying vegetation. The height measurements are geo-referenced to create a “point cloud” that is a 3-dimensional computer representation of the landscape (Figure 3). Vertical and horizontal accuracy is supplied with associated metadata for each capture area but is approximately 0.3m and 0.2m, respectively.

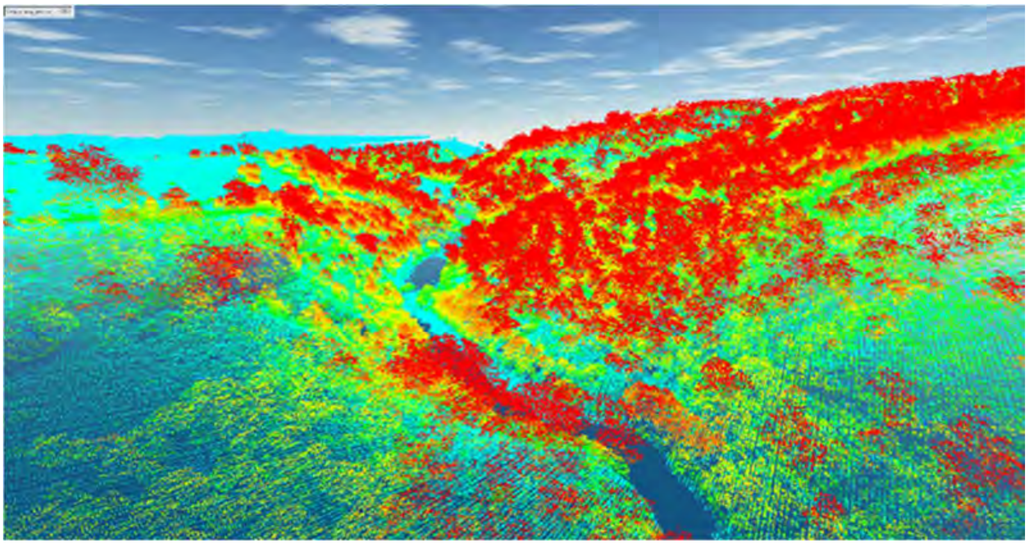


Figure 3 Example of LiDAR scan point cloud showing the stream channel and adjacent vegetation.

3.2 LiDAR Data Sets

The individual points in the LiDAR point cloud are classified as ground, buildings, or vegetation. The point cloud data is then filtered and aggregated into derived raster data sets that are spatially referenced for use in GIS (Figure 4):

- Digital Elevation Model (DEM) is a raster data set that uses the ground points to map the height of the land surface in every 1m^2 (excluding vegetation and built infrastructure).
- Fractional Canopy Cover (FCC) maps the density of woody vegetation within 2m pixels, calculated as the number of vegetation points in each pixel divided by (vegetation + ground points). Raster maps are generated for all vegetation together, and for separate height strata that can be used to compare understorey and overstorey vegetation providing the basis for comparing shrubs and trees as used in the ISC.
- Canopy Height Model (CHM) maps the maximum height of woody vegetation with 2m pixel resolution

Together with the point cloud data these represent a standard suite of data products from the LiDAR survey.

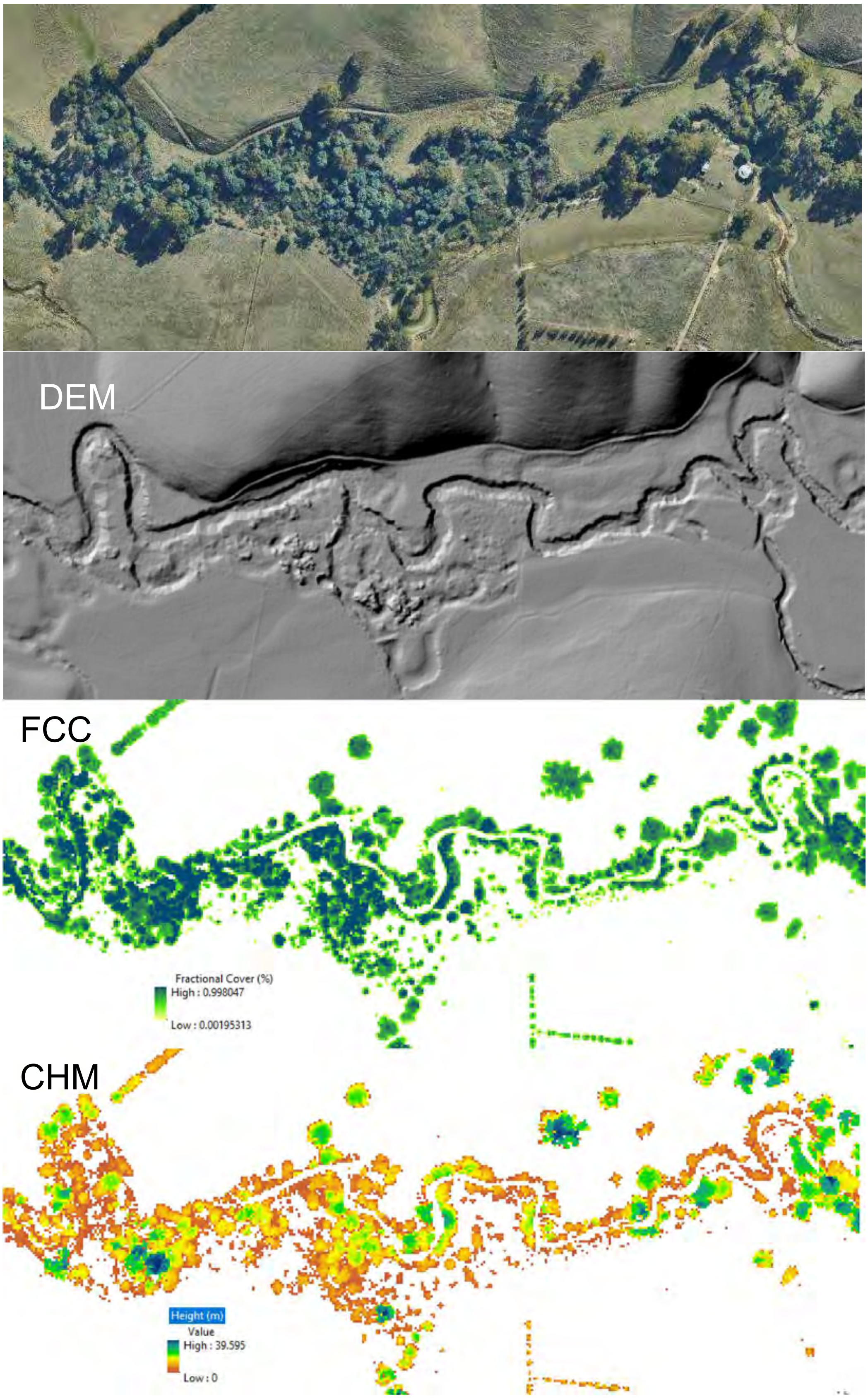


Figure 4 Example showing an aerial photo from a short section of King Parrot Creek (top) along with the associated 1m resolution Digital Elevation Model (DEM) and 2m resolution vegetation Fractional Canopy Cover model (FCC) and Canopy Height Model (CHM) that are derived from the LiDAR point cloud.

3.2.1 Modifications made to the 2010 ISC3 LiDAR data sets required to support a reliable baseline for change assessment

The 2010 ISC3 fractional canopy cover (FCC) data was recalculated from the source data for all CMA regions for three reasons:

1. Correcting for overlapping data collection
2. Correcting calculation of FCC to include the understorey
3. Changing the calculation of Height Interval FCC (vegetation strata)

Correction for overlapping data collection

Inspection of the 2010 ISC Fractional Cover data revealed banding of elevated vegetation cover associated with overlapping data collection flight paths in Glenelg-Hopkins and Mallee regions that were not visible in other CMA regions (Figure 5). The anomalies appear to be due to differential processing of ground reflections vs vegetation reflections with points from overlapping swathes removed from the ground layer thus inflating the FCC (and associated metrics). This was corrected by reprocessing the LiDAR point cloud data to remove the extra points in the overlap zones before regenerating the FCC outputs (Figure 5).

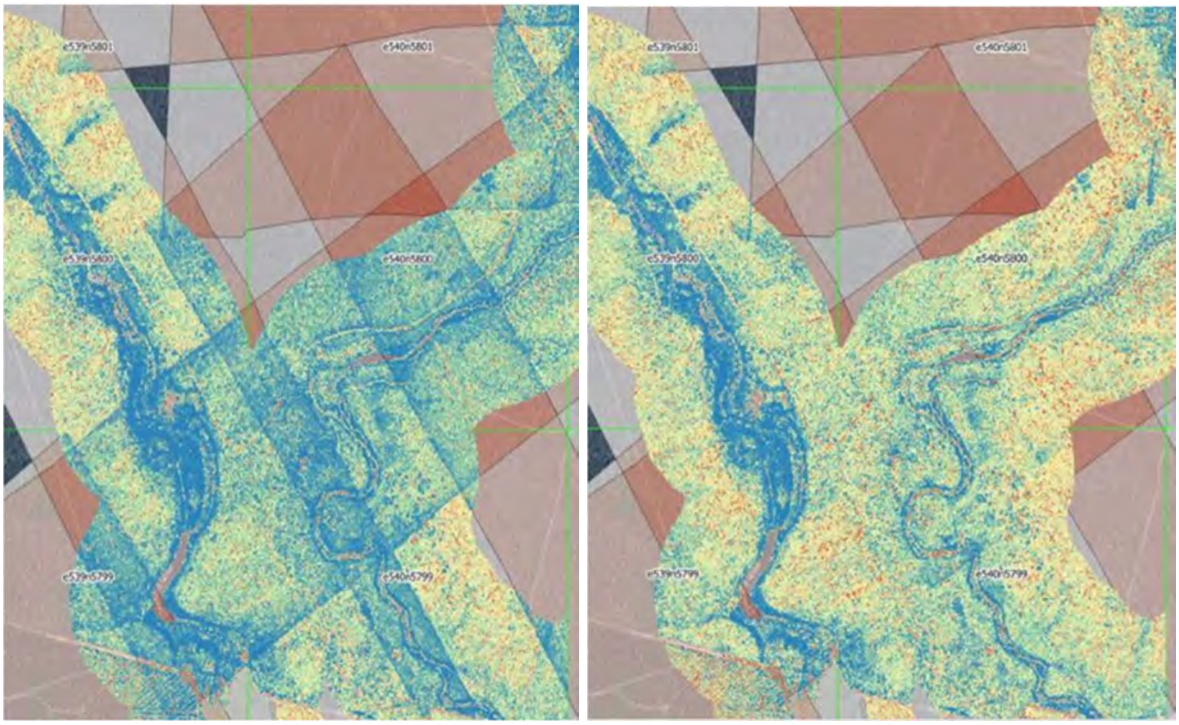


Figure 5 Duplicate counting of vegetation in overlapping passes of the aircraft (left) compared to corrected data (right). Higher vegetation cover is represented by blue colours and red rectangles in the background are the flight path of the aerial LiDAR aircraft.

Correcting calculation of FCC to include the understorey

Overall FCC was originally calculated for the 2010 ISC3 from the LiDAR point cloud as (Fugro 2013):

$$Overall\ FCC = \frac{Number\ of\ vegetation\ points > 1.5m\ high}{(Number\ of\ vegetaion\ points > 1.5m\ high + number\ of\ ground\ points)}$$

The exclusion of vegetation <1.5m had the unintended consequence of inflating tree canopy cover in places with dense low understorey (e.g. among thick blackberry infestations or in swampy areas dominated by sedges and reeds). In these places there are fewer LIDAR reflections from the ground because the laser is blocked by the thick understory that is subsequently excluded. For example, a site with 10% tree cover, 90% sedges <1.5m and no bare ground would be recorded as FCC 100%

once the sedges are excluded. The correct FCC calculation includes ALL LiDAR points as the denominator to capture the low understory:

$$Overall\ FCC = \frac{Number\ of\ vegetation\ points > 1.5m\ high}{(All\ LiDAR\ points)}$$

This calculation was applied to the 2010 ISC data so that FCC could be compared to the data supplied in 2018-20.

Changing the calculation of Height Interval FCC (vegetation strata)

Vegetation strata are quantified in 5m height bands to inform calculation of the ISC Streamside Zone Structure 1 and Structure 2 metrics. The strata were quantified for the ISC using a formula that Fugro (2013) label as "Height Interval FCC":

$$Height\ Interval\ FCC = \frac{Number\ of\ vegetation\ points\ in\ height\ class}{(Total\ Number\ of\ vegetation\ points > 1.5m\ high)}$$

The name "$Height\ Interval\ FCC$" is a misnomer because the ratio is the *proportion* of the canopy that is present in each height interval and is not a measure of fractional canopy cover. For example, shrubs are classified as a single height stratum class (1.5 to 5m). A location with very sparse shrubs shading 5% of the ground area, and no other vegetation present, will have a Fractional Canopy Cover of 5%. The same location will have a Height Interval FCC of 100% because the formula only considers the vegetation and excludes the 95% bare ground (the denominator of the formula does not include the ground points). The correct interpretation is that *of the small amount of vegetation that was present (<5%)*, the foliage was proportionally distributed in the one height class (1.5-5m). This will always be the case for shrubs by definition

Complicating matters further, Fugro (2013) present the logic for ISC3 Streamside Zone Structure1 and 2 as if the strata were indeed measuring fractional cover. They convert the strata rasters to binary maps of presence/absence using the rule that Height Interval FCC < 20% = absent and Height Interval FCC ≥ 20% = present. This creates a bias against taller trees that have their canopy distributed over several height classes and inevitably some will contain less than 20% and be excluded. Shorter trees and shrubs with all their canopy in one height class (Height Interval FCC =100%) will never be excluded.

The interpretation of the vegetation strata is greatly clarified by recalculating the Height interval FCC for all regions as true fractional cover using an approach that is consistent with the Overall FCC above and matches the LiDAR survey data supplied in 2018-20:

$$Height\ Interval\ FCC = \frac{Number\ of\ vegetation\ points\ in\ height\ class}{(All\ LiDAR\ points)}$$

The raster maps for each height class can then be interpreted more simply as representing the density of the canopy (fractional canopy cover) within each height class. The data has an added utility that summing all the Height Interval FCC provides the same value as Overall FFC and the proportion of canopy in different height classes can be calculated if required:

$$Height\ Interval\ Proportion = \frac{Height\ Interval\ FCC}{Overall\ FCC}$$

The revised formula for Height Interval FCC represents the industry standard for representing fractional canopy cover and the 2018-20 data was supplied using this approach. To facilitate a reliable assessment of change between the 2010 and 2018-20 data it was necessary to recalculate the FCC for 2010 using this new formula so that both time periods represented vegetation cover in the same way.

Figure 6 Illustration of fractional canopy cover in the six different height interval classes (left panel), and example showing the distribution of different height classes at the Ovens River (right panel).

3.3 Vector maps

The 2010 ISC3 used manual interpretation of aerial photography and the LiDAR DEM to digitise the position of the river banks. This task was labour intensive and prone to error in locations where the banks of the river were difficult to discern. To improve repeatability of river mapping, DELWP commissioned the CRC for Spatial Information (now FrontierSI) to develop automated river mapping tools. The “Riverlines Toolkit” (RLT) uses the 1m digital elevation model (DEM) along with other data layers derived from the LiDAR point cloud (e.g. ground slope, “no data” areas that may represent water) and attempts to map the river channel and bank lines.

The RLT was applied to map the river channel using both the 2010 and recent LiDAR re-capture. The RLT methods still required substantial manual checking and interpretation and it was not possible to fully automate the mapping of the channel. Instead, a subset of the tools was used to develop a semi-automated workflow to automate the production of a draft streambed that was then manually adjusted to:

1. remove unwanted tributaries and anabranches and areas of “spill” where the automated process mapped adjacent areas outside of the channel.
2. fill gaps where the RLT missed areas of riverbed that were evident in the aerial photography.

To map the river bed, the RLT uses the increase in slope from the bed of the river to the banks to identify the potential bottom (toe) of the river bank. The DEM is levelled (to remove the upstream-downstream slope) and digitally filled (as if filling a bathtub with water) to find the inflection point where the rate of increase in the surface area of the channel slows indicating the “water” has reached the toe of the bank and is not spreading laterally across the bed. The output from the RLT is a raster map of the river bed (Figure 7).

Figure 7 Example showing the river bed mapped from the DEM (photo shown in Figure 4).

The difficulty in automating the streambed mapping was related to artefacts in the DEM caused by artificially high points along the bank. These high points occur where LiDAR reflections from the canopy of dense riparian vegetation are miss-interpreted as ground points. Triangular artefacts in the river channel of the DEM (Figure 8) occur where the DEM is interpolated across the channel to fill gaps in the data where water absorbed the LiDAR laser pulses. A process was developed to flatten the water surface, but this was not successful in all cases and some manual editing was still required.

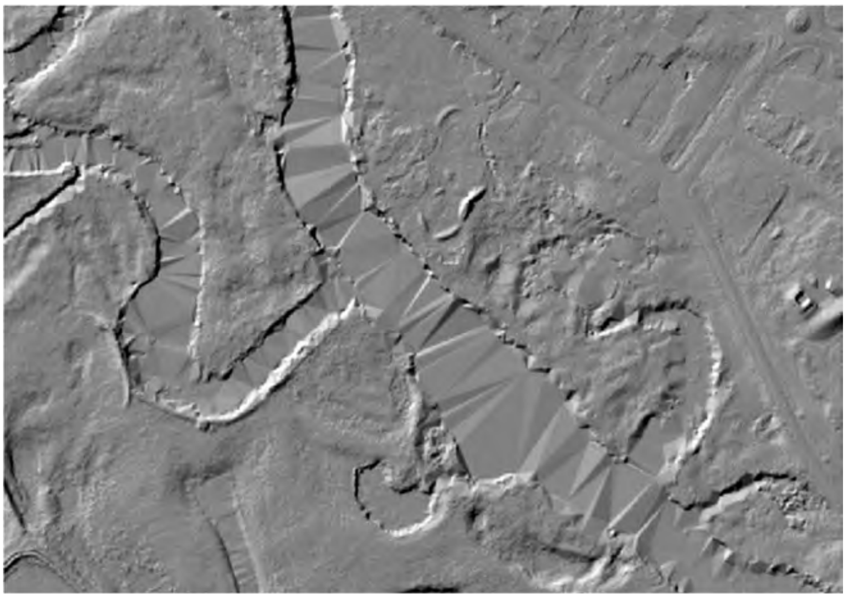


Figure 8 Triangular artefacts in the river channel in the DEM are caused by interpolation across the water from artificially high points on the bank where LiDAR is measuring the canopy of dense vegetation and not the ground.

The margins of the streambed are used to create a vector line map of the toe of the bank. The mid-point of the streambed is mapped as the centreline (Figure 9). The bank toe and centrelines are divided into ISC reaches and then further divided into 100m sections which are labelled with unique ISC identifiers using the river basin number, reach number and section numbers (Figure 9). This project replicated all ISC3 Streamside Zone vector data products required for the riparian assessment (Table 2). Riparian vegetation can then be assessed for each section at varying buffer widths from the toe of the bank to accommodate different user needs delineated as 10m, 15m, 20m, 30m and 40m buffers. This differs from the ISC3 2010 which calculated all riparian metrics for a single 40m buffer width in all areas. Sections are aligned with the 100m ISC3 centreline sections (20m and 40m buffer widths shown in Figure 9). In this report, results are summarised using a buffer width of 40m to coincide with ISC3. It is possible that conclusions around the level of change that has occurred between sampling periods will vary based on the selection of a particular buffer width (see Section 4.4).

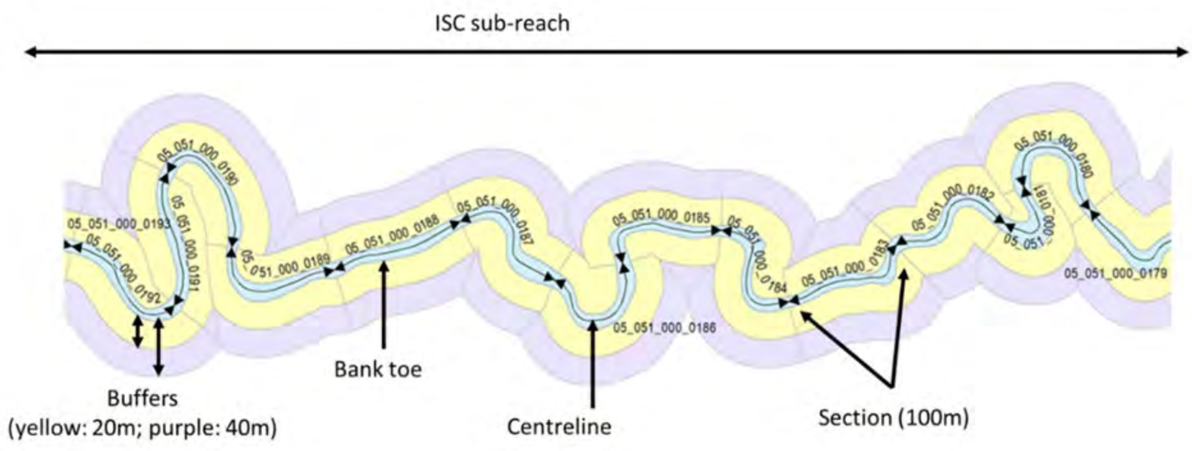


Figure 9 Vector data products for a section of an ISC sub-reach, derived from the streambed (blue) include the centreline divided into 100m sections, with buffers of different width extending from the toe of the bank.

Table 2 Comparison of vector data products that were generated for the ISC3 Streamside Zone and the SCA project

Vector Product	ISC3	Stream Change Assessment
Centreline (Reaches)	✔	✔
Centreline (100m sections)	✔	✔
Toe of bank (Reaches)	✔	✔
Toe of bank (100m sections)	-	✔
Streambed Width	✔	✔
Vegetation Width	✔	✔
Streambed Transects	-	✔
Riparian Assessment Areas (10m, 15m, 20m, 30m and 40m)	-	✔
Thiessen_Regions (template to generate assessment areas)	-	✔
Fragmentation	✔	✔
Vegetation Overhang	✔	✔
Large Trees	✔	✔
Vegetation Cover	-	✔
Bankfull Width (Reaches)	✔	-
Channel Transects (Bankfull)	✔	-
Top of bank (Reaches)	✔	-
Bare Ground	✔	-
Water Bodies	✔	-

3.3.1 New riparian buffer assessment area boundaries to support change assessment

Measuring change between two assessment periods requires comparable data and consistent methods so that observed differences can be attributed to environmental change and are not an artefact of different methods used. Given the changes to the vegetation FCC data (section 3.2.1 above) it was necessary to recalculate all of the ISC3 2010 vegetation metrics. The was not immediately possible because the 2010 ISC3 Streamside Zone process generated the 100m section x 40m buffer assessment areas “on the fly” as part of the scripted calculation of metrics and a published vector product was not published (Table 2). To ensure the change measurements in 2010 and 2018-20 were comparable required generating new assessment areas for both 2010 and the contemporary data to ensure the regions were generated the same way for each assessment period. This provided the opportunity to include multiple buffer widths to suit different policy settings and to retain the assessment area mapping, enabling the riparian metrics to be spatially aligned to other data layers (e.g. land use and riparian management within the riparian buffer or other remote sensing data) The template that divides the riparian buffer into 100m sections is saved as a vector data product (Thiessen_Regions) that allows buffers of any width to be constructed using the correct coded reach and section identifiers.

The ISC3 identifier attributes were mapped across to the 2018-20 assessment areas but due to channel migration and subtle changes in the centreline position the individual sections vary from the nominal 100m length in 2018-20. In places where there was substantial channel movement and section end points moved more than 30m a new section identifier was allocated. Section identifiers therefore are not always in sequential numerical order from one end of the reach to the other. A position counter and start and end measurements along the reach length were added to clarify the position of each 100m assessment section.

3.4 Calculated metrics and ISC Streamside Zone scores

The complete array of riparian metrics (except weeds – see section 3.4.1) generated for the 2010 ISC3 were recalculated using the new assessment areas and revised FCC data derived from the 2010 LiDAR capture and the new capture in 2018-20 (Table 3). The updated 2010 data set provides a baseline from which to measure change with increased confidence in the data due to corrections made to the underlying cover data and simplified interpretation of the vegetation height strata informing the metrics. These improvements will ultimately be extended to the remainder of the ISC network as more LiDAR capture is undertaken to assess future changes in other reaches and catchments. Importantly, there is now a standard set of tools and assessment areas that can be used to compare different LiDAR capture dates maximising the inference that observed differences can be attributed to measured environmental change.

Table 3 Outline and brief description of riparian metrics used in the ISC3 assessment. For full methods description of these see Fugro (2013). Metrics were calculated from the bank toe outwards. Results are presented in this report for fractional canopy cover, canopy height, vegetation width and fragmentation; other metrics were used in the calculation of ISC Streamside Zone scores but not presented.

Metric	Brief description of methods and spatial resolution
Fractional canopy cover (FCC)	• Measures the average density of vegetation in each riparian assessment area using the LiDAR FCC raster (Figure 4)
Canopy height (m)	• Measures the average canopy height in each riparian assessment area using the LiDAR CHM raster (Figure 4)
Vegetation width (m)	• Defined as the distance from the toe of the bank to where the overall FCC is less than 20% or the riparian vegetation edge is met • Measured perpendicular to the stream channel every 25m along the centreline and up to a maximum distance of 200m (Figure 10) Each 100m section on the left and right bank is assigned the mean length of the vegetation width transects that originate in that section (nominally 4 transects but may be less on the inside of sharp bends)
Fragmentation (%)	• Represents gaps in vegetation cover • Defined as any areas where Overall FCC is less than 20% for an area of least 10m x 10m (essentially the white-space in Figure 10) • Measured in each 100m section as the proportion of the assessment area that is classified as gap
Overhang (%)	• Represents shading of the river bed • Calculated as the proportion of the toe of bank line that is overlapped by woody vegetation with FCC > 20%
Large Trees (%)	• The canopy area of large trees is mapped by recording contiguous areas of vegetation with FCC > 20% with minimum crown height and diameter determined from EVC benchmarks (lookup table in Fugro 2013) • Calculated as the proportion of the section that is defined as “Large Tree Canopy” (Figure 11)
Structure 1 (Trees and Shrubs)	• Uses the vegetation FCC in two height classes. • Shrubs are defined as the vegetation < 5m in height • Trees are the vegetation >5m in height • Calculated as the average FCC for each height class within each 100m section
Structure 2	• A structure 2 raster layer is created where each 2m x 2m pixel represents a count of the number of strata layers with FCC > 20% • Stratum layers are defined in 5m increments as <5m, 5-10m, 10-15m, 15-20m, 20-25m, 25m-99m • Calculated as the average Structure 2 pixel value within each 100m section (Figure 12)
Weeds (Willows and Hawthorn)	• Woody weeds were mapped for the 2010 ISC as line features representing the longest width of the weed patch. • The weeds metric is the mapped length of weeds as a proportion of the 100m section length

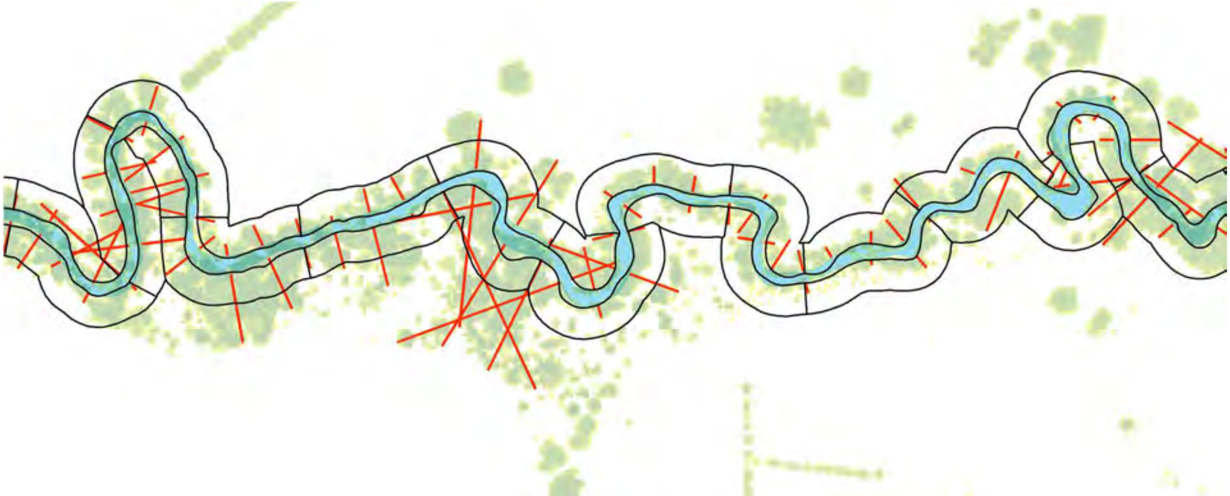


Figure 10 The woody riparian vegetation FCC (green) is used in combination with the vector line mapping to generate metrics. Vegetation width is shown in red. Vegetation overlapping the streambed maps overhang, vegetation overlapping the area for riparian vegetation assessment is used to map cover, height and structure, and the gaps between the vegetation map fragmentation.

Figure 11 Large Trees are shown as hashed areas over the LiDAR CHM. This area of King Parrot Creek is Floodplain Riparian Woodland (EVC 56) where large trees are defined as having a minimum height of 20m and minimum crown area of 400m^2 (20m x 20m).

Figure 12 The Structure 2 metric is the count of 5m height classes present with FCC > 20%.

Using the derived metrics as the inputs, the ISC Streamside Zone sub-index score was calculated for each 100m section using the scoring tables in DEPI (2014) and Fugro (2013). ISC scores for Structure1 and Structure2 metrics rely on information about Ecological Vegetation Classes (EVCs) and are based on the difference between measured values and expected values that are calculated from EVC reference areas specific to each CMA region. Given the changes to the 2010 baseline FCC vegetation data it was necessary to calculate new EVC reference values for the different metrics. Reference areas for each EVC are mapped in the 2010 ISC3 data set as areas with minimal disturbance within each CMA with much of the reference area located outside of the 2018-20 capture area. New 2010 reference values were calculated for each metric by first calculating Structure1 and 2 metrics for all reference reaches within each CMA region, then averaging the metric values from all 100m sections within each EVC reference area.

The average of the ISC Streamside scores from all 100m sections on both banks was used to calculate the ISC Streamside Zone sub-index score for each ISC reach.

3.4.1 Differences compared to the 2010 ISC3 Streamside Zone metrics

All metrics were calculated within the riparian buffer assessment areas to represent each 100m section on the left and right bank. Reach averages were then calculated as the average of all sections along a reach and this was repeated for the different buffer widths (10m, 15m, 20m, 30m and 40m). This differs from the 2010 ISC3 calculations which generated some metrics in “EVC seed polygons” at the ISC reach scale. The ISC3 approach copied the one result from each EVC seed polygon to all 100m sections that intersected the polygon. EVC seed polygons are sometimes many km in length and the single aggregated metric may not be a good representation of the riparian conditions at a particular location along the length of the reach.

Woody weeds (willows and hawthorn) were not re-measured in 2018–20. The woody weeds mapping for the ISC3 Streamside zone metric 2010 was done through visual interpretation of the aerial photography and image analysis that was not repeated for the current project. The weeds metric represents the proportion of the bank length that is represented as woody weeds in the mapping layer. To enable the development of the necessary processing tools and calculation of metrics needed to generate ISC Streamside Zone scores for the most recent assessments, 2010 woody weed data were used. This assumes no change in woody weeds between assessment periods – which is reasonable in many cases but incorrect in others, particularly where woody weed removal has been undertaken. It is possible for CMAs to adjust the woody weed metric scores in individual sections to reflect changes in known areas of woody weed management and/or expansion of woody weeds since 2010 until such time that more detailed woody weed surveys are available.

As described in section 3.2.1, the Height Interval FCC data used to map vegetation strata were recalculated to represent the fractional cover of vegetation within each stratum instead of the proportion of canopy present. These data sets are then used to measure the ISC3 Streamside Zone Structure 1 fractional cover of shrubs (1.5m - 5m in height) and trees (>5m in height) and the Structure 2 (count of vegetation strata present). The methods for calculating these metrics are as described for the ISC3 by Fugro (2013) but as each stratum is now represented as fractional cover and not proportion of canopy the resulting metrics will differ from that reported in ISC3.

3.5 Do differences in processing change the 2010 ISC3 Streamside Zone scores?

The 2010 ISC3 LiDAR capture was suitable for its purpose of supporting spatial comparisons in river condition but not for comparing vegetation change through time. A significant component of the SCA project was therefore to generate a revised 2010 baseline to allow repeatable comparisons of riparian vegetation over time. This was done via a combination of reprocessing LiDAR inputs, data processing and aggregation at different spatial scales (100m sections versus entire ISC reaches), and recalculation of metrics (especially Structure 2).

The primary focus of this report is on describing vegetation change using some of the underlying metrics from the ISC. However, Streamside Zone scores were also calculated both to provide a link between the SCA and ISC but also to explore if the methodological differences between the original and re-generated 2010 dataset result in changes in these scores. Identifying these changes is important given the ISC Streamside Zone Scores are used by CMAs to help prioritise locations for riparian management.

To examine if reprocessing the 2010 data lead to differences in ISC Streamside Zone Scores, scores were calculated twice, one using the original data and again using the reprocessed data. Differences between scores and underlying metrics (Table 3) were calculated, with the latter providing information about which metrics might be driving differences in scores.

Streamside Zone Scores and metrics were recalculated for 141 ISC reaches. In summary, the differences in processing had no or negligible impact on the ISC Streamside zone score in most reaches. For 56% (79 of 141) reaches, the ISC Streamside Zone Score was identical between the reprocessed and original data. Where there were differences between scores, these were greater than one scoring unit at only 5% (8 of 141) of reaches (Figure 13).

The Structure 2 metric (Table 3) is the metric causing most of the differences in scores, which was expected because the revised method (described above) records a greater number of vertical height classes (canopy strata) because it does not exclude the strata that contain <20% by proportion of the canopy as the original method did. Only 12% of reaches had identical Structure 2 scores, and scores differed by more than one and two units at 60% and 22% of reaches respectively. In comparison, for the six other metrics that contribute to the Streamside Zone score (Table 3), most reaches (65-90%) had identical scores and nearly all reaches that did change only differed by less than one unit.

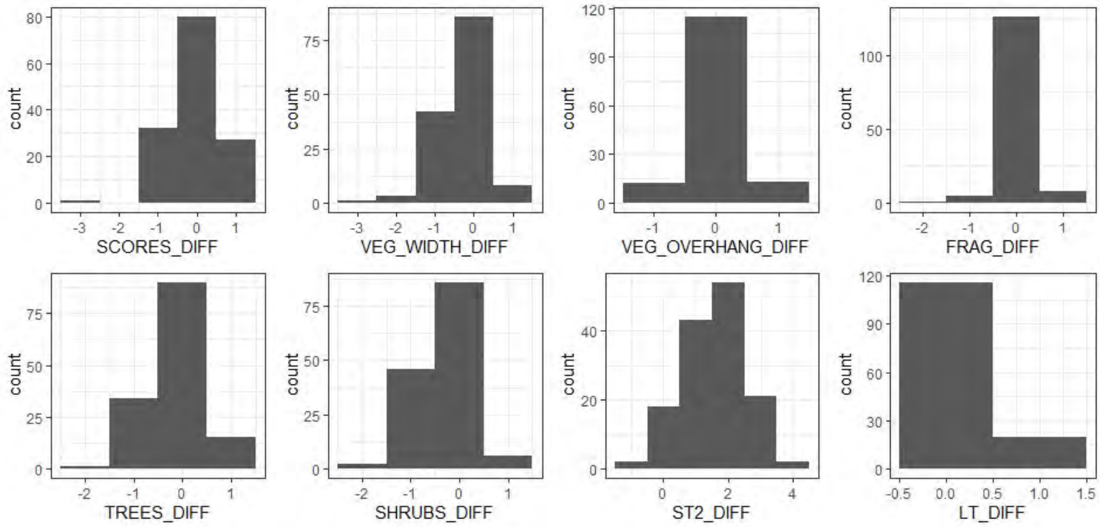


Figure 13 Illustration of how differences in calculation of metrics (at 141 ISC reaches sampled for the SCA) have altered Index of Stream Condition Streamside Zone Scores (Scores_diff) and seven metrics (Vegetation width, Vegetation overhang, Fragmentation, Tree cover, Shrub cover, Vegetation structure, Large trees; see Table 3 for details). The x-axis shows the difference as re-processed value – original ISC 2010 value; the y-axis shows the count of number of ISC reaches.

3.6 Describing changes in riparian vegetation

The evaluation of change in riparian vegetation was restricted to sections that overlapped by more than 50% between time periods to ensure that metrics calculated for each time period were representing enough of the same patch of vegetation. For example, there was little lateral movement of the channel along King Parrot Creek shown in Figure 14 and the sections from 2010 and 2018 overlapped almost completely (by 85-97%). Observed changes in the vegetation metrics are therefore likely to represent changes in the vegetation, not changes in sampling area. In total, less than 2% of the nearly 65000 sections where LiDAR was captured were excluded from the results summaries due to overlap of <50% (Appendix Table 9).

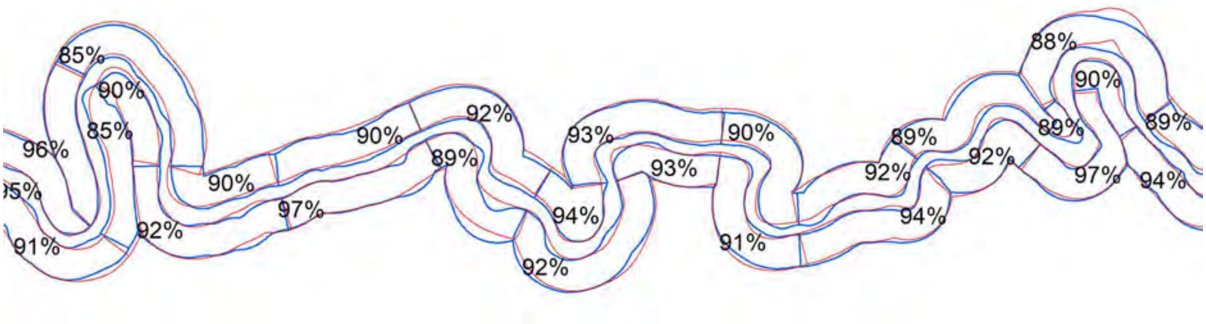


Figure 14 Percent overlap in sections between 2010 (blue) and 2018 (red) for a section of King Parrot Creek shown in Figure 4.

Three pieces of information are presented in the results section of this report to visualise and evaluate changes in riparian metrics. First, histograms are presented showing the distribution of values for each vegetation metric in each of the two assessment periods. For instance, in Figure 15, data from 1000 hypothetical “sections” (i.e. analogous to the 100m sections shown on each river bank in Figure 14) shows vegetation width in Time 1 (blue) and Time 2 (green). We can see that while there is overlap in the two histograms between the two time periods, in Time 2 many of the sections have a greater vegetation width (note green sections above ~30 m versus blue sections below ~30 m). This provides a visual representation of the data from each time period, providing one way to quickly evaluate changes of interest.

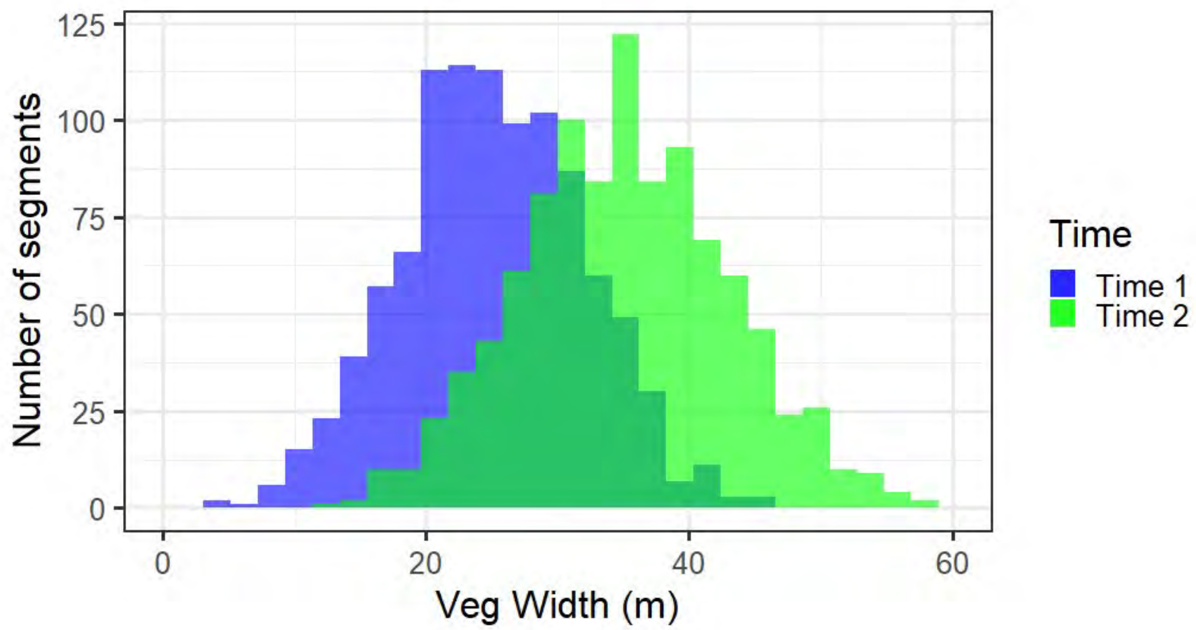


Figure 15 Histograms showing summary of vegetation width at 1000 hypothetical sections in two times.

Second, the percentage of sections that increased, decreased, or did not change, between assessment periods are presented. For each section, the difference between assessment periods was calculated for each vegetation metric i.e. metric value in period 2 – metric value in period 1. The percentage of sections that increased (i.e. difference over time > 0), decreased (i.e. difference over time < 0) and did not change (i.e. difference over time = 0) was then calculated at the state- and CMA-region scale. To examine changes at the ISC-reach scale, the mean of all the section-level differences between assessment periods within each of the 141 reaches was calculated. For example, a reach with 200 sections will have 200 replicate values of the difference between assessment periods whereas a reach with 500 will have 500 replicate values. The percentage of the 141 ISC reaches were each vegetation metric increased (mean change > 0), decreased (mean change <0) or did not change was then calculated.

To be consistent with the ISC3 methodology, Streamside Zone scores needed to be compared at the ISC reach scale. For each section, the difference over time was calculated as for vegetation metrics (i.e. Score in assessment period 2 – Score in assessment period 1). The mean at the ISC reach scale was calculated. Each reach was then categorised as having increased (difference in score between assessment periods > 0), decreased (difference in score between assessment periods < 0) or remaining unchanged.

This provides a broad summary of the frequency of increases and decreases but does not consider the magnitude of these changes (i.e. if a section has increased this summary doesn't indicate whether the change was large or small). To illustrate the magnitude of change, the mean change between the two assessment periods is also presented.

Using the data from the hypothetical sections presented in Figure 15, vegetation width increased at 82% of sections in Time 2, and on average, this was a 10% increase.

Table 4 Example of presentation of data showing percentage of sections that decreased, increased or did not change.

Location	% sections decreased	% sections no change	% sections increased	Section Mean change (%)
ISC Reach	18	0	82	+10

Third, the change in the percentage of sections within particular threshold values was calculated. This provides a quantitative assessment of change for a given threshold of interest (these could conceivably be recalculated based on any threshold/s of interest in addition to those provided here). For example, the percentage of sections with >20m vegetation width at Time 1 and in Time 2 were calculated separately, and then subtracted to find the difference (i.e. % of sections > 20m veg. width in Time 2 - % sections > 20m veg. width in Time 1).

Using the same data presented in Figure 15 we can see (Figure 16) that 76 of sections had vegetation width >20m in Time 1, and 97% of sections >20m in Time 2 i.e. an increase of 19%. If we instead consider the percentage of sections with a vegetation width >40m, we can see that this represented 2% of sections in Time 1 and 27% of sections in Time 2, which is an increase of 25%.

Histograms similar to Figure 15 are presented in the results below. Data describing the percentage of sections that increased or decreased, the mean change, and change relative to different thresholds were tabulated following the structures of Table 4 and Table 5 and are provided as appendices for all metrics at all ISC reaches.

	>10m	>20m	>40m
% Segments above threshold (Time 1)	97	76	2
% Segments above threshold (Time 2)	100	97	27
% change Time 1 to Time 2	+3	+19	+25

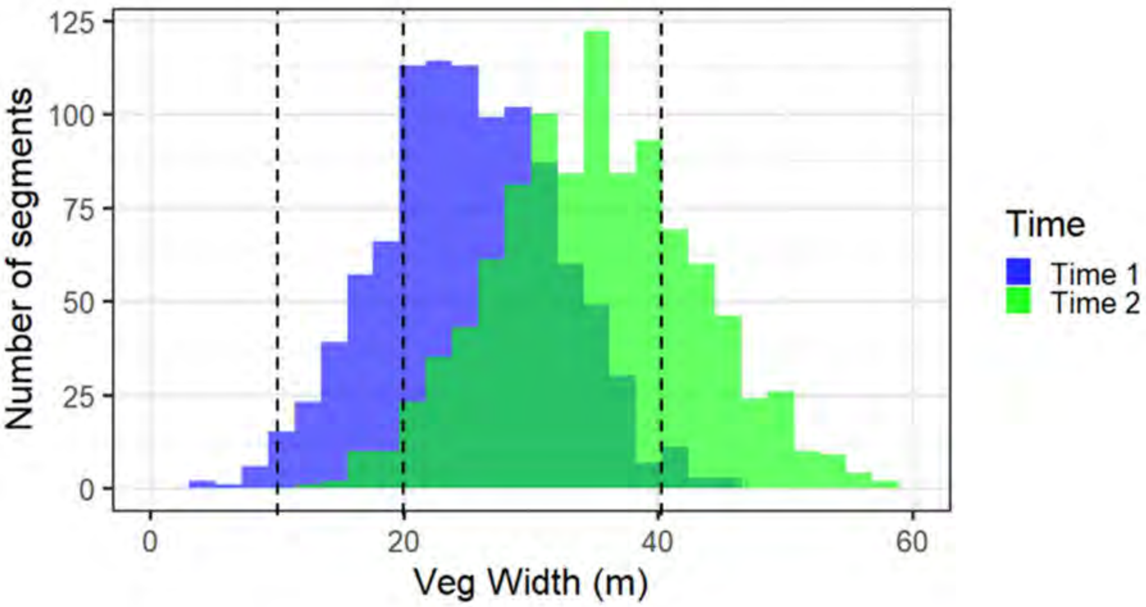


Figure 16 Histograms showing summary of vegetation width at 1000 hypothetical sections at Time 1 and Time 2. The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above these thresholds.

Table 5 Example of presentation of data showing % change in sections above different vegetation width thresholds

	Vegetation width thresholds (m)		
Location	**>10m**	**>20m**	**>40m**
ISC Reach	3.0	19.0	25.0

For vegetation width, a threshold of 20m was used as the Victorian Waterway Management Strategy (DEPI 2013) outlines the aim for riparian fencing to be at least 20m wide on average from the top of the bank. This value was used for vegetation width given its management relevance, noting that calculations of width from the captured LiDAR data were actually from the toe of the bank. The percentage of sections above 10m and 40m width were also calculated.

In the absence of any strong rationale for the remaining metrics a range of thresholds were used that represent the spread of values based on preliminary evaluations of the data. These were:

- Fractional canopy cover: 20, 40, 60 and 80% cover
- Canopy height: 2, 5 and 10m
- Fragmentation: 25, 50, 75 and 90% cover
- Vegetation width: 10, 20 and 40m

Calculations for changes in all metrics in relation to these thresholds (calculated for the 40m buffer assessment area) are provided in Table 12 in Appendix A. Representative examples are presented using the thresholds to illustrate key differences throughout the results.

4. Results

4.1 State-wide summary

When data from across the state are considered collectively, the overall patterns are subtle (Figure 17). ISC Streamside Zone scores remained unchanged at 81% (114 of the 141 assessed ISC reaches), increased by 1 unit at 18% (26 reaches), and increased by two units at one reach. 17 of the ISC reaches where scores increased were in either East Gippsland (7) or West Gippsland (10) regions, four were in the Mallee, three were in the Goulburn-Broken and one was in each of the Corangamite, North Central and Wimmera regions.

Looking at the underlying metrics:

- Fractional canopy cover increased at 69% of sections and decreased at 28%; the mean overall change was an increase of 3% (Figure 18).
- Canopy height increased at 76% of sections and by approximately one metre on average.
- Fragmentation decreased at 68% of sections and by ~4% on average
- Vegetation width increased at 60% of sections and by ~4m on average.

It is important to note that cover of woody weeds was not recalculated in the second period – the results from the ISC3 2010 assessment were reapplied to the more recent assessment. This has implications for interpreting any observed changes. For example, a decrease in Streamside Zone Score between assessment periods could be the result of woody weed management - the reduction of cover and height which in this case is a desirable outcome. The woody weed component of the Streamside Zone Score could feasibly be recalculated but requires labour and time-intensive manual interpretation of aerial photography. Reliable spatial data on woody weed management between the two time periods is also a source of data that can be used to aid interpretation of results.

Substantial changes in riparian vegetation were not predicted or observed at the state-wide scale. One reason for the small changes at the state-wide scale is because changes in riparian vegetation are likely to occur over a longer time interval than the eight-ten years between sampling periods. Riparian vegetation can vary at a range of scales, from the very small (i.e. plant growth at the scale of less than metres) to very large (i.e. in relation to physiography or weather conditions). This means that when data are aggregated at reaches across the state, increases at some are likely to mask decreases at others, meaning that substantial changes are only likely if there's systematic change in the same direction. It is also important to note that LiDAR was recaptured at reaches for a range of reasons, so results should be viewed through expectations of change in a local context, based on whether or not management was undertaken along a reach (its timing extent and quality) or the influence of disturbances such as floods, drought and bushfire.

Given the relatively minor changes observed at broad spatial scales in this assessment it is reasonable to be confident that the ISC3 2010 benchmark continues to provide a contemporary estimate of riparian 'condition' at the ISC reach scale. Where data weren't recaptured in 2018-20, the ISC3 2010 Streamside Zone score and underlying metrics, coupled with information on management effort, will provide DELWP and CMA regions with reliable information to inform their plans and strategies.

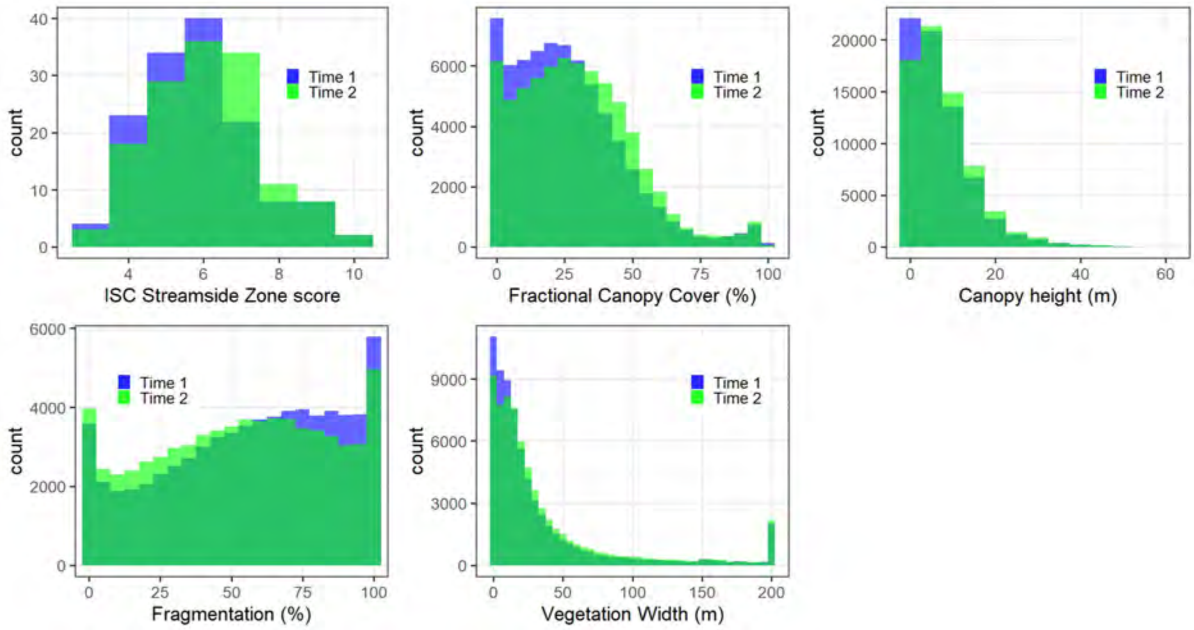


Figure 17 Changes in Streamside Zone ISC scores and the five riparian vegetation metrics at CMAs sampled across the state. The count on the y-axis is the number of ISC reaches for the ISC Streamside Zone score panel and the number of sections for all other panels.

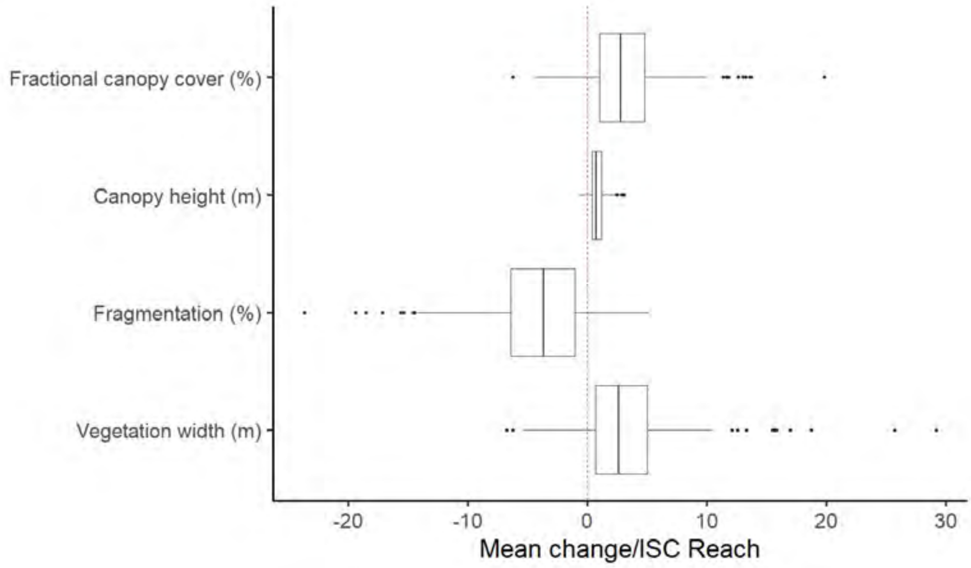


Figure 18 Summary of changes in vegetation metrics across the state. The change in each vegetation metric was calculated (i.e. metric value in Time 2 – metric value in Time 1) at each section, and then the averages of these sections taken at each ISC reach.

4.2 Regional summary

CMA regions differ broadly in terms of vegetation type, environmental context (e.g. rainfall, slope) and level and types of investment in riparian management. It is therefore likely that the magnitude and extent of riparian change might vary among regions.

Streamside zone ISC scores

Streamside Zone ISC scores were unchanged at 100% of ISC reaches in two regions (Glenelg-Hopkins, and North-East), at more than 80% of reaches in four more regions (Corangamite, Goulburn-Broken, North-Central and Wimmera), and at 70% of reaches in the Mallee (Table 6; Figure 19). Scores increased at 54% of reaches (7 of 13) in East Gippsland but by half a unit on average. Scores increased at 48% of reaches in West Gippsland (10 of 21), also by half a unit on average. The only reach in the state where the score increased by more than one unit was the Macalister River reach 8, with a two unit increase.

Woody vegetation metrics

While Streamside Zone scores did not change between assessment periods, some differences were observed among CMA regions in terms of changes in vegetation metrics (Table 7). For instance, canopy cover increased on average by between 5 and 7% at the two Gippsland regions, Goulburn-Broken region and the Mallee region (Table 7; Figure 20; Figure 23). Fragmentation decreased most significantly in the two Gippsland regions (Figure 21). In the East Gippsland region, fragmentation had decreased at 75% of sections and by an average of 8%. In the West Gippsland region CMA, fragmentation had decreased at 77% of sections and by an average of 9.5%. Canopy height increased at 66% or more sections at all CMA regions and at more than 80% of sections in the East Gippsland, Goulburn-Broken, Mallee, Wimmera and West Gippsland regions. The largest magnitude increases were observed in West Gippsland (1.6m), East Gippsland (1.2m) and the Goulburn-Broken regions (1.2m). Differences in rates of vegetation growth between regions as well as post-flooding recruitment events in northern regions are both likely to explain some of these patterns and are worthy of more detailed analyses.

More detailed analyses in the future will explore the potential drivers of these differences. However, preliminary work (Box 1) illustrates that spatial variability in vegetation change is likely related to variability in rainfall.

Table 6 Summary of changes in Streamside Zone ISC scores for nine catchments. The percentage of ISC reaches in each CMA that increased, did not change, or decreased is show, along with the average change across all ISC reaches in each CMA are shown.

Catchment Management Authority Region	Shift in Streamside Zone ISC3 score (% of ISC reaches)			Average change in Streamside Zone ISC score
	Increase	No change	Decrease	
Corangamite	4	96	0	0.04
East Gippsland	54	46	0	0.53
Goulburn-Broken	21	79	0	0.21
Glenelg-Hopkins	0	100	0	0.0
Mallee	31	69	0	0.3
North Central	7	93	0	0.10
North East	0	100	0	0.0
Wimmera	8	92	0	0.10
West Gippsland	48	52	0	0.53

Table 7 Summary of changes in riparian vegetation for nine CMA regions. The percentage of 100m sections in each CMA that increased, did not change, or decreased is shown for the fractional canopy cover, canopy height, fragmentation and vegetation width. The average percent change across all surveyed sections in each CMA is also shown.

CMA Region	Shift in fractional canopy cover (% of sections)			Average change in sections	Shift in canopy height (% of sections)			Average change in sections
	Increase	No change	Decrease		Increase	No change	Decrease	
Corangamite	58	3	39	1.2	67	3	30	0.4
East Gippsland	71	1	29	4.8	83	1	16	1.2
Goulburn-Broken	77	0	23	5.1	83	0	17	1.2
Glenelg-Hopkins	57	6	37	0.6	66	5	29	0.3
Mallee	91	1	8	6	82	1	17	1.1
North Central	73	2	26	2.5	77	2	21	0.7
North East	56	0	44	0.7	77	0	23	1.2
Wimmera	77	3	20	2.3	80	3	17	0.6
West Gippsland	74	1	25	7.3	85	1	14	1.6

CMA Region	Shift in fragmentation (% of sections)			Average change in sections	Shift in vegetation width (% of sections)			Average change in sections
	Increase	No change	Decrease		Increase	No change	Decrease	
Corangamite	39	5	56	-1.9	53	9	38	0.7
East Gippsland	25	0	75	-7.9	69	4	27	3.8
Goulburn-Broken	23	0	77	-6.3	67	2	31	6.8
Glenelg-Hopkins	48	0	52	0.1	45	15	40	-0.6
Mallee	21	0	79	-5.4	64	2	34	8.2
North Central	29	2	69	-2.8	58	7	35	2.8
North East	37	1	62	-2.2	59	1	40	4.8
Wimmera	22	1	77	-3.4	59	11	30	1.4
West Gippsland	18	5	77	-9.5	72	3	25	7.9

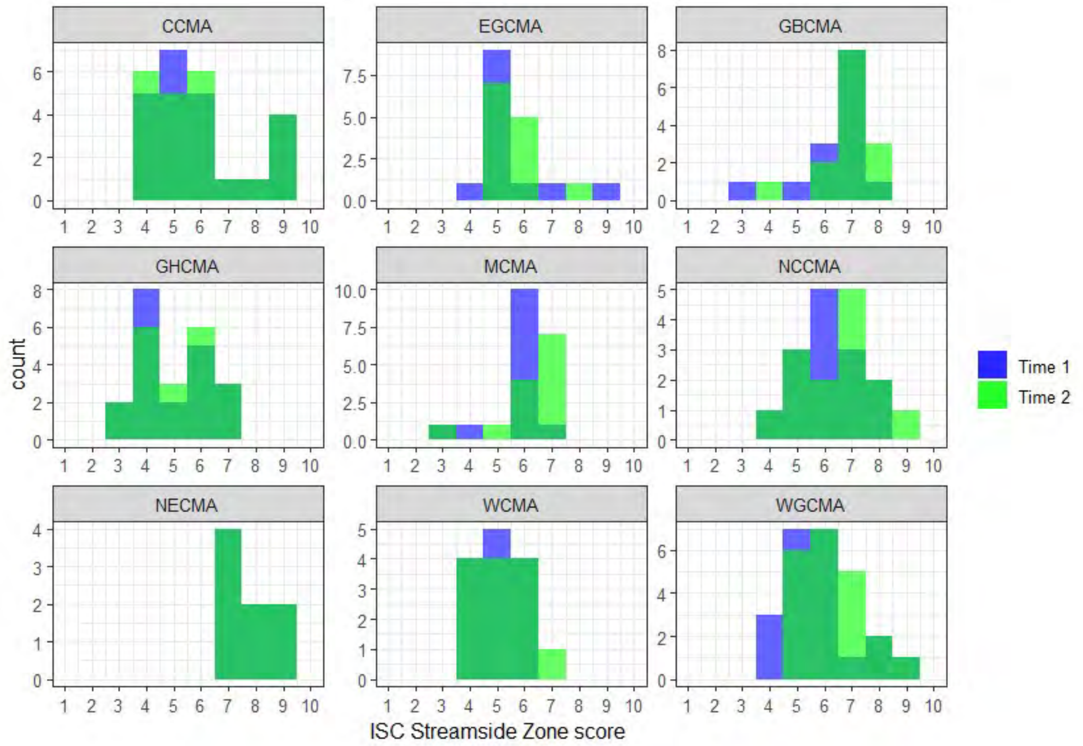


Figure 19 Changes in ISC Streamside Zone ISC scores across CMA regions. The count on the y-axis is the number of ISC reaches.

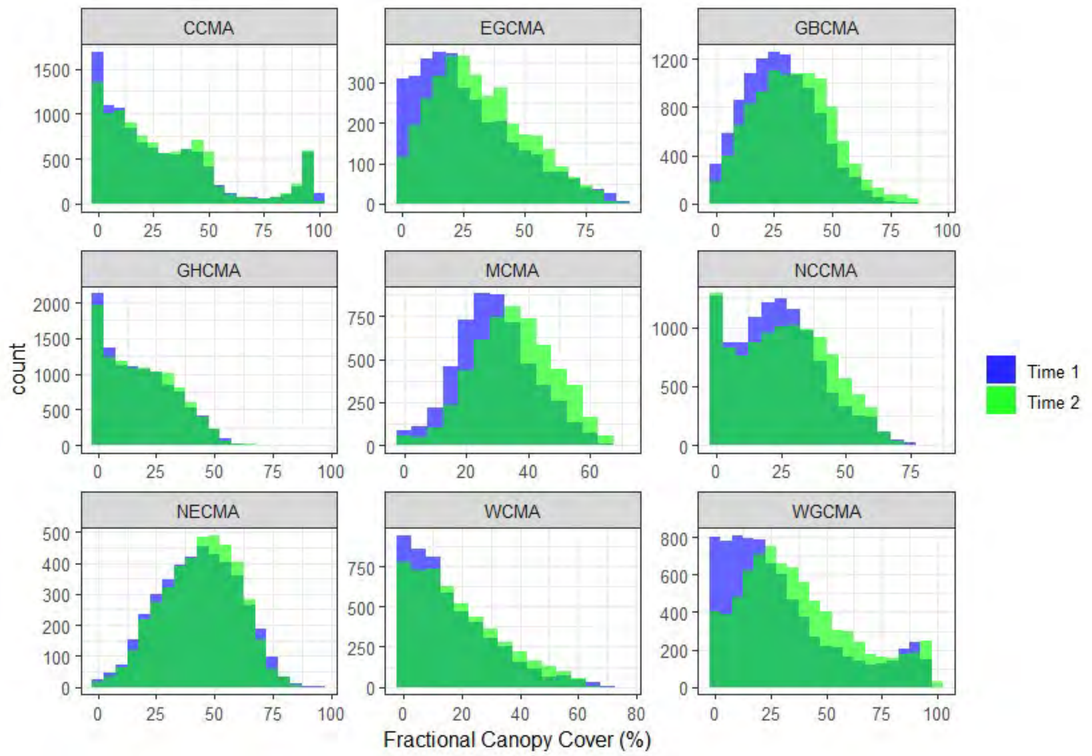


Figure 20 Changes in fractional canopy cover across CMA regions. The count on the y-axis is the number of sections.

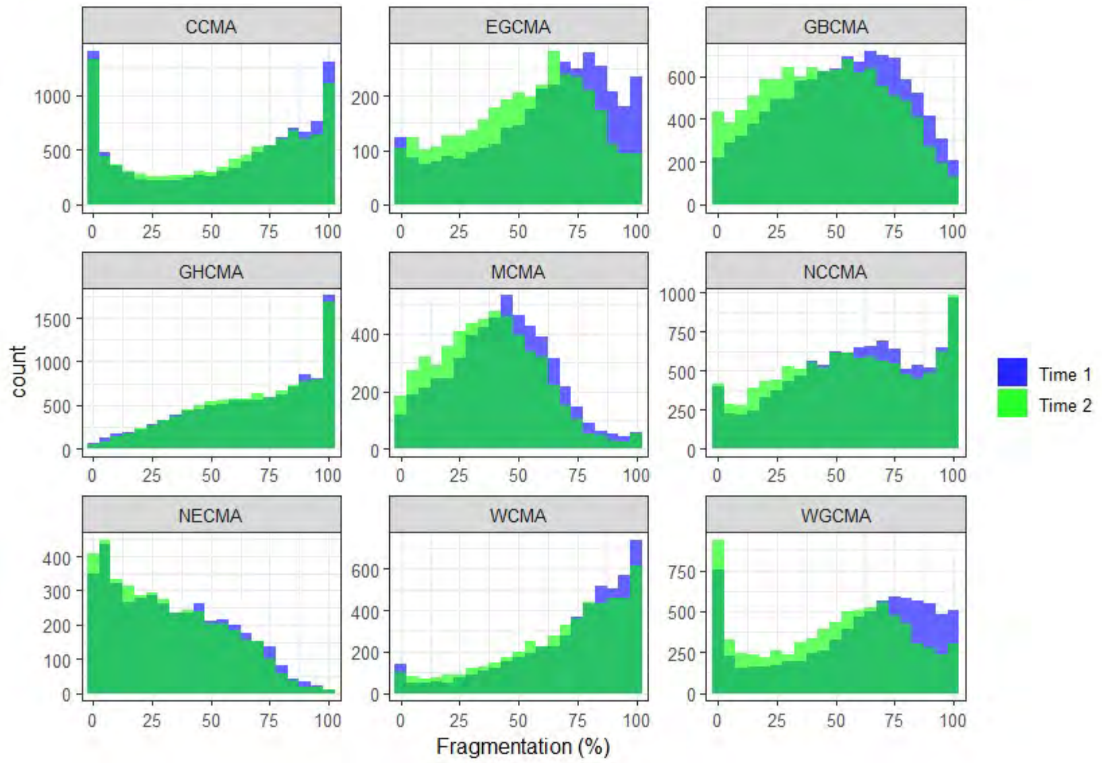


Figure 21 Changes in fragmentation across CMA regions. The count on the y-axis is the number of sections.

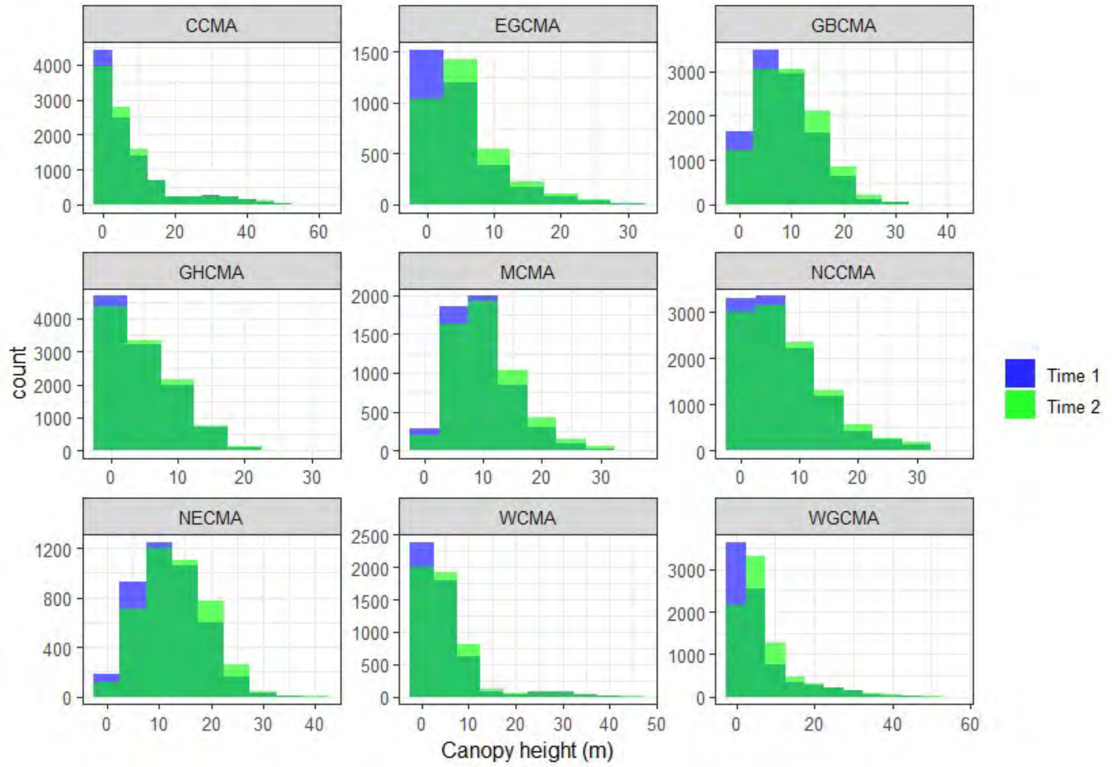


Figure 22 Changes in canopy height across CMA regions. The count on the y-axis is the number of sections.

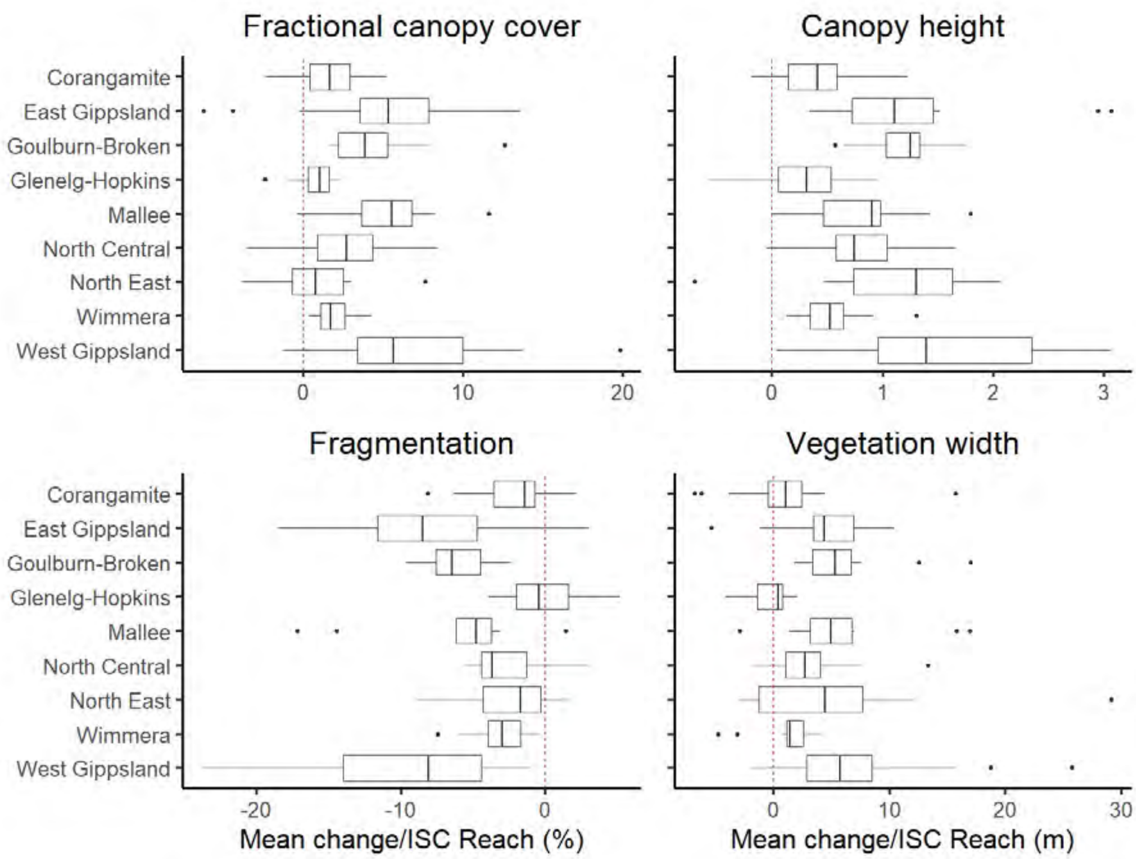


Figure 23 Summary of changes in vegetation metrics in each CMA region. The change in each vegetation metric was calculated (i.e. metric value in Time 2 – metric value in Time 1) at each section, and then the averages of these sections taken at each ISC reach.

Box 1: The likely influence of rainfall on spatial variability in changes in vegetation

Rainfall is likely to be one of the key determinants of woody vegetation growth. ISC reaches were dispersed across the state and in regions that vary in terms of rainfall (e.g. from wetter areas in Gippsland to drier areas in the northwest of the state). Preceding a full analysis exploring the drivers of changes in riparian vegetation, some preliminary work was undertaken examining the relationship between changes in canopy cover and rainfall.

Rainfall data were downloaded as raster layers with ~25km^2 grids from the Bureau of Meteorology Australian Landscape Water Balance model (http://www.bom.gov.au/water/landscape). These rasters were joined to a spatial layer with the centroid of each reach using QGIS. Rainfall data was downloaded for 2010-2018 and the median annual rainfall across this period calculated.

The aim was to examine if rainfall is a predictor of the maximum changes in riparian vegetation that might have occurred in response to management. Given this, ~40 reaches were selected where CMAs had provided information to indicate that significant riparian management had been undertaken (livestock removal and/or revegetation). For each ISC reach, a subset of sections where canopy cover had increased by more than 5% were selected and the mean change in canopy cover of these was calculated. The 5% cut-off was used as an estimate that was likely above the bounds of measurement error (e.g. smaller increases may be due to this rather than actual responses to management).

There was a positive relationship between the magnitude of increases in canopy cover and rainfall between the two assessment periods (Figure 24). Canopy cover increased by more than 10% at only one of 18 ISC reaches with less than 500mm annual rainfall, whereas it increased by more than 10% at all ISC reaches with more than 800mm rainfall.

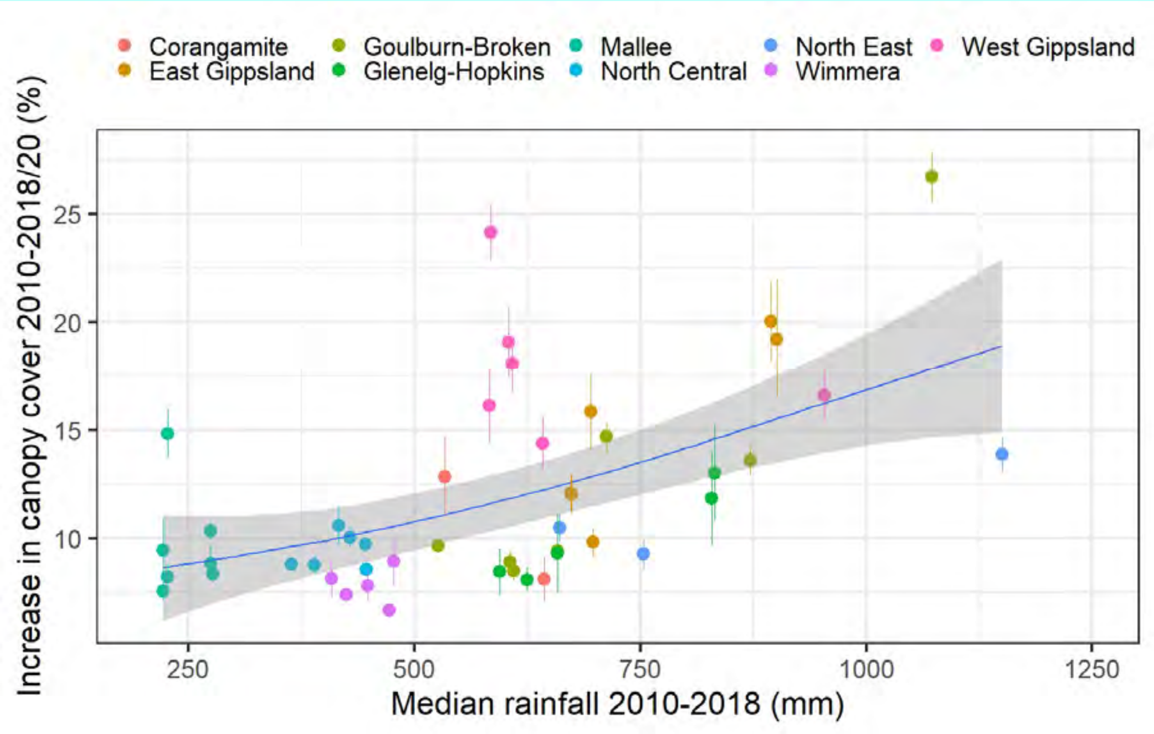


Figure 24 Relationship between increases in fractional canopy cover and rainfall at ISC reaches. Blue line and grey shading are mean and 95% confidence interval from a generalised additive model. Each point represents the mean increase in canopy cover at an ISC reach, with 95% confidence intervals. Only sections where 5% increase or greater were included in results.

4.3 Individual CMA regional summaries

4.3.1 Corangamite Region

For most ISC reaches in the Corangamite region, the two assessment periods were in December 2009 and January 2010 (Time 1), and again in 2019 (Table 9). Streamside Zone scores increased by one unit at Thompson Creek reach 37 but remained unchanged at all other reaches (Figure 25; Table 10).

Fractional canopy cover was higher at 18 of the 25 reaches in the Corangamite region (Figure 26; Table 11), although these changes were variable and typically small. The largest increase was at Sutherland Creek West Branch Basin reach 8, where canopy cover increased by 5%, and there was a 24% increase in the proportion of sections with canopy cover greater than 40% (Table 12). The largest decrease was at Moorabool River Basin reach 3, where canopy cover decreased by 2% overall, and 9% fewer sections had canopy cover greater than 60%. It is important to note that LiDAR capture at several reaches (such as Barwon River West Branch reach 6 and Barwon River East Branch reach 27) within the Corangamite region was undertaken in June, deliberately after willow leaf fall to ensure the channel was most visible and could be defined with greater reliability. As such, small decreases in canopy cover at these reaches may be attributable to differences in the timing of data capture.

Canopy height increased at 21 of the 25 reaches but the magnitude of these changes was very small (Figure 27; Table 11). The largest increases were observed at Aire River reach 56 (1.2m), Unnamed Creek reach 39 (0.9m), and Thompson Creek reach 37 (0.9m). The largest decreases were of small magnitude (<0.2m), and were observed at Aire River reach 28, Moorabool River East Branch reach 10 and Moorabool River West Branch reach 5.

Increases in vegetation width were observed a relatively small number of sections at some reaches (Figure 28; Table 11). For instance, at the Dewing Creek reach 25 and Thompson Creek reach 37 10% and 17% more sections had vegetation widths greater than 10m (Table 12).

Decreases in fragmentation (Figure 29, Table 10, Table 11) were also observed at a relatively small number of sections at some reaches. At the Dewing Creek and Thompson Creek reaches highlighted above, 15% and 18% fewer sections had fragmentation >75% in 2018.

Livestock removal and revegetation have occurred on Dewing Creek (see Box 2 below). However, changes in vegetation width and fragmentation were relatively small overall across the Corangamite region.

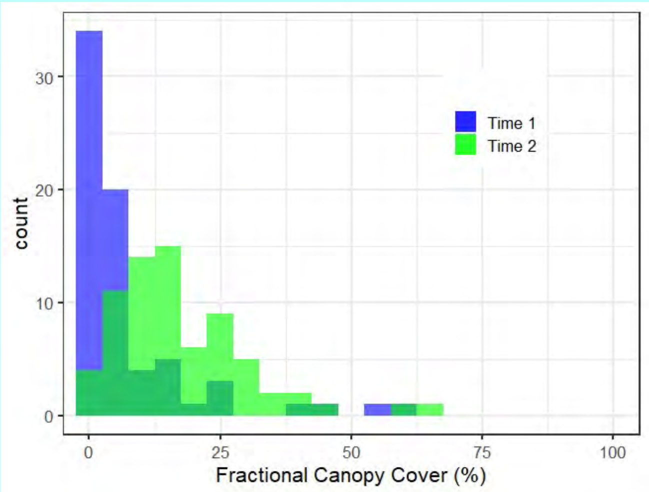
Box 2: Case study of Dewing Creek

Dewing Creek is a tributary of the Barwon River on the edge of the Otway Ranges. Between 2017 and 2021, Barwon Water Corp, Upper Barwon Landcare Network and the Corangamite CMA fenced and revegetated a large section of the creek frontage. In total, livestock were excluded from 2800 metres of waterway frontage, resulting in 57 hectares of stock free and revegetated frontage.

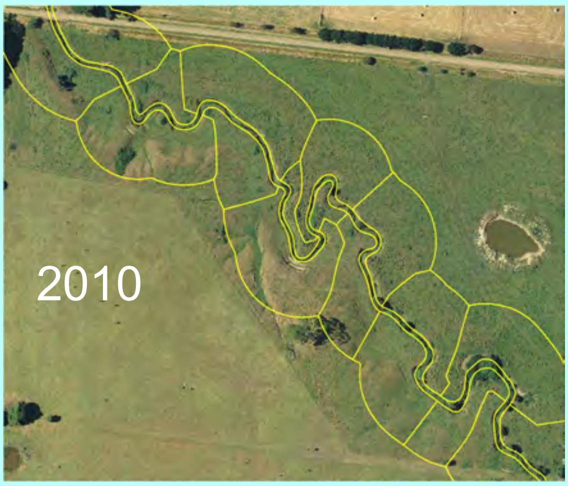
Significant changes in riparian vegetation were observed along ~2km of the site where livestock exclusion and revegetation were undertaken. Mean canopy increased from 7% in 2010 to 17% in 2020 (panel a below), and mean canopy height increased from 1.9 m to 3.1 m (panel b below). The percentage of sections with canopy heights greater than 2m had also increased by 28% in 2020 (from 21% of sections in 2010 to 49% of sections in 2020; panel b). A smaller increase in the percentage of sections with canopy cover greater than 5m (from 8 to 13%), and no change in the percentage of sections with canopy higher greater than 10m, were observed, reflecting the short time since revegetation and stock exclusion.

Aerial images were taken at the same time as the LiDAR capture. The image from 2010 is shown (panel c) with the 40m x 100m assessment sections as polygons with yellow borders, compared to the corresponding area in 2020 (panel d).

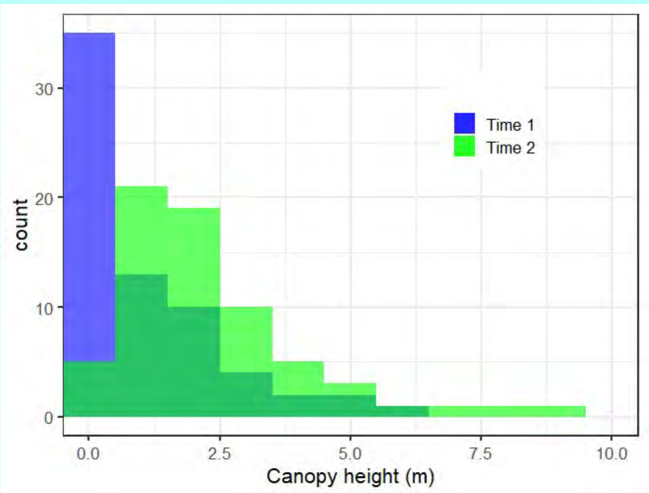
(a)



(c)



(b)



(d)

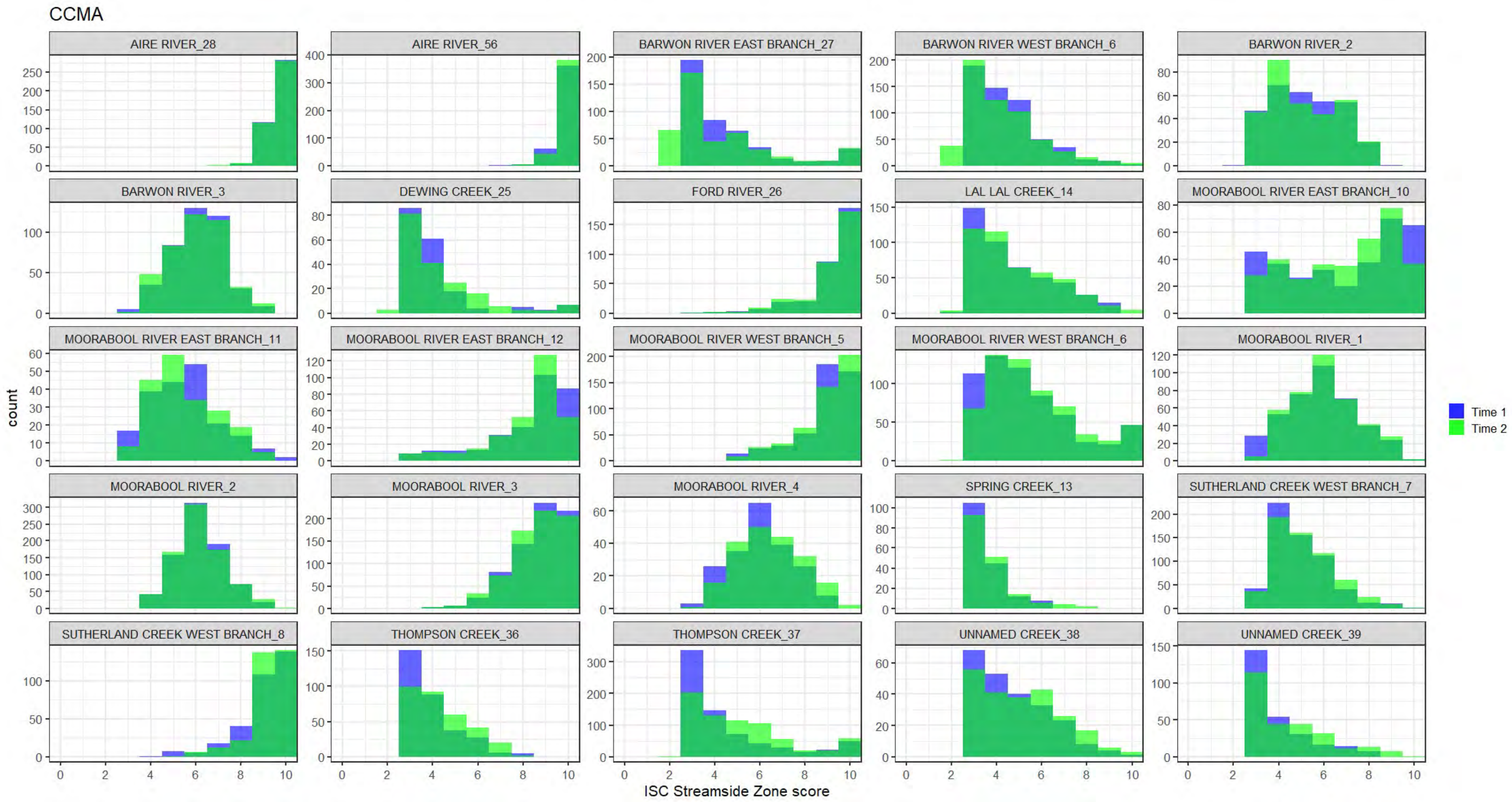


Figure 25 Streamside ISC scores for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections.

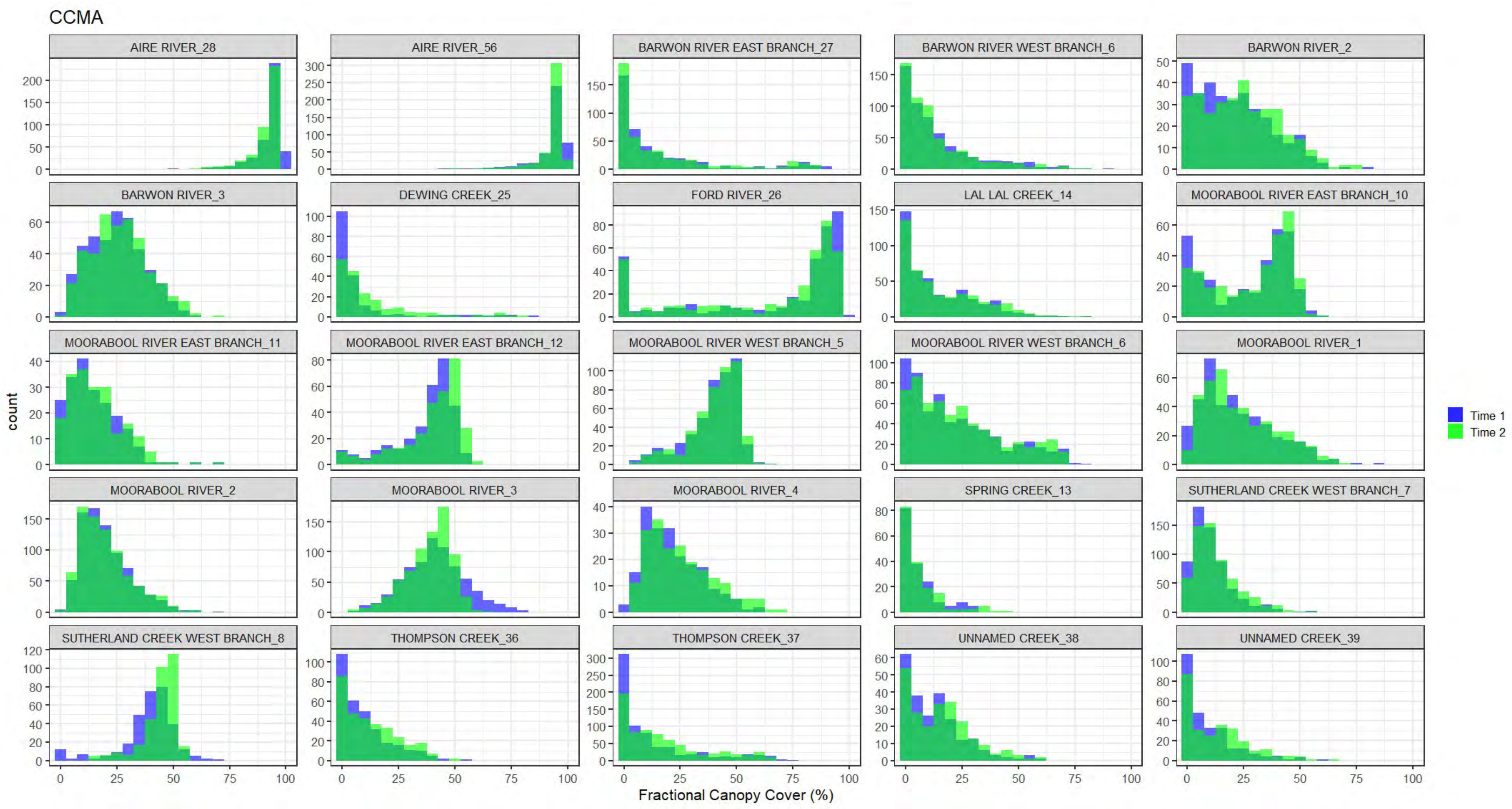


Figure 26 Fractional canopy cover for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections.

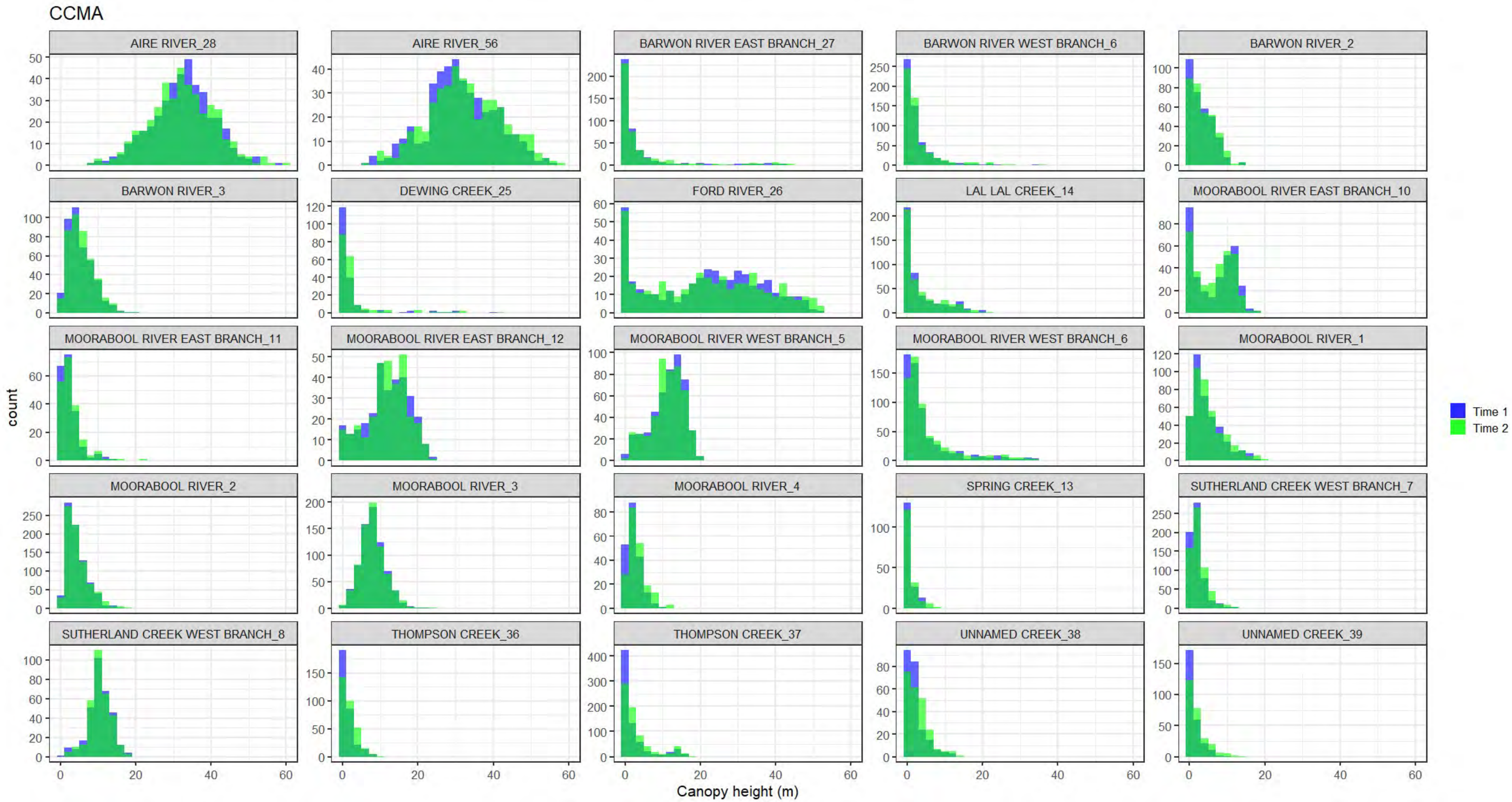


Figure 27 Canopy height for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections.

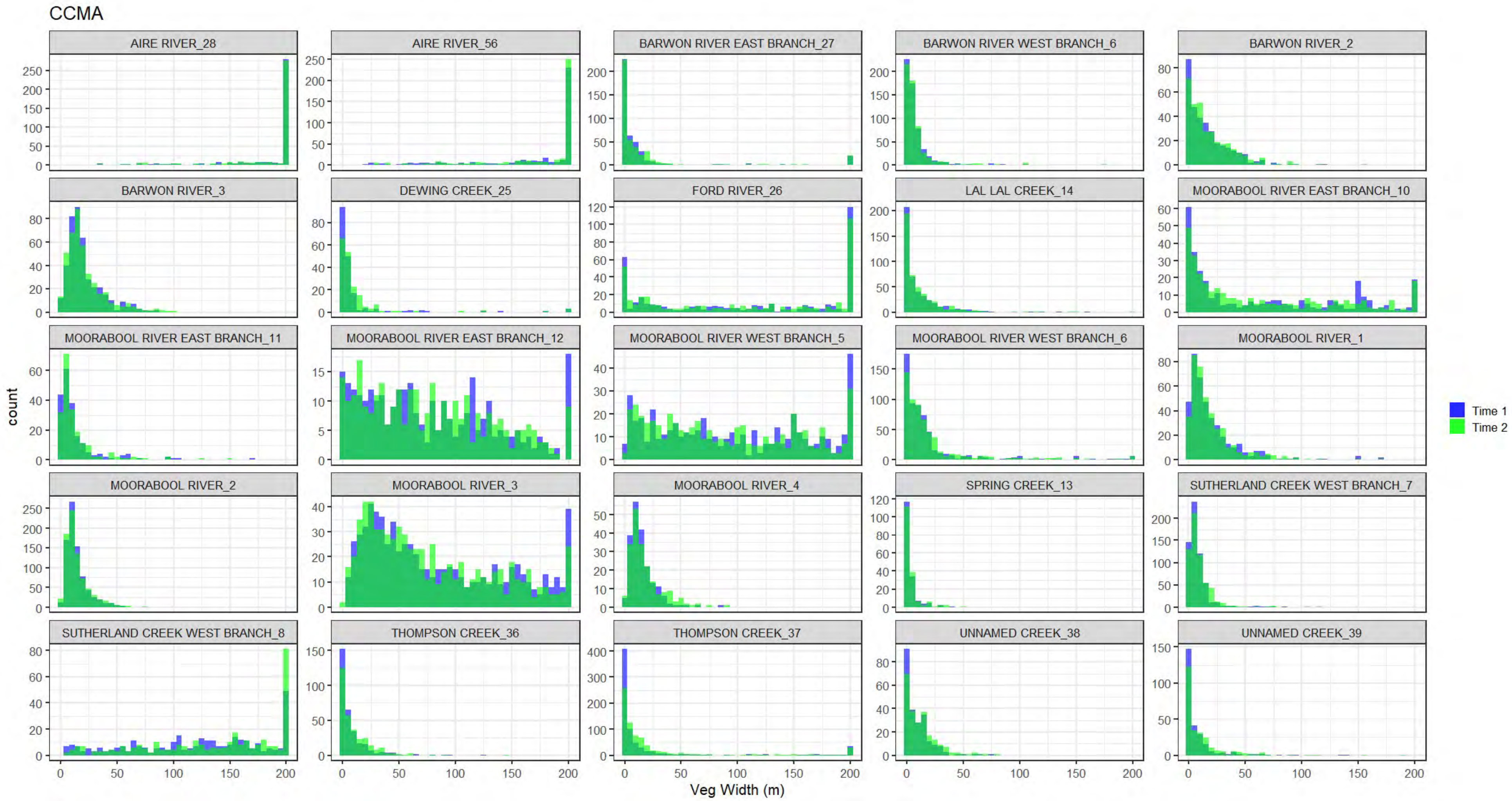


Figure 28 Vegetation width for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections.

OFFICIAL

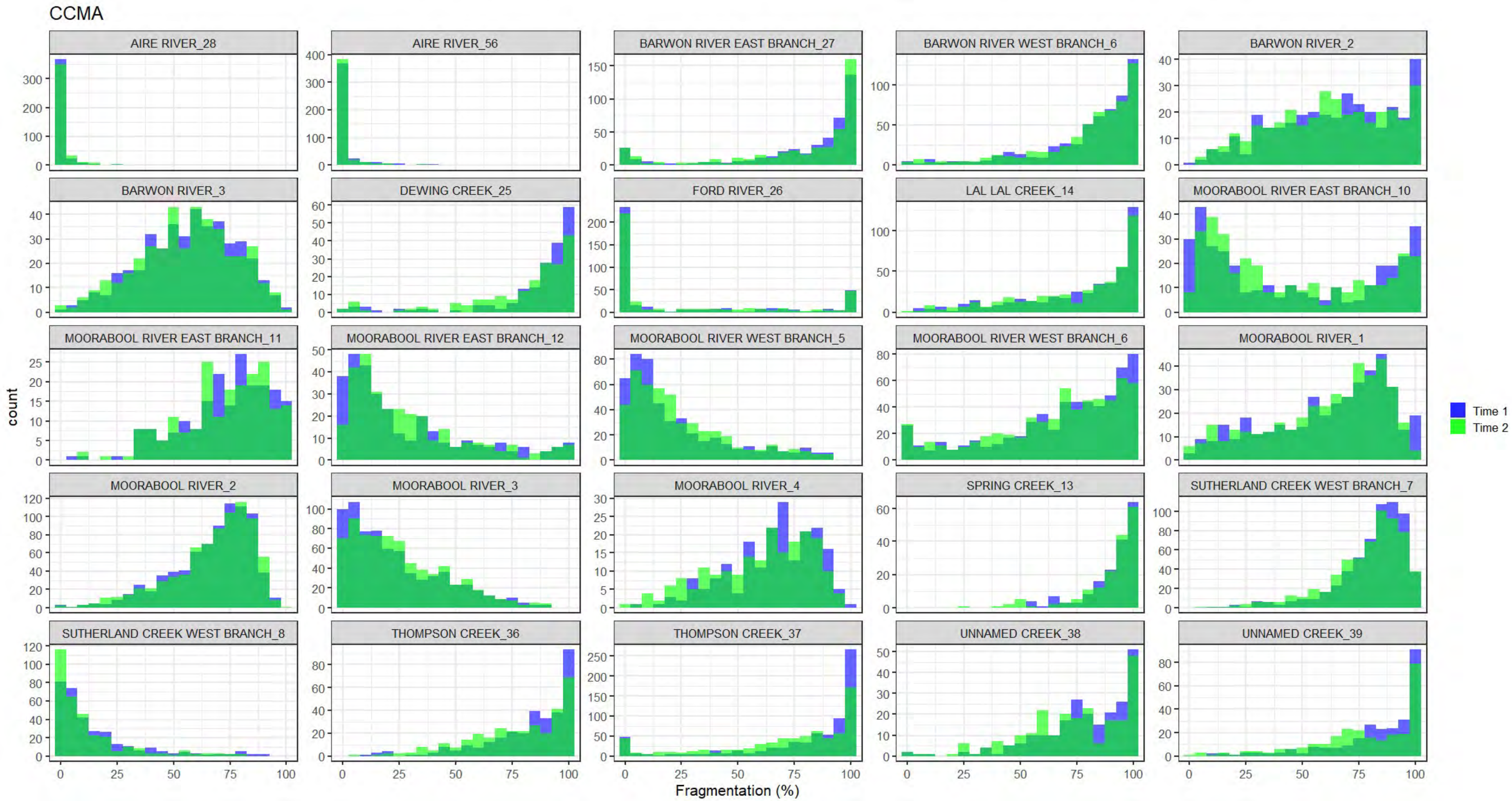


Figure 29 Fragmentation for locations in the CCMA at the two assessment periods. The count on the y-axis is the number of sections.

4.3.2 East Gippsland Region

The two assessment periods for the East Gippsland region (Table 9) were December 2009-February 2010 (Time 1) and 2018 (Time 2).

ISC Streamside Zone scores increased by one unit at eight reaches – Buchan River reach 11, Mitchell River reaches 6, 204 and 205, Snowy River reaches 203, 3 and 4, and Tambo River reach 204 (Figure 30; Table 10).

Fractional canopy cover increased at more than 50% of sections at all reaches, with the exception of two reaches on the Cann River (reaches 13 and 14), where canopy cover was 4 and 6% lower respectively (Table 11; Table 12; Figure 31). The largest increases in canopy cover (~13%) occurred at reaches 3 and 4 of the Snowy River. At these two reaches, ~28% more sections had canopy covers greater than 40% in 2018 (Table 12).

Canopy height increased at all reaches in the East Gippsland region between the two periods (Figure 32, Table 11). The most substantial changes in canopy height occurred at Snowy River reaches 3 and 4 with increases of ~3m.

Vegetation width also increased at most reaches (Figure 33 Table 11). The largest increases also occurred at Snowy River reaches 3 and 4. For example, at Snowy River reach 3, there were 21%, 20% and 7% more sections with vegetation wider than 10, 20 and 40m in 2018 (Figure 34).

Fragmentation decreased at most reaches (Figure 35). At Snowy River reaches 3 and 4, fragmentation decreased at more than 82% of sections, by 15-19% on average. ~30% fewer sections at these two reaches had fragmentation greater than 50% (Table 12). Fragmentation also decreased at the majority of sections at Mitchell River reaches 204 and 6 (96% and 81% respectively).

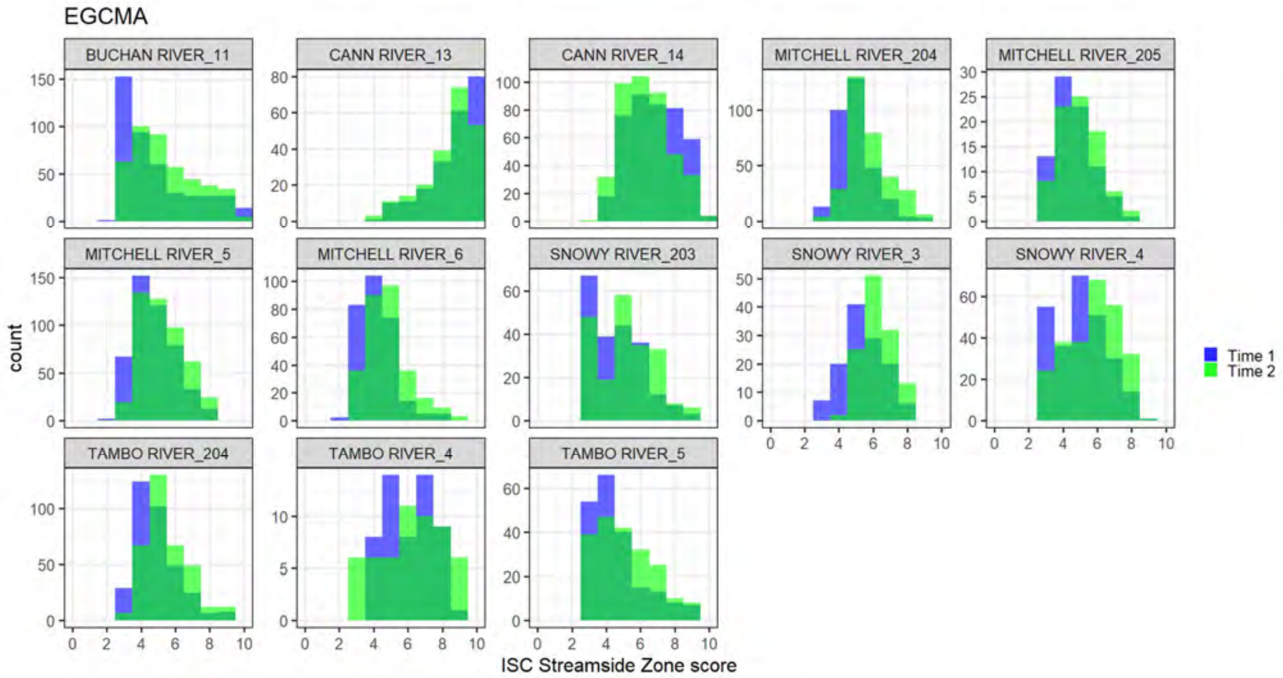


Figure 30 Streamside Zone ISC score for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections.

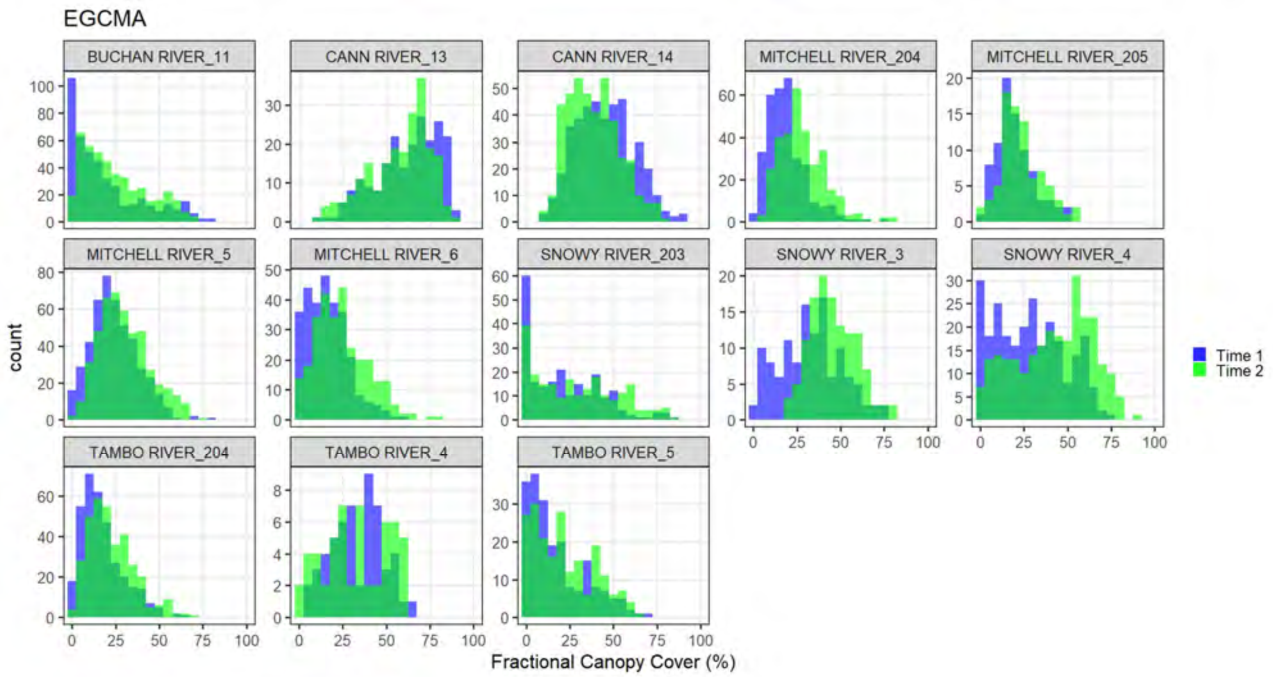


Figure 31 Fractional canopy cover for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections.

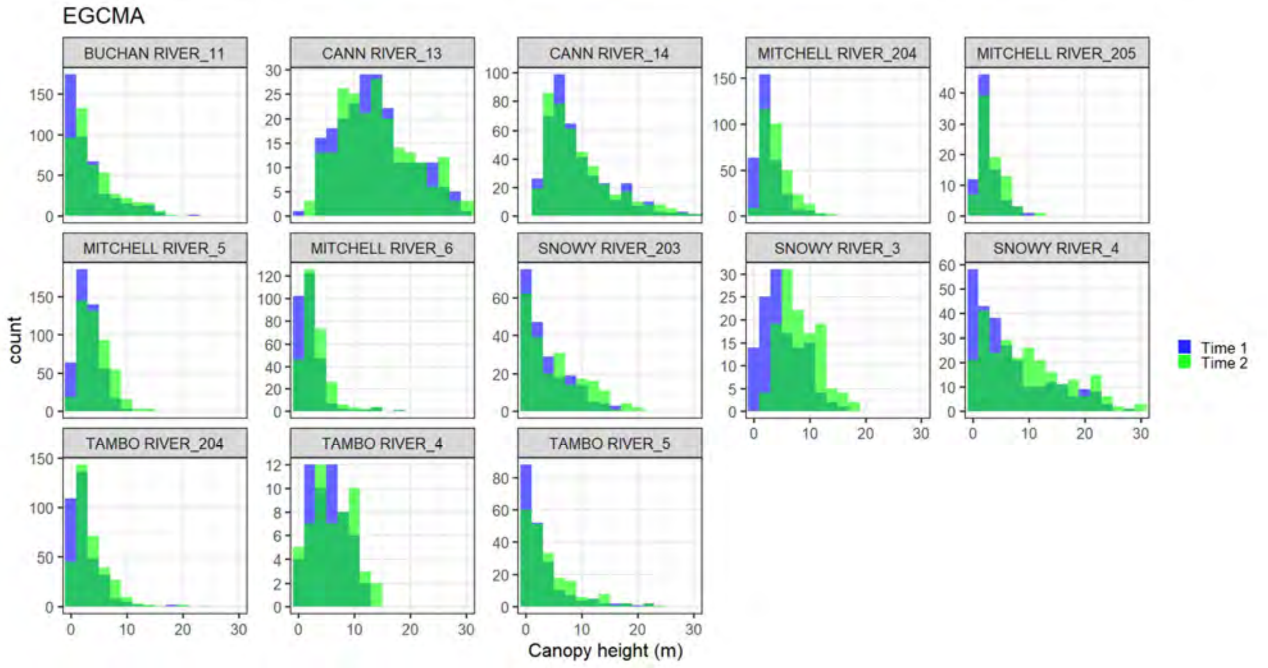


Figure 32 Canopy height for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections.

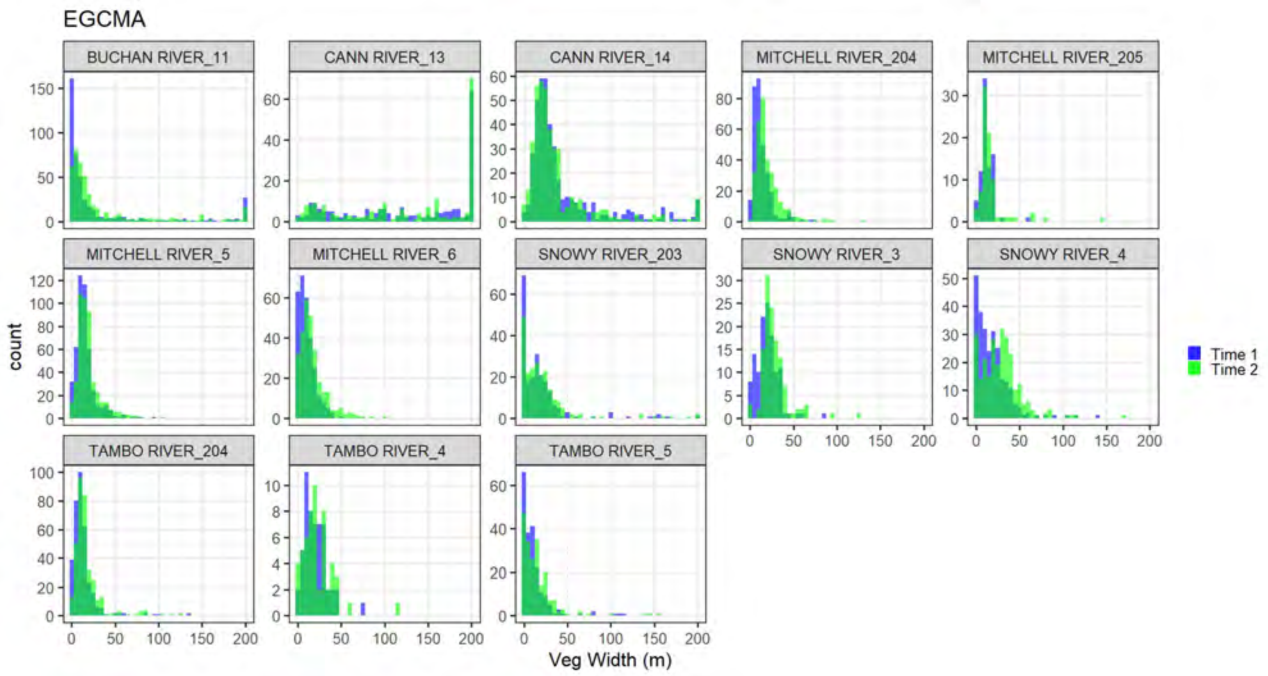


Figure 33 Vegetation width for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections.

	>10m	>20m	>40m
% Segments above threshold (Time 1)	76	49	4
% Segments above threshold (Time 2)	97	69	10
% change Time 1 to Time 2	+21	+20	+6

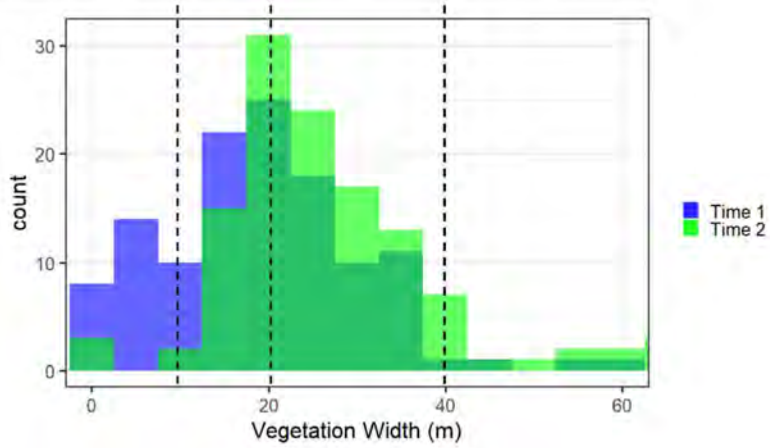


Figure 34 Histograms showing summary of vegetation width at Snowy River reach 3 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above those thresholds.

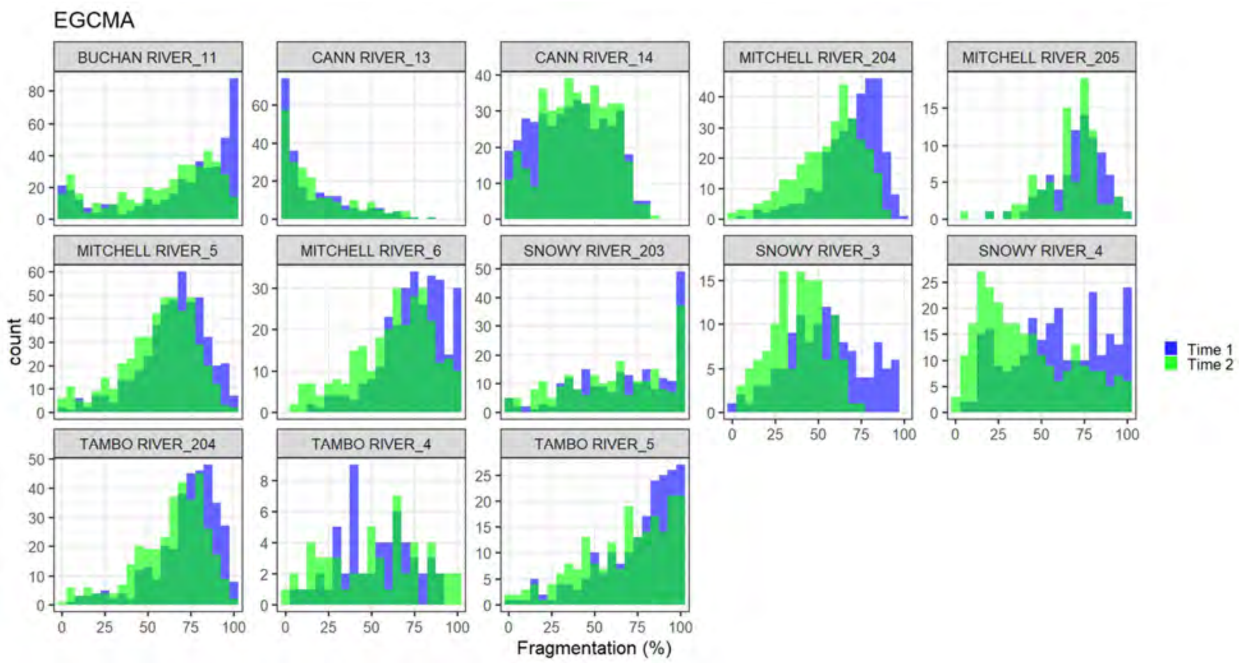


Figure 35 Fragmentation for locations in the EGCMA at the two assessment periods. The count on the y-axis is the number of sections.

4.3.3 Goulburn-Broken Region

The two assessment periods for the Goulburn-Broken region were in 2010 (mostly in November and December) and 2018 (in March and April) (Table 9).

ISC Streamside Zone scores increased by one unit at three reaches in the Goulburn-Broken region – Faithfulls Creek reach 21, King Parrot Creek reach 51, and Sevens Creek reach 17 (Figure 36; Table 10).

Fractional canopy cover increased at more than 60% of sections across all reaches (Figure 37; Table 11), and this ranged from 64% of sections at Goulburn River reach 14 to 97% of sections at Sevens Creek reach 17. The biggest changes were observed at Acheron River reach 62 and Seven Creeks reach 17, where canopy cover increased on average by 13 and 8% respectively. At Acheron River reach 62, 29% more sections had canopy cover greater than 40% in 2018 than in 2010, and 23% more sections had canopy cover greater than 60% in 2018 (Table 12). Bushfires in the upper Acheron River catchment prior to the 2010 assessment are likely to explain the dramatic increase in canopy cover along this reach between the two assessments. At Seven Creeks reach 17, 27% more sections had canopy cover greater than 40% in 2018 than in 2010. Seven Creeks has been subject to sustained riparian management over the last 10-15 years which could explain this result.

Canopy height also increased at more than 60% of sections across all reaches (Table 11; Figure 38); Increases in canopy cover ranged from 0.6m at Acheron River reach 62 to 1.8m at Sevens Creek reach 17. The average increase was 1.2m across all reaches.

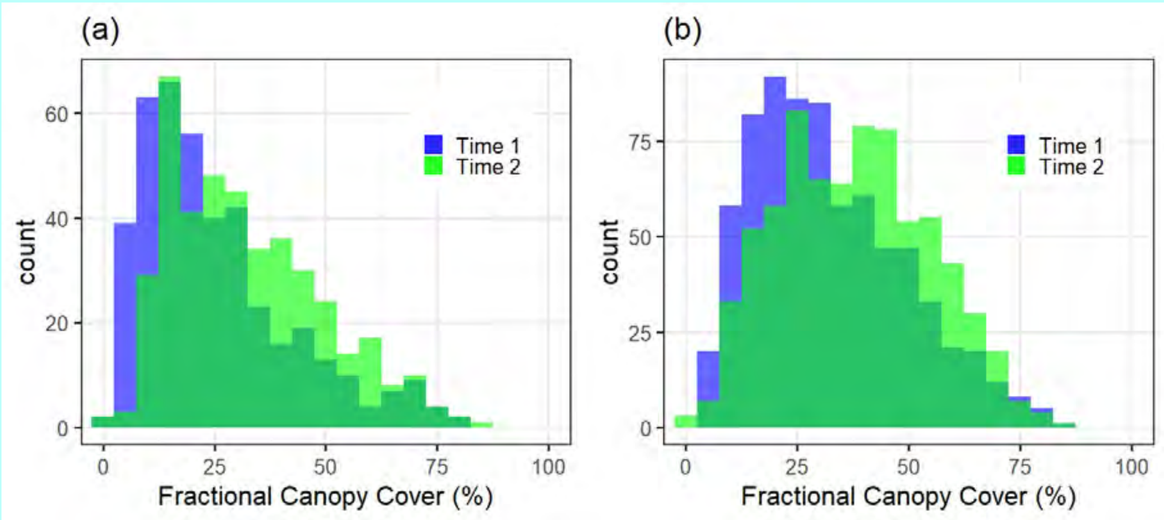
Vegetation width increased at all reaches across the Goulburn-Broken (Figure 39). These changes ranged from at 49% of sections at Broken River reach 5 to at 77% of sections at Seven Creeks reach 17. For example, at Faithfuls Creek reach 21, 21% more sections had vegetation wider than 10m in 2018 than in 2010, and 24% more sections had vegetation wider than 20m (Figure 41).

Fragmentation decreased at most reaches (Figure 40) ranging from at 65% of sections at Hughes Creek reach 38 to 94% of sections at Seven Creeks reach 17 (Table 12). At some locations though, the magnitude of change in fragmentation was small, such as Seven Creeks reach 20 where there were decreases in fragmentation overall, but by less than 3%.

Box 3: Case study of King Parrot Creek from Flowerdale to Strath Creek

King Parrot Creek is a tributary of the Goulburn River west of Yea. Over the past decade riparian management has foccussed predominantly on woody weed control (willow and blackberry), as well as a program of livestock exclusion and revegetation. Significant riparian management along the entire creek was undertaken prior to 2010 and changes in vegetation reflect both recent and historical work. To illustrate changes in riparian vegation between 2010 and 2018, a ~15km stretch of King Parrot Creek from Flowerdale to its confluence with Strath Creek where a significant length of riparian frontage was managed by a single landholder was selected. To place results from this stretch in context, changes were compared to the rest King Parrot 51 ISC reach when the focal area removed.

Fractional canopy cover in 2010 at the focal reach (average 25%; panel a) was lower than the remainder of the King Parrot Creek (average 32%, panel b) From 2010 to 2018, 21% more sections had fractional canopy cover greater than 20% in the focal reach (panel a; an increase from 50 to 71% of sections) compared to only 11% at other sections of King Parrot Creek (panel b; an increase from 71 to 83% of sections). However, these increases in canopy cover were patchy, reflecting both past and recent management regimes which included a mosaic of woody weed control and revegetation.

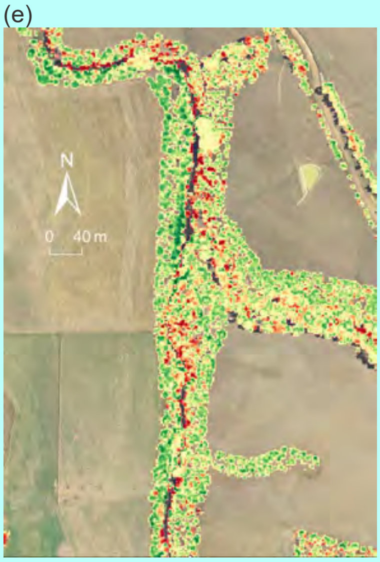


Panel c shows a ~550m length of King Parrot Creek between Flowerdale-Strath Creek in 2010. Panel d is the same section in 2018. Panel e shows the fractional canopy cover with areas of woody weed control showing as red areas with up to a 100% reduction in canopy cover, whereas green areas indicate increased canopy cover of between 25 and 100% due to revegetation and growth.

(c)

(d)

(e)



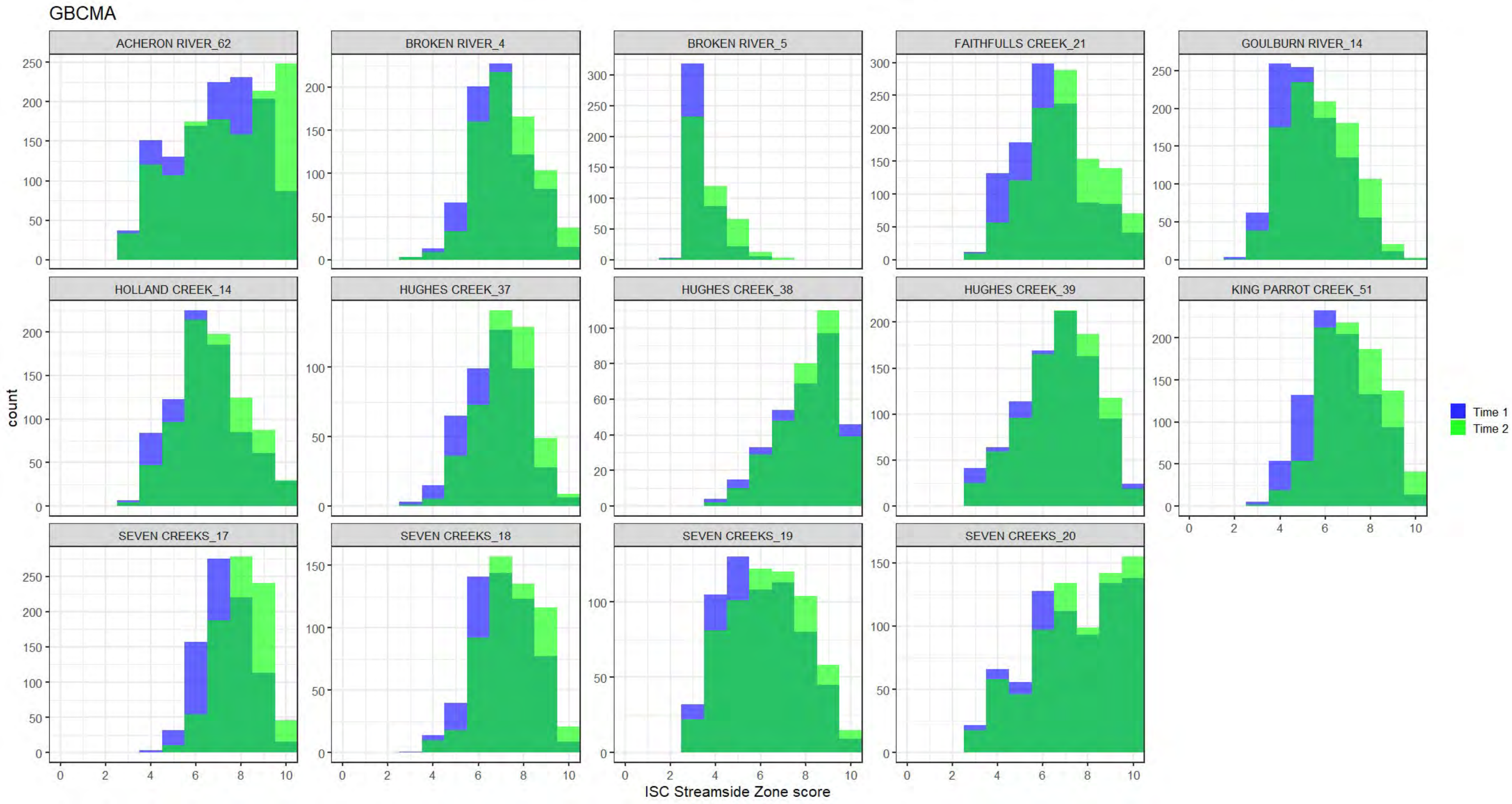


Figure 36 ISC Streamside Zone scores for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections.

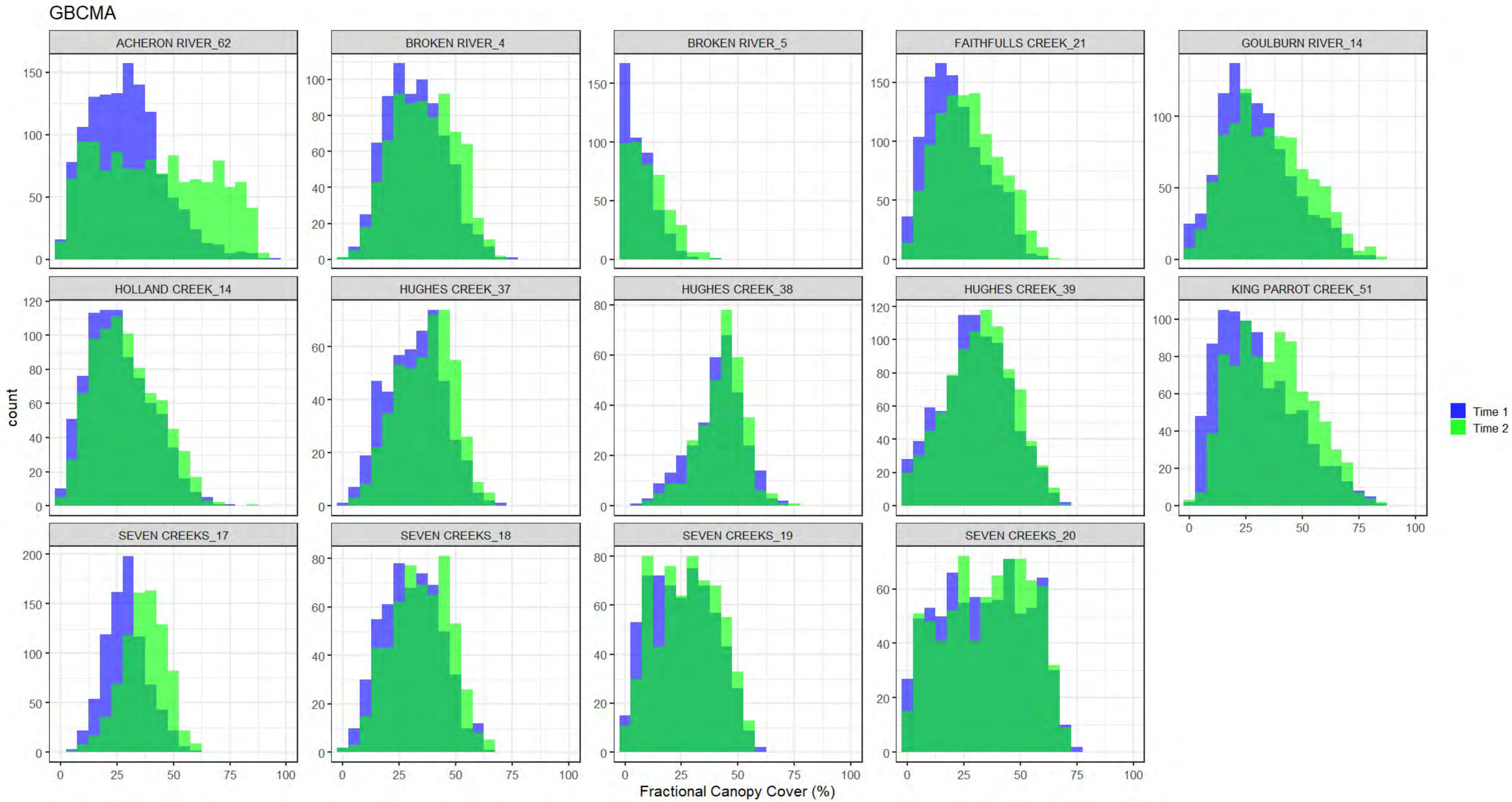


Figure 37 Fractional canopy cover for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections.

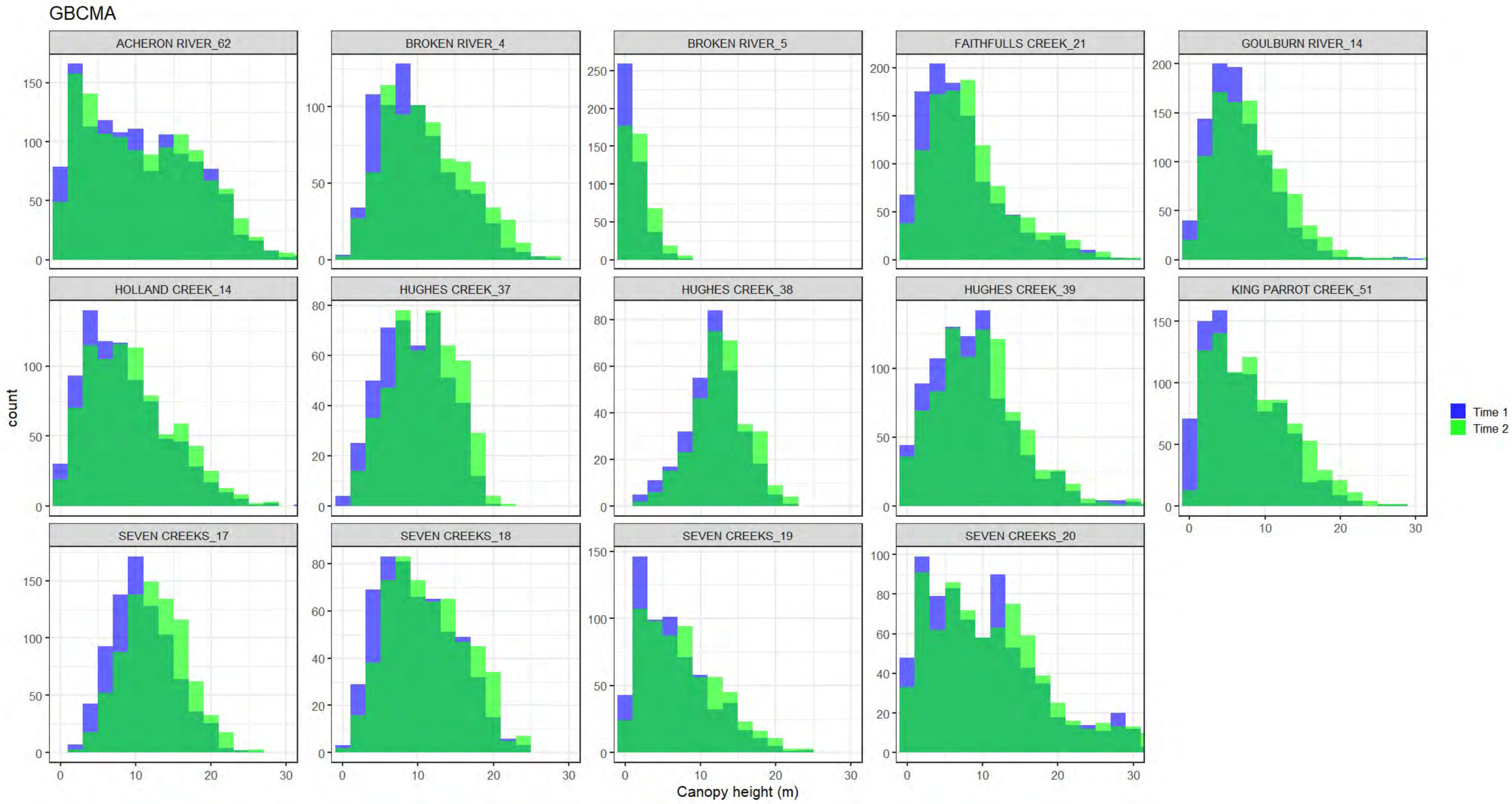


Figure 38 Canopy height for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections.

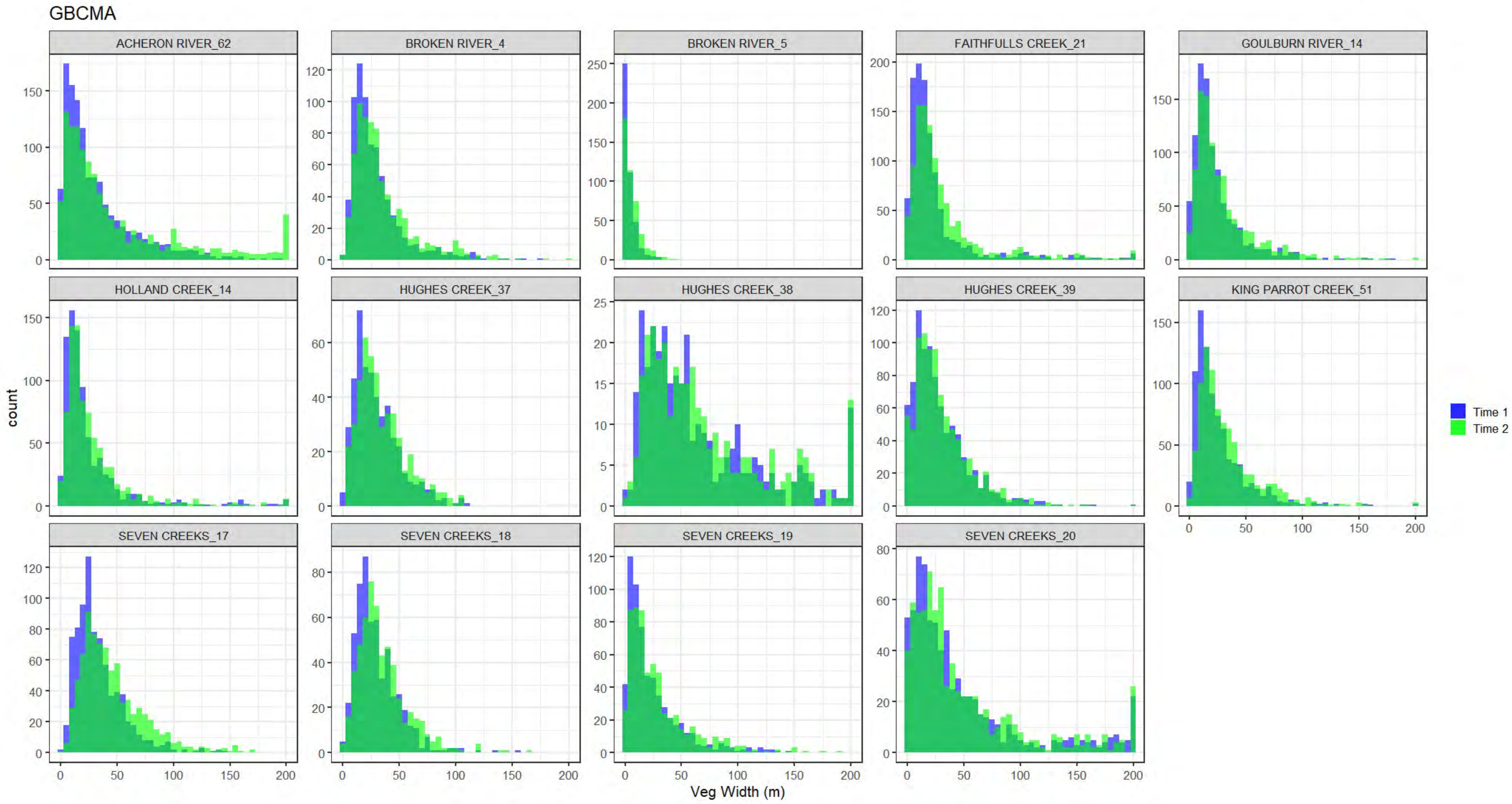


Figure 39 Vegetation width for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections.

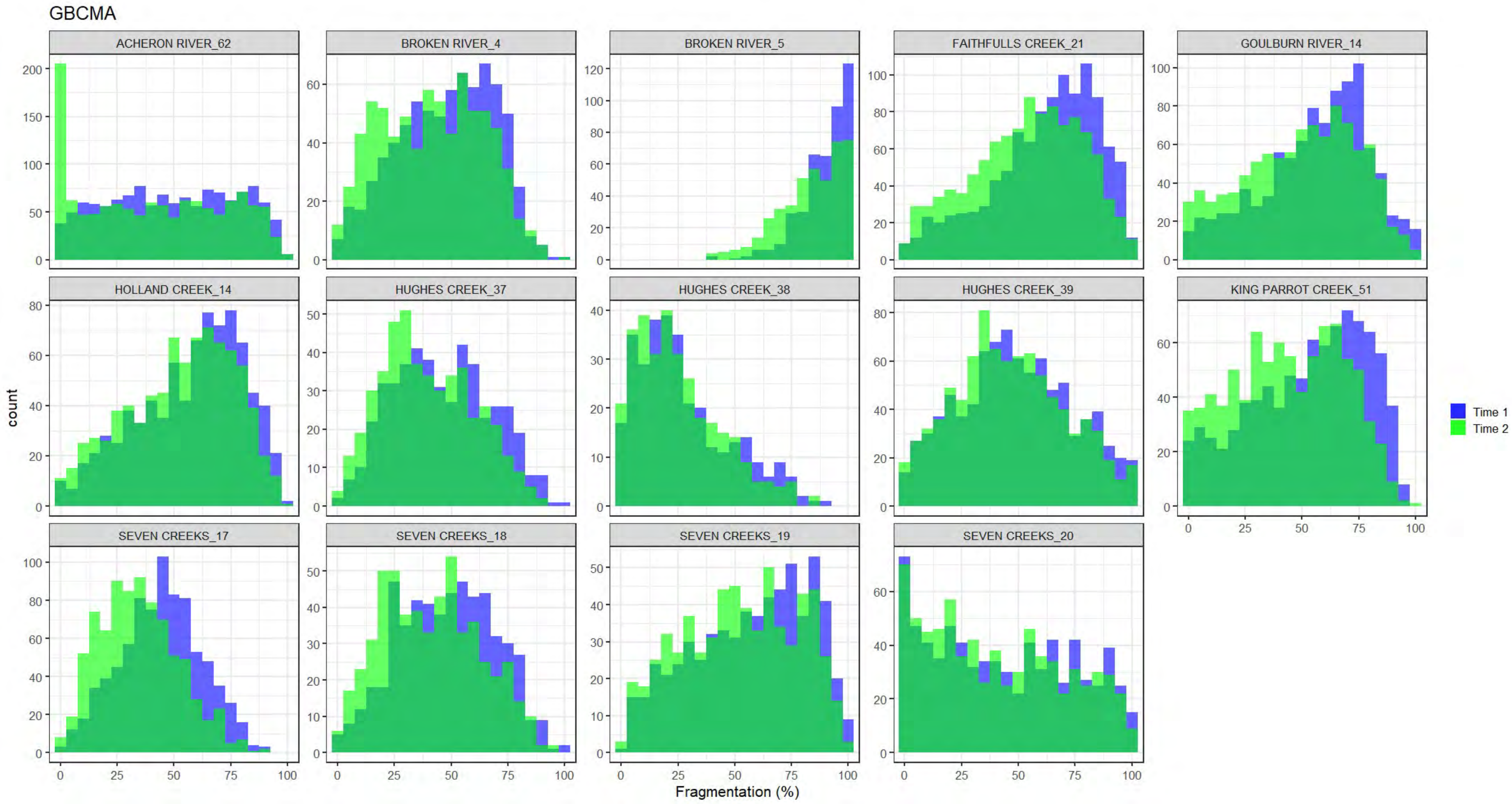


Figure 40 Fragmentation for ISC reaches in the GBCMA at the two assessment periods. The count on the y-axis is the number of sections.

	>10m	>20m	>40m
% Segments above threshold (Time 1)	67	35	13
% Segments above threshold (Time 2)	79	50	21
% change Time 1 to Time 2	+12	+15	+8

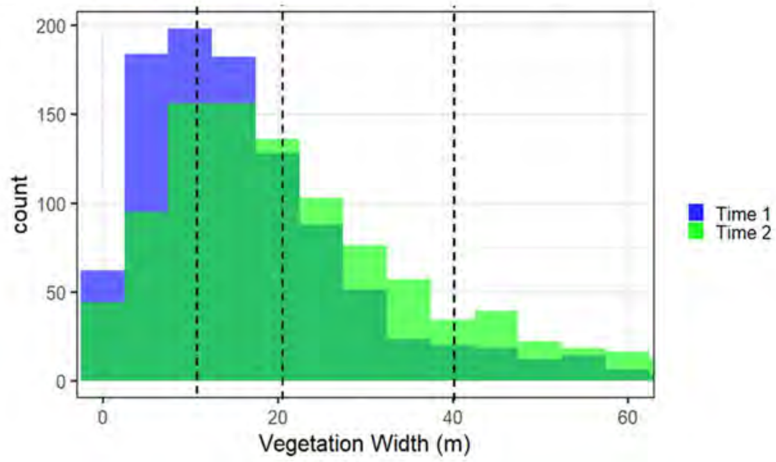


Figure 41 Histograms and aerial imagery showing vegetation width at Faithfuls Creek reach 21 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 40m in the two periods and the % change in the proportion of sections above those thresholds. Green lines on photographs are transects perpendicular to the stream used to measure vegetation width.

4.3.4 Glenelg-Hopkins Region

The two assessment periods for the Glenelg-Hopkins region were in 2009 (October and November) and 2018 (February-April) (Table 9).

ISC Streamside Zone scores did not change at any reaches between assessment periods (Figure 42; Table 10).

Fractional canopy cover did not change more than a 3% in either direction at any reach (Figure 43; Table 11; Table 12).

Canopy height did not change by more than 1m in either direction at any reach (Figure 44). Canopy height increased by more than 0.5m at four reaches (Bryans Creek reach 32 and 33, Chetwynd River reach 47, Merri River reach 39 and Wando River reach 44), and decreased by more than 0.1m only at Trewalla Creek reach 23 (0.6m).

Changes in vegetation width were also mostly small, ranging from a 4m decrease at Glenelg River reach 11 and Steep Bank Rivulet reach 46 to a ~2.1m increase at Merri River reach 39 (Figure 45). Across all reaches, the mean change in vegetation width was negligible (a decrease of less than 0.5m)

Only small changes in fragmentation were observed, ranging from a 4% decrease at Merri River Basin reach 39 to a 5% increase at Trewalla Creek reach 23 (Figure 46). At both reaches, the changes were at sections with high fragmentation: at Merri River reach 39, 10% fewer sections had fragmentation over 75% in 2018; at Merri River reach 39, 14% more sections had fragmentation over 90% in 2018 (Table 12).

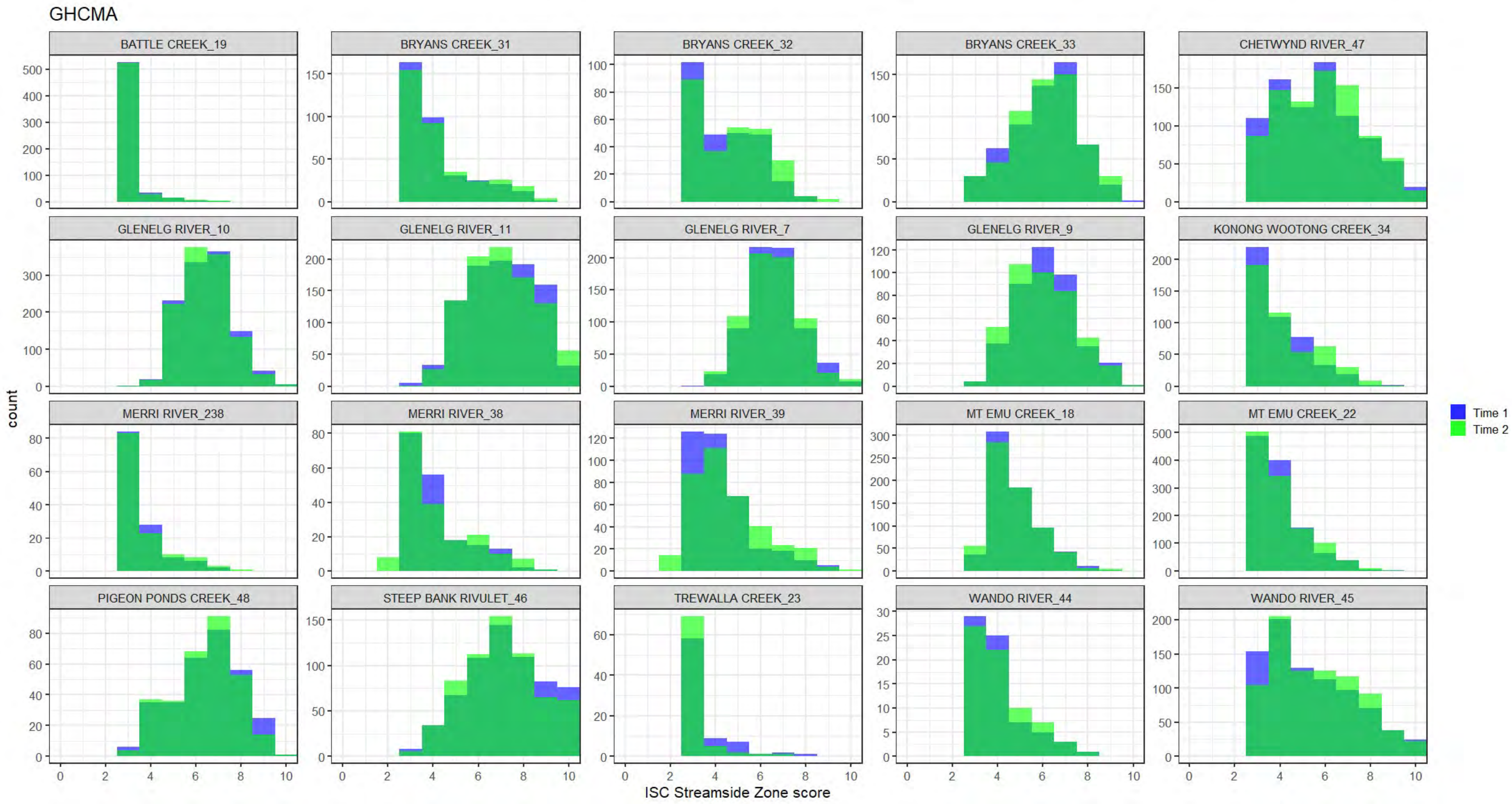


Figure 42 Streamside Zone ISC scores for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections.

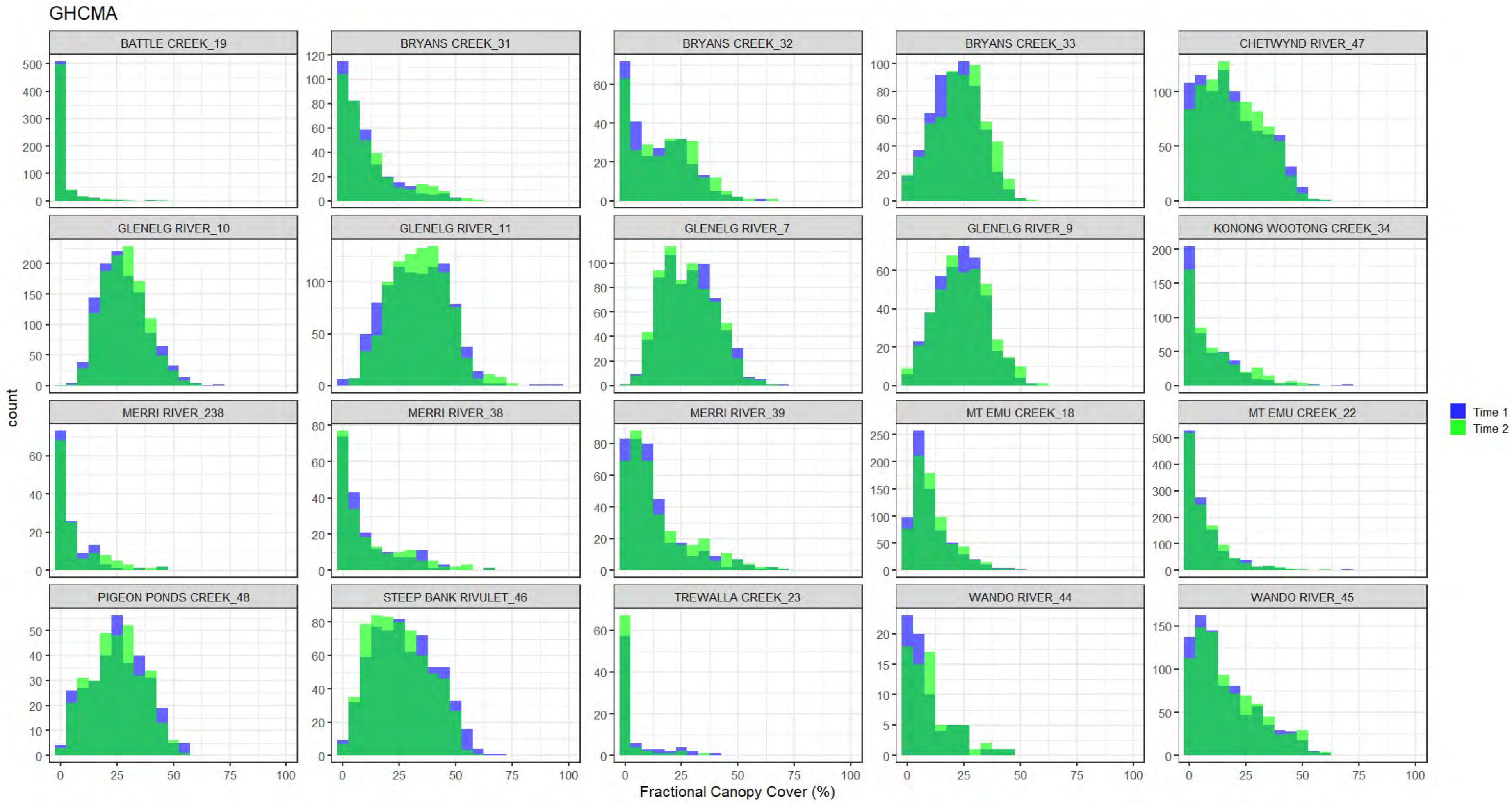


Figure 43 Canopy cover for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections.

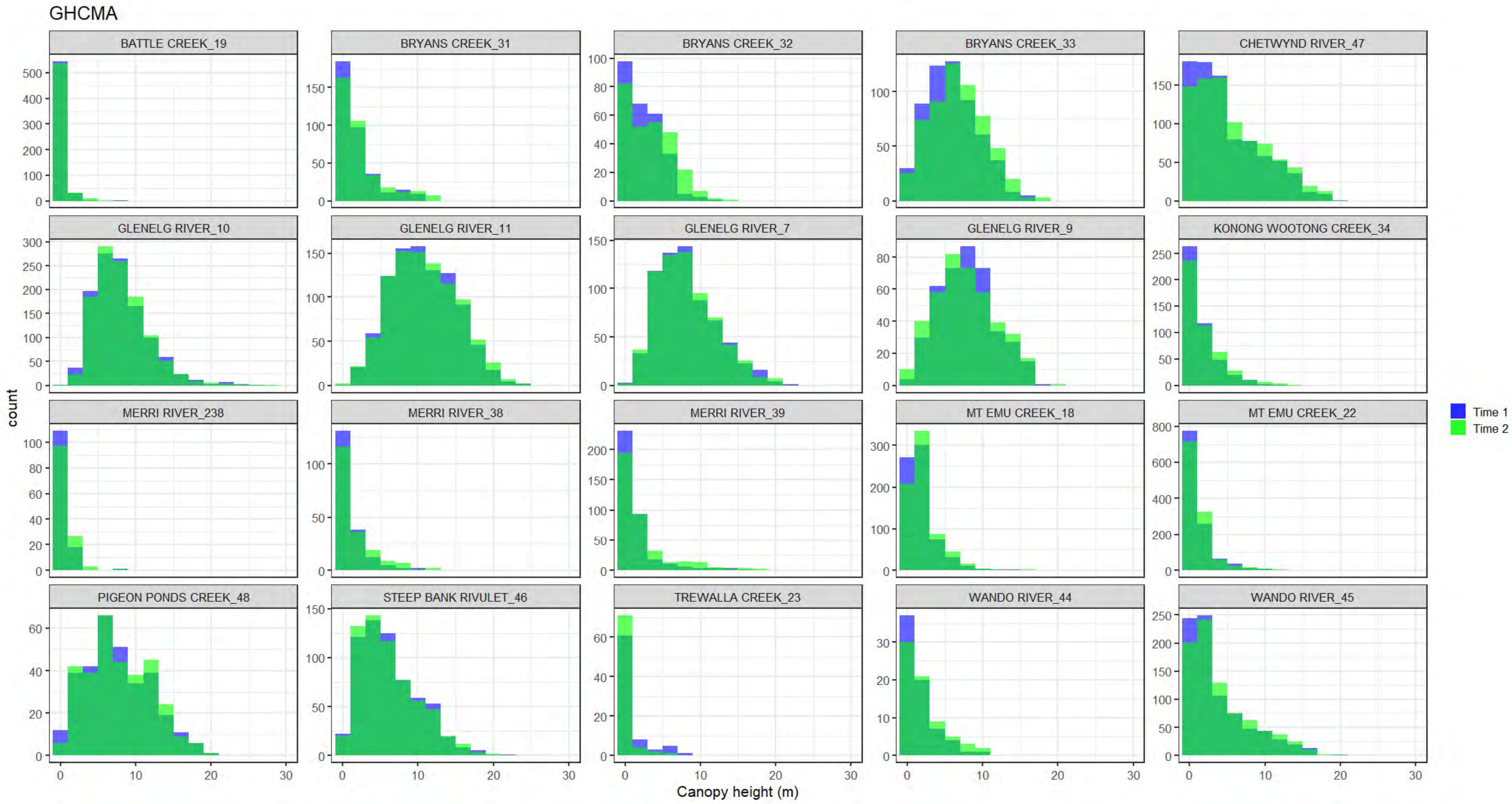


Figure 44 Canopy height for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections.

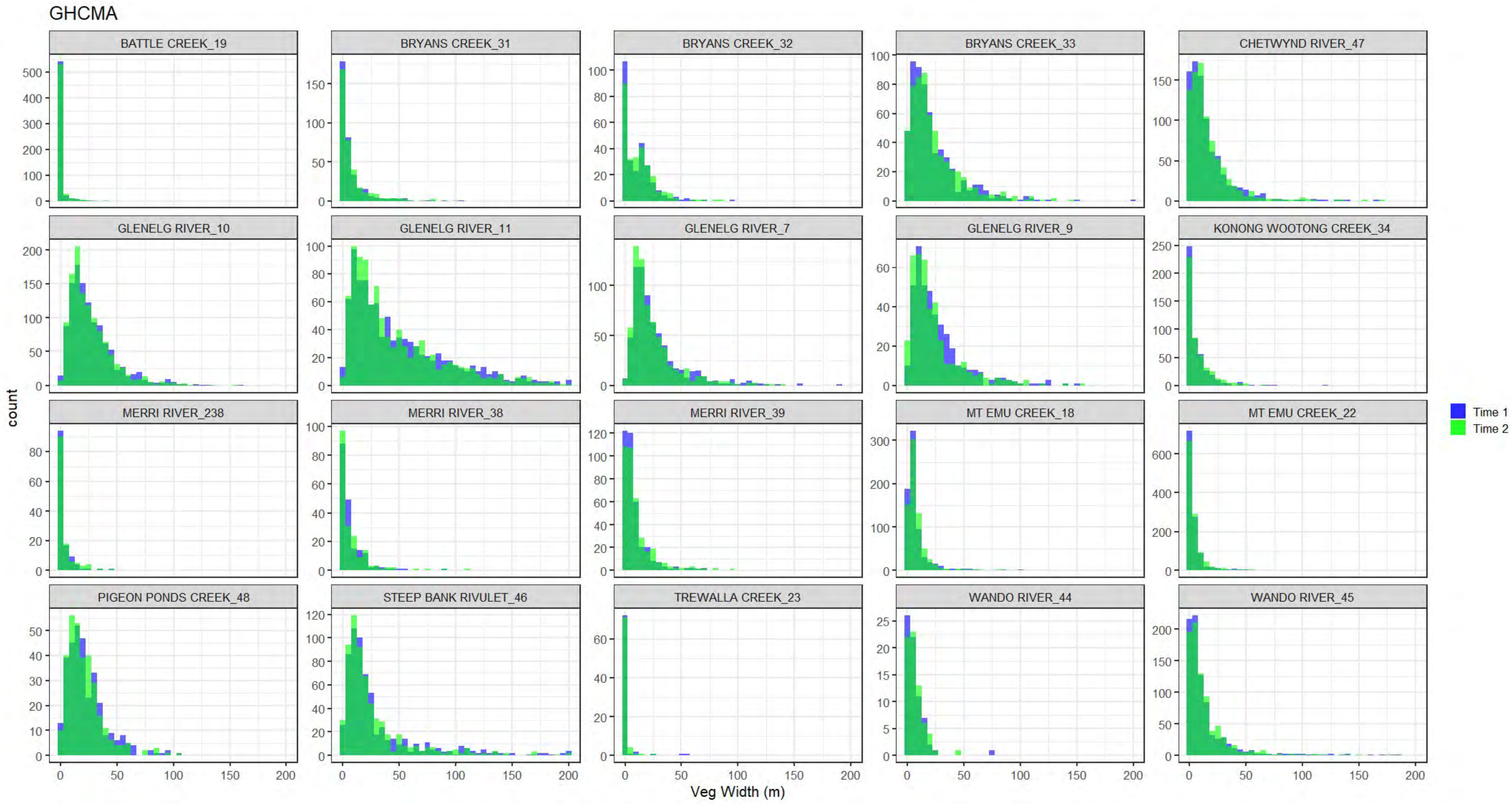


Figure 45 Vegetation width for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections.

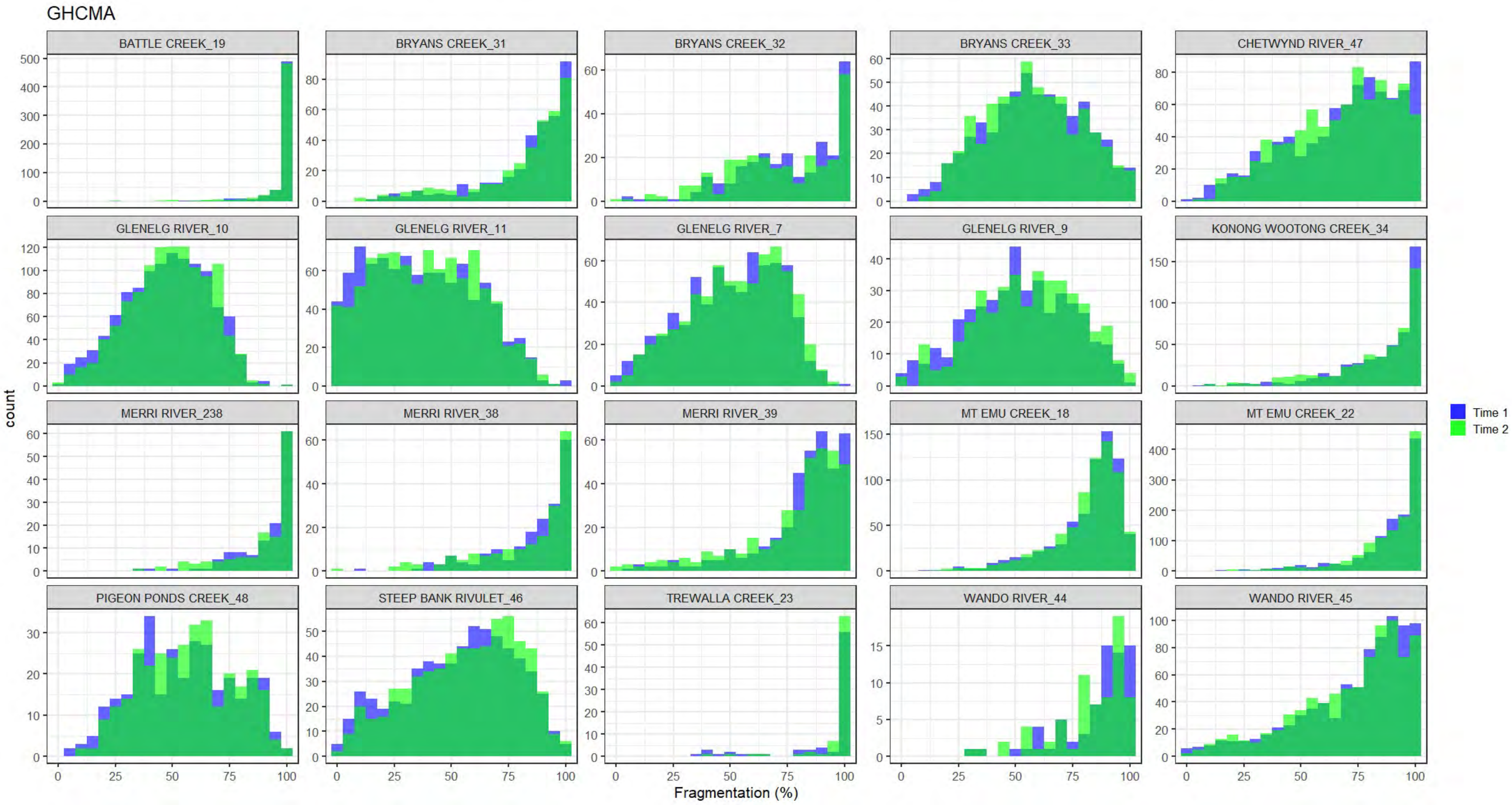


Figure 46 Fragmentation for locations in the GHCMA at the two assessment periods. The count on the y-axis is the number of sections.

4.3.5 Mallee Region

The two assessment periods for the Mallee region were in 2010 (mainly July-August) and 2018 (February) (Table 9).

ISC Streamside Zone scores were higher by one unit at four reaches (Lindsay River reach 68, Murray River reaches 10 and 11, and Unnamed Creek reach 66) and unchanged at the other nine (Figure 47; Table 10).

With the exception of Unnamed Creek reach 20, canopy cover increased at all reaches and by between 3 and 12% (Figure 48; Table 11; Table 12). The largest increases, of 8% and 12% respectively, were observed at Chalka Creek reach 39 and Lindsay River reach 68. At the two sites, there were 23% (Chalka Creek) and 34% (Lindsay River) more sections with canopy cover above 40% in 2018 when compared to 2010 (Table 12).

Canopy height increased at most reaches, but the magnitude of these changes was very small (Table 11; Table 12). Increases of 1m or greater were observed at four reaches: Murray River River reach 12 (1m), Chalka Creek reach 39 (1.2m), Murray River reach 10 (1.4m) and Lindsay River reach 68 (1.8m).

Vegetation width increased at more than 50% of sections across all reaches other than Unnamed Creek reach 20 (Figure 50), and by between 1 and 17 metres. The largest magnitude changes were observed at Lindsay River reach 68, where ~30% more sections had vegetation wider than both 20m and 40m in 2018. At Unnamed Creek reach 20, vegetation width was ~3m narrower in 2018 than 2010.

Fragmentation decreased at more than 70% of sections at all reaches except Unnamed Creek reach 20, and by more than 14% at Lindsay River reach 68 and Unnamed Creek reach 66 (Figure 52).

At some locations in the Mallee CMA, hydrological variation (including environmental watering) may have led to changes in woody riparian vegetation cover (Chalka Creek, Box 4).

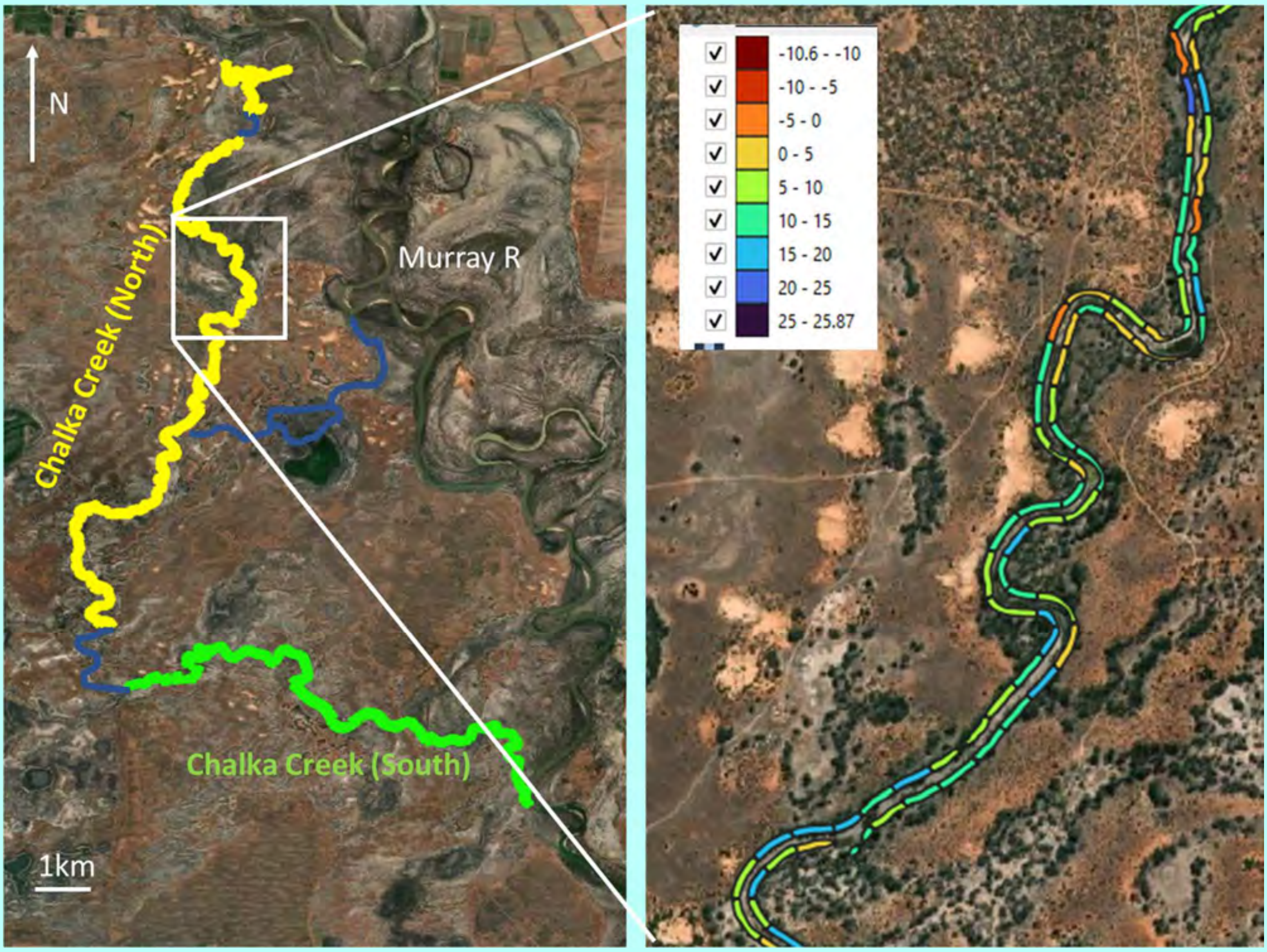
Box 4: Case study of environmental watering on Chalka Creek

Chalka Creek provides an example of how environmental water management may have led to changes in woody riparian vegetation.

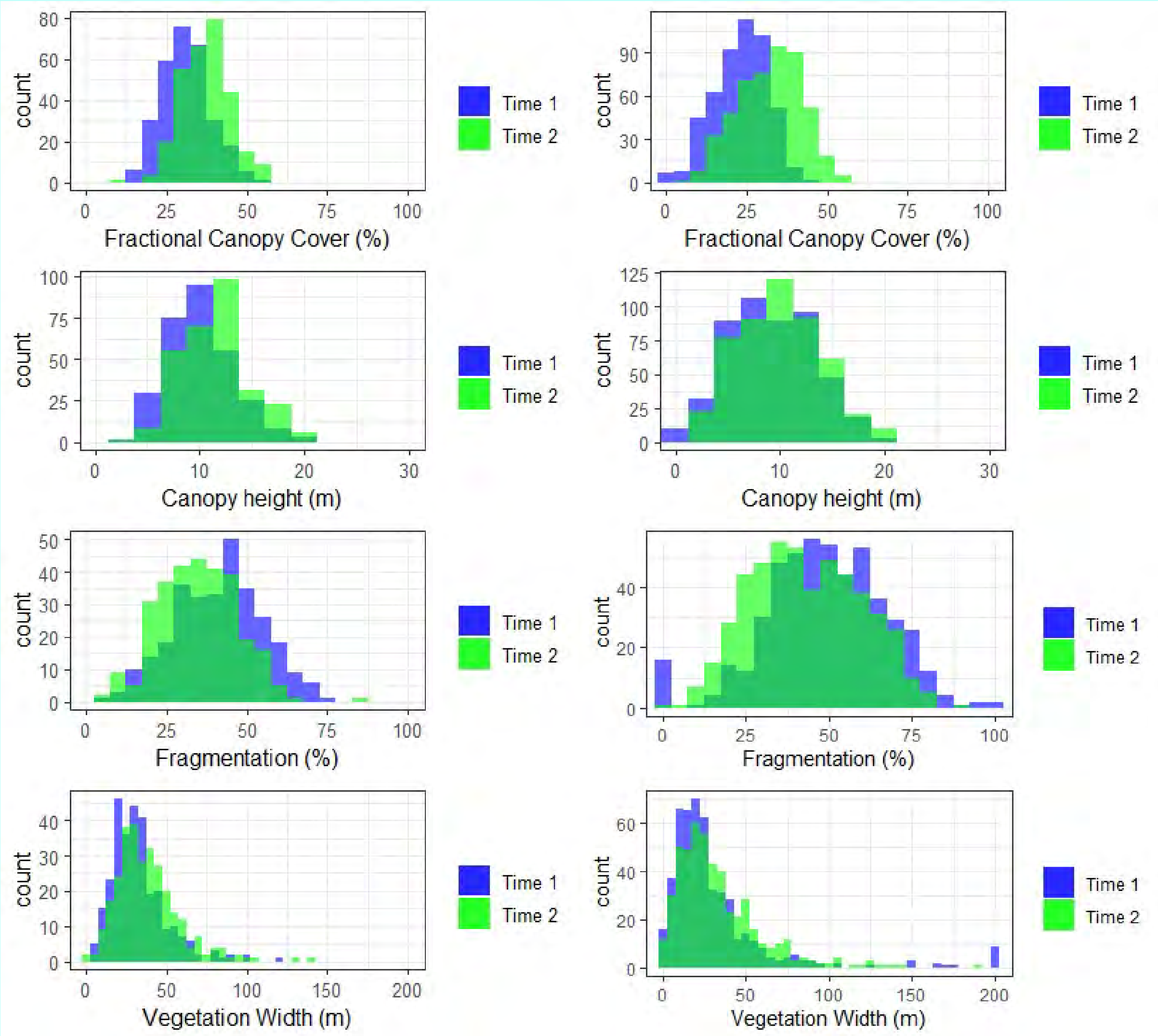
The period prior to 2010 coincided with the Millennium drought. Prior to 2010, a ~14km section of Chalka Creek north (Chalka North) did not receive environmental water whereas a ~10km section of Chalka Creek which feeds the Hattah Lakes (Chalka South) received water in 2005-2006 and again in 2009-2010. In 2010, canopy cover was higher (32 vs 23%), vegetation was wider (33 vs 31m), and fragmentation was lower (41 vs 49%) at Chalka South compared to Chalka North, suggesting that the provision of environmental water during the Millennium drought may have benefited woody vegetation.

Between 2010-2017, both sections of Chalka Creek received environmental water several times, in addition to widespread and significant flooding which occurred after the Millennium drought broke in 2010. Along both sections, canopy cover increased during this period (by 5% at Chalka South, 9% at Chalka North) as did vegetation width (by ~5m at both sections), whereas fragmentation decreased (by 6% at both sections). Canopy height increased by 2m at Chalka Creek South, and by 1m at Chalka Creek north.

Sampling locations on Chalka Creek (left panel), and example of changes in canopy cover along a representative ~3.5km section of Chalka Creek (North). The shading of the riparian buffer on the right panel illustrates difference in canopy cover 2018-2010.



Summary of changes in riparian vegetation at Chalka Creek (left panels show Chalka Creek South; right panels show Chalka Creek North).



Summary of changes in vegetation metrics on Chalka Creek

Mean changes	Chalka Creek South			Chalka Creek North		
Metric	**2010**	**2018**	**Diff**	**2010**	**2018**	**Diff**
Fractional canopy cover (%)	32	37	+5	23	32	+9
Canopy height (m)	10	12	+2	9	10	+1
Fragmentation (%)	41	34	-7	49	43	-6
Vegetation width (m)	33	38	+5	31	33	+2

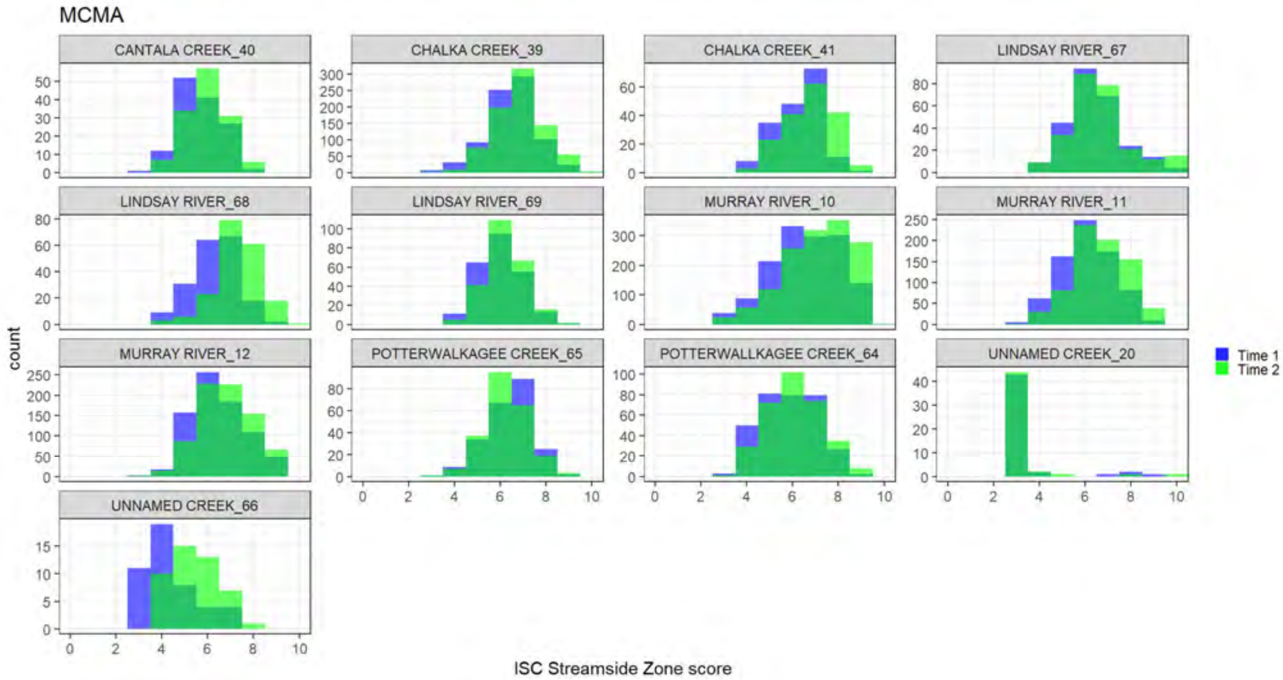


Figure 47 ISC Streamside Zone scores for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections.

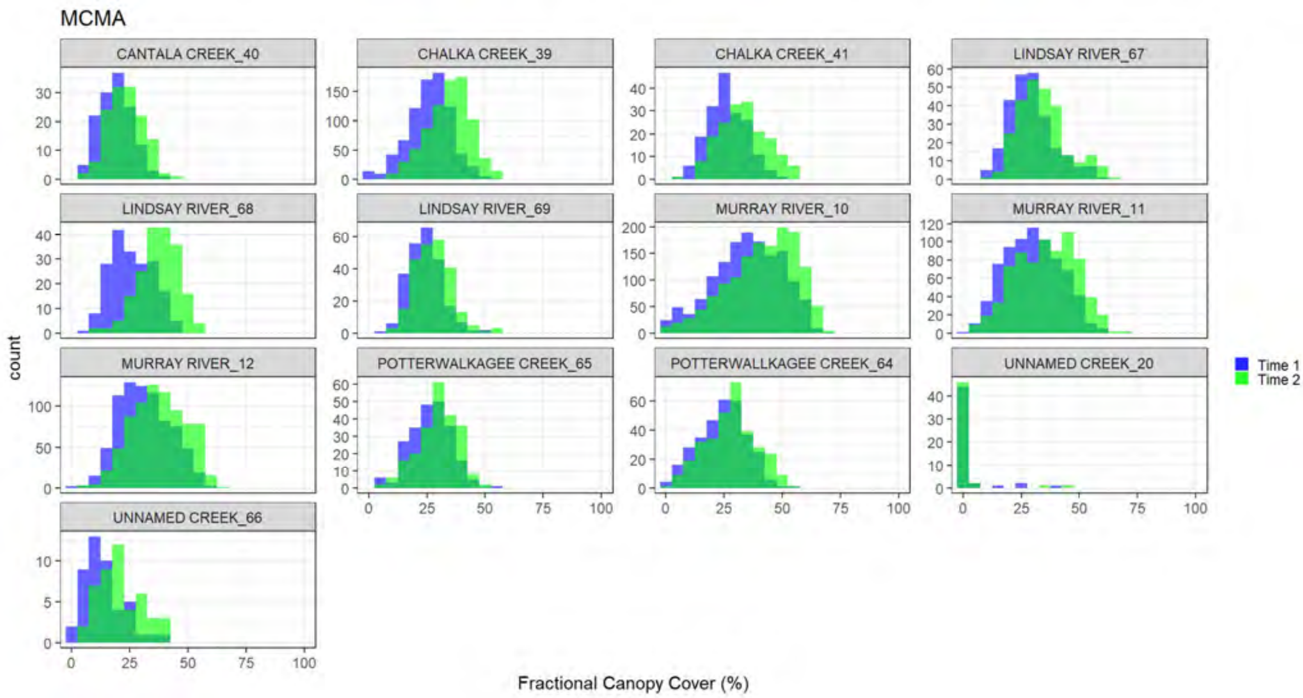


Figure 48 Canopy cover for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections.

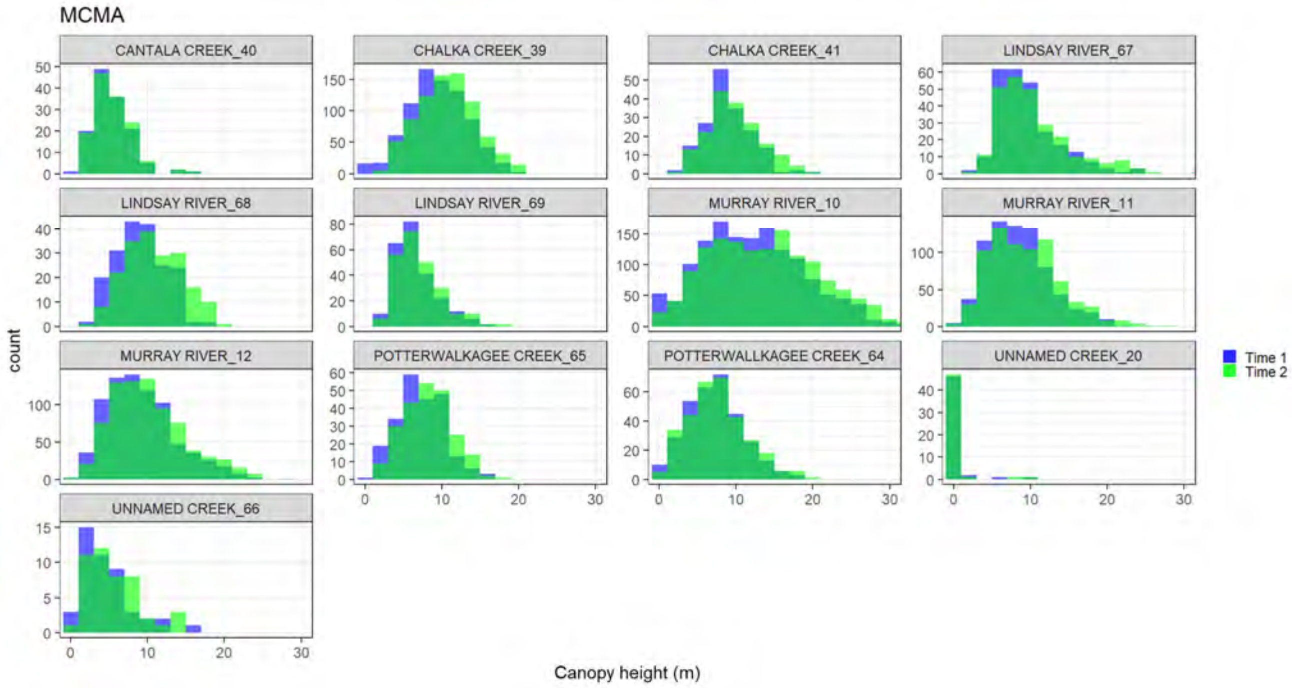


Figure 49 Canopy height for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections.

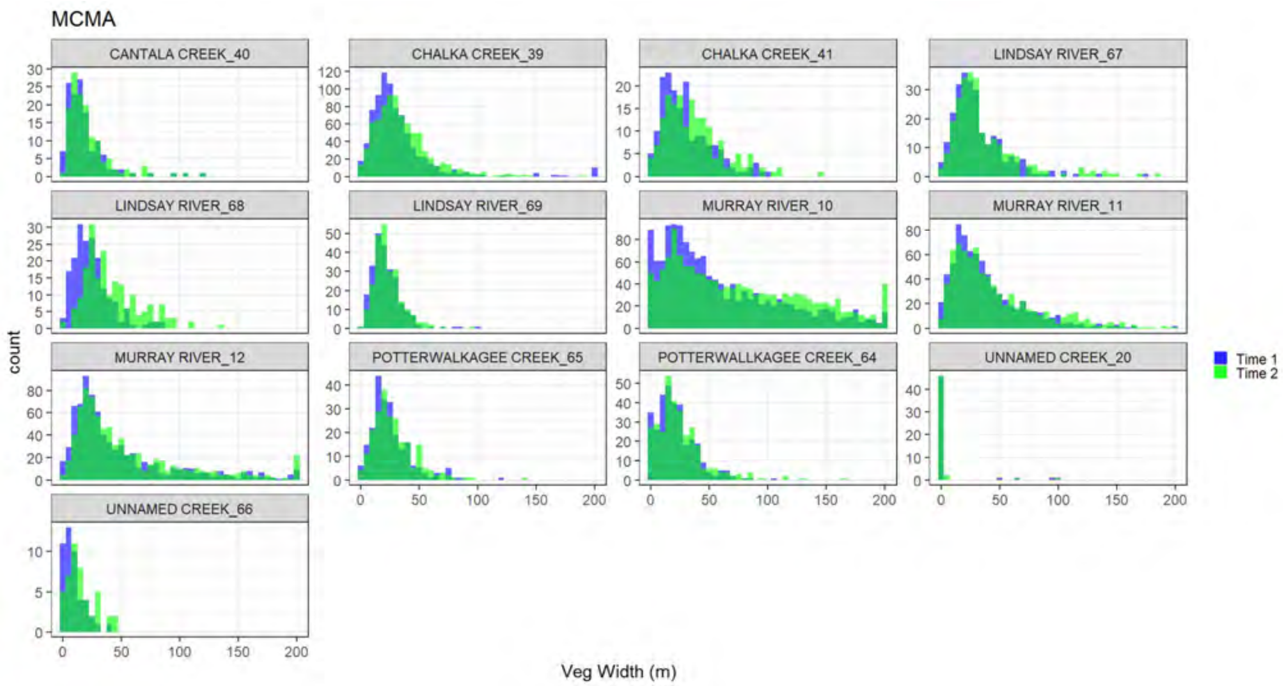


Figure 50 Vegetation width for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections.

	>10m	>20m	>40m
% Segments above threshold (Time 1)	84	56	15
% Segments above threshold (Time 2)	97	86	43
% change Time 1 to Time 2	+13	+30	+28

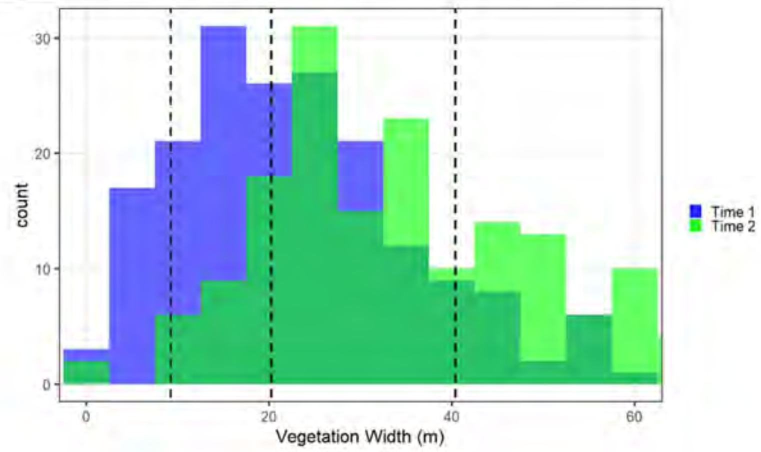


Figure 51 Histograms showing summary of vegetation width at Lindsay River reach 68 in 2010 (Time 1) and 2018 (Time 2). The box at the top shows the % of sections where the vegetation width exceeds 10m, 20m and 30m in the two periods and the % change in the proportion of sections above those thresholds.

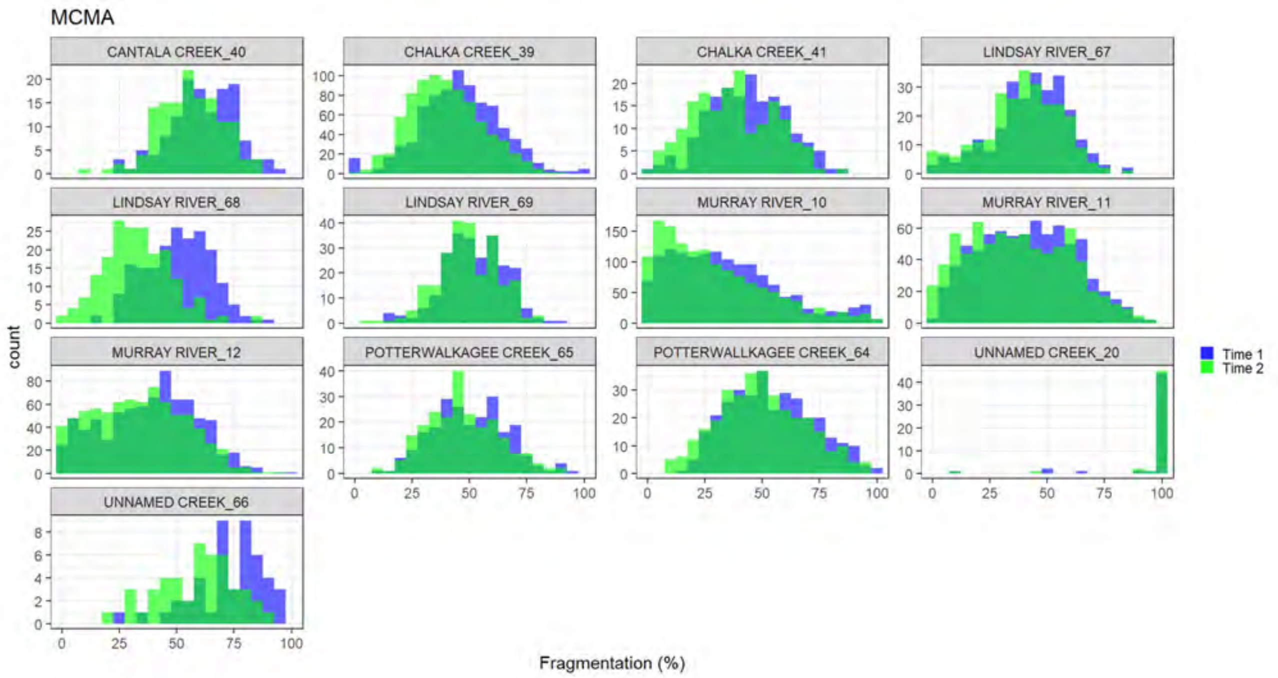


Figure 52 Fragmentation for locations in the MCMA at the two assessment periods. The count on the y-axis is the number of sections

4.3.6 North-East Region

The two assessment periods for ISC reaches in the North-East region were in 2010 (during various months) and 2018 (April to June) (Table 9).

ISC Streamside Zone scores did not change at any reach (Figure 53; Table 10).

Fractional canopy cover was higher at six of the eight reaches assessed (Figure 54; Table 11). The most significant increase was at King River reach 53 where there were 7% more sections with canopy cover greater than 40% in 2019, and ~34% more sections with cover greater than 60% (Table 12). Mean changes in canopy cover ranged from a decrease of 4% (Ovens River Basin 3 reach 6, King River Basin 3 reach 23) to an increase of 8% (King River West Branch Basin 3 reach 53).

Canopy height (Figure 55) decreased by 0.7m at Ovens River reach 7 but increased at all other reaches, by between 0.5m (Ovens River reach 6) and 2.1m (Ovens River reach 4) (Table 12).

Vegetation width increased at more than 50% of sections across all reaches but the magnitude of this change was generally small (Figure 56).

Fragmentation decreased at more than 50% of sections at all reaches in 2018 (Figure 57), although the magnitude of these changes was relatively small overall, <5% change. The exception to this was Ovens River reach 7, where there was a 29% decrease, and ~27% fewer sections with fragmentation above 25% in 2018.

Box 5: The challenges of a shifting channel in the King River

Victoria is characterised by an array of different stream types, including both confined systems (e.g. gorges, confined headwaters), and unconfined systems (e.g. cut and fill or anabranching systems, and meandering rivers (Alluvium 2020)). Laterally active, coarse grained streams are one such type and are very challenging for river managers because of their highly dynamic nature and the fact they are frequently located in extensive cleared agricultural landscapes. These streams often have high stream power and their channels can undergo major changes during flood events.

Panels a and b below show an 800m section of the King River ISC Reach_23, which is a laterally active, coarsed grained river (Alluvium 2020). These two panels show significant changes in the position of the channel between 2010 (blue bank lines) and 2018 (orange bank lines).

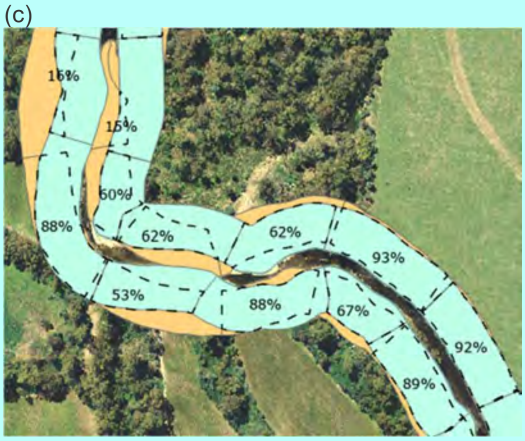
(a)

(b)

Lateral shifts in the channel is challenging for assessment of change in riparian vegetation because the position of the riparian zone, and the vegetation it contains, changes through time. The amount of overlap of buffer regions (panel c) was used in this study to identify river sections with migrating channels. Sections were excluded from summary results if they overlapped by less than 50% between the two assessment periods.

Comparing 2010 and 2018 mapping of the King River ISC reaches 23 and 24, approximately 8% of sections overlappped by less than 50% and were excluded (e.g. panels a and b and the two sections at the top of panel c).

(c)



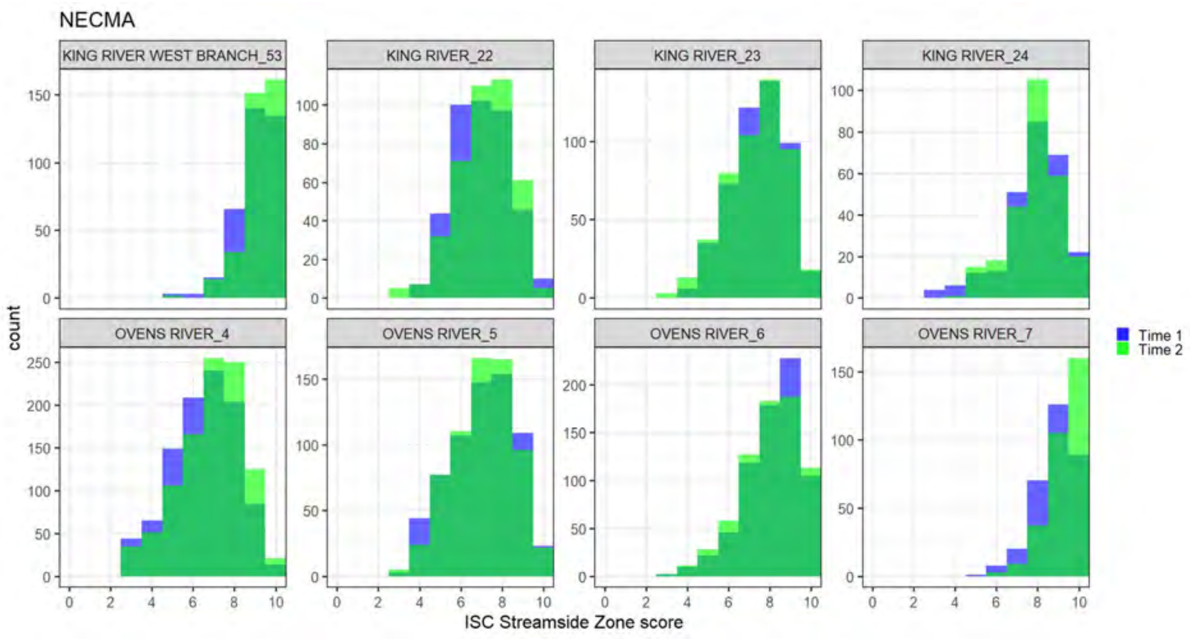


Figure 53 Streamside Zone ISC scores for locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections.

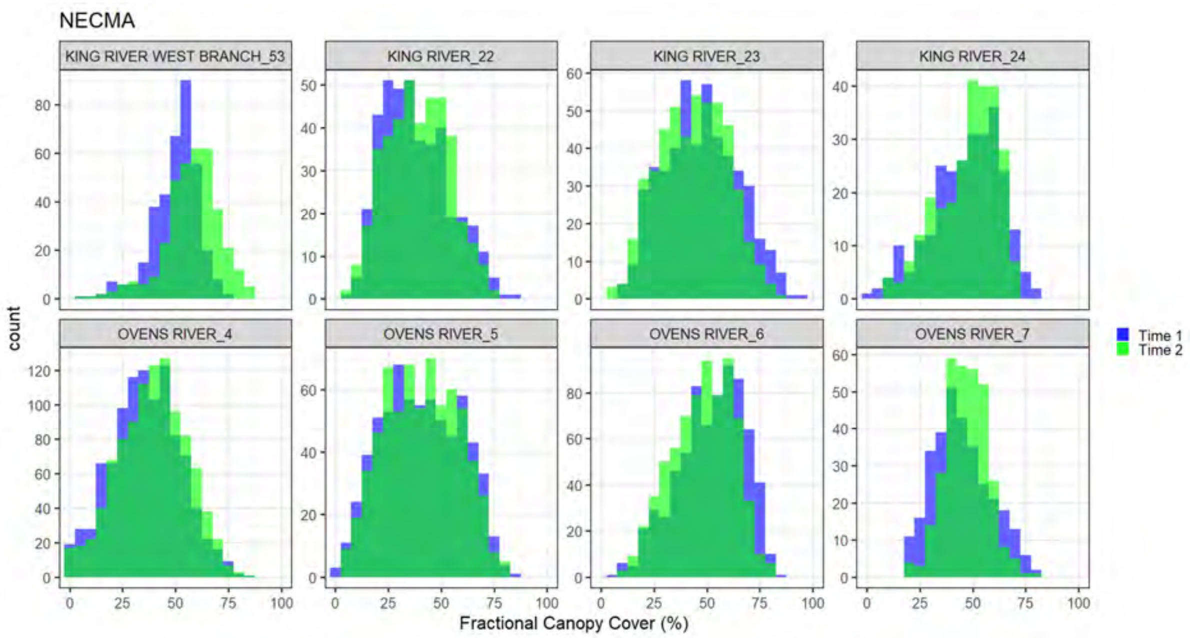


Figure 54 Fractional canopy cover for locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections.

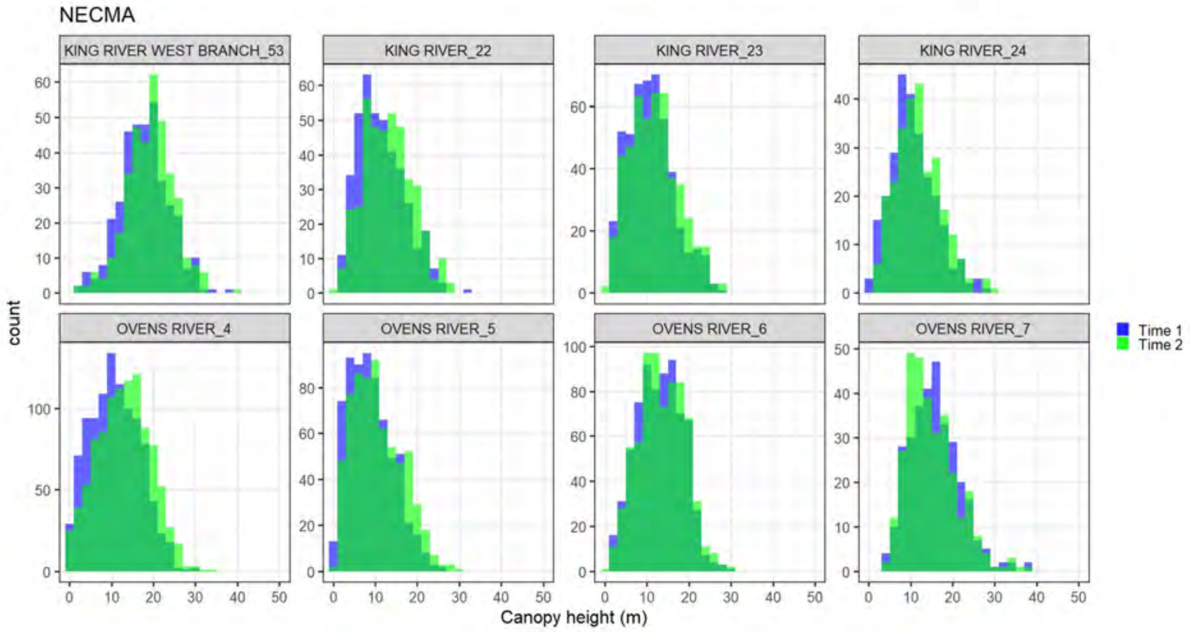


Figure 55 Canopy height locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections.

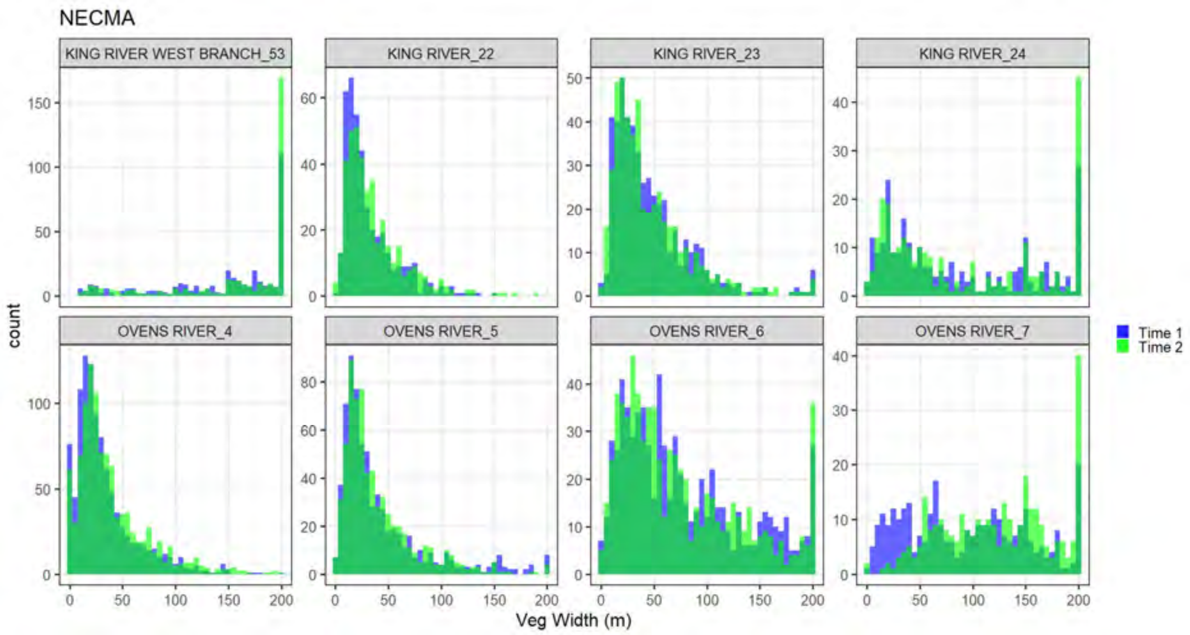


Figure 56 Vegetation width locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections.

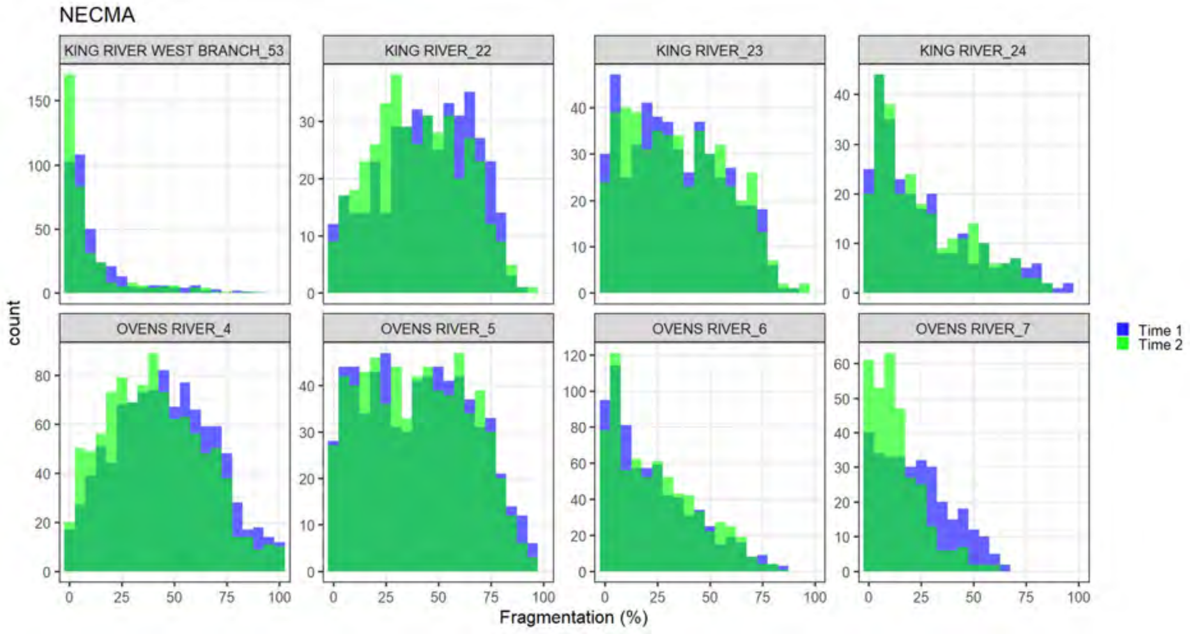


Figure 57 Fragmentation locations in the NECMA at the two assessment periods. The count on the y-ais is the number of sections.

4.3.7 North Central Region

For most reaches in the North Central region, the two assessment periods were in 2010 (Time 1) and 2018 (Table 9). However, for two reaches on the Loddon River and one on the Coliban River, the first assessment period was in December 2009.

ISC Streamside Zone scores increased by one unit at Campaspe River reach 1 but did not change at any other reaches (Figure 58; Table 10).

Increases in canopy cover occurred at some reaches, especially on the Campaspe River (Figure 59; Table 11; Table 12). At Campaspe River reaches 1, 2, 3 and 4, canopy cover increased at between 84 and 97% of sections, and by between 4 and 9%.

Canopy height increased at most reaches (Figure 60). The largest increases occurred at Coliban River reach 22 and Campaspe River reach 3, of 1.7m and 1.2m respectively.

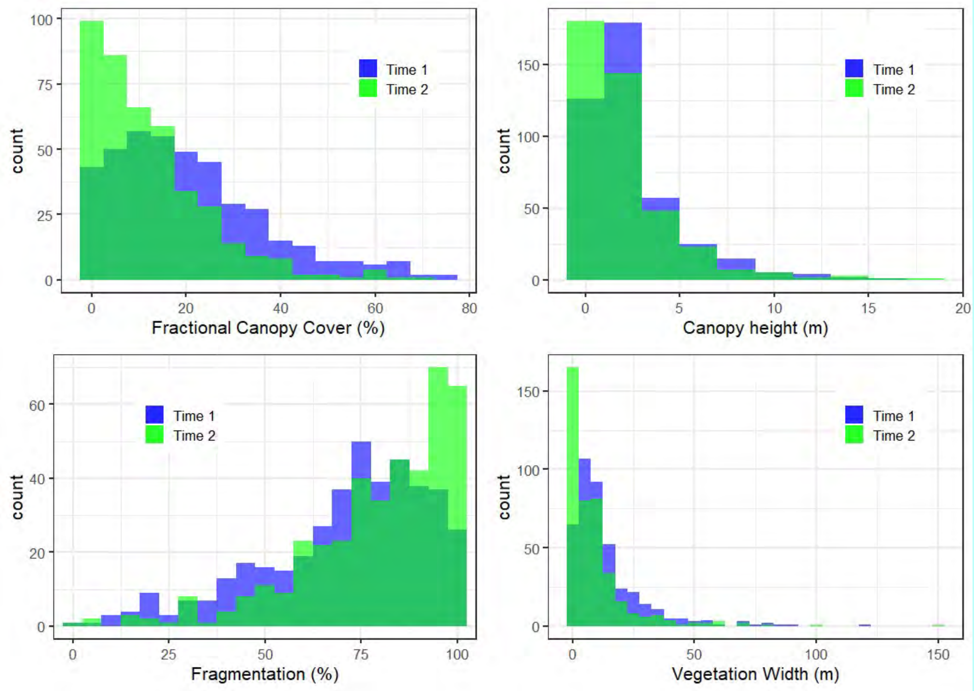
Fragmentation decreased at more than 50% of sections across all reaches except Kangaroo Creek reach 21 (Figure 62), but changes were typically small (a <5% change: Table 10).

Vegetation width also generally increased at all reaches, with the exception of Birch’s Creek reach 21 (Figure 61). However, the magnitude of these changes was also small (on average less than 10m). The exception to this magnitude and extent of change was Campaspe River reach 1, where vegetation width increased at 69% of sections, and by on average 13m (Table 10).

Fragmentation decreased at more than 50% of sections across all reaches except Birch’s Creek reach 21 (Figure 62), but changes were typically small (a <5% change: Table 10).

Box 6: Willow removal in Birch's Creek

Significant willow removal was undertaken along sections of Birch's Creek in the upper Loddon catchment between 2010 and 2018. Willow removal has resulted in large decreases in fractional canopy cover at the reach scale (by 9%), canopy height (by 0.4m), and vegetation width (by 5%), with commensurate increases in fragmentation (by 8%). There is some evidence of regrowth of native woody vegetation with an increase in canopy at heights below 2.5m and canopy cover below 20%.



Aerial photography from 2010 and 2018 showing willow removal at Birch's Creek. Right panel shows changes in fractional canopy cover, with 100% reductions in red, and small patches of regeneration (increases in green).

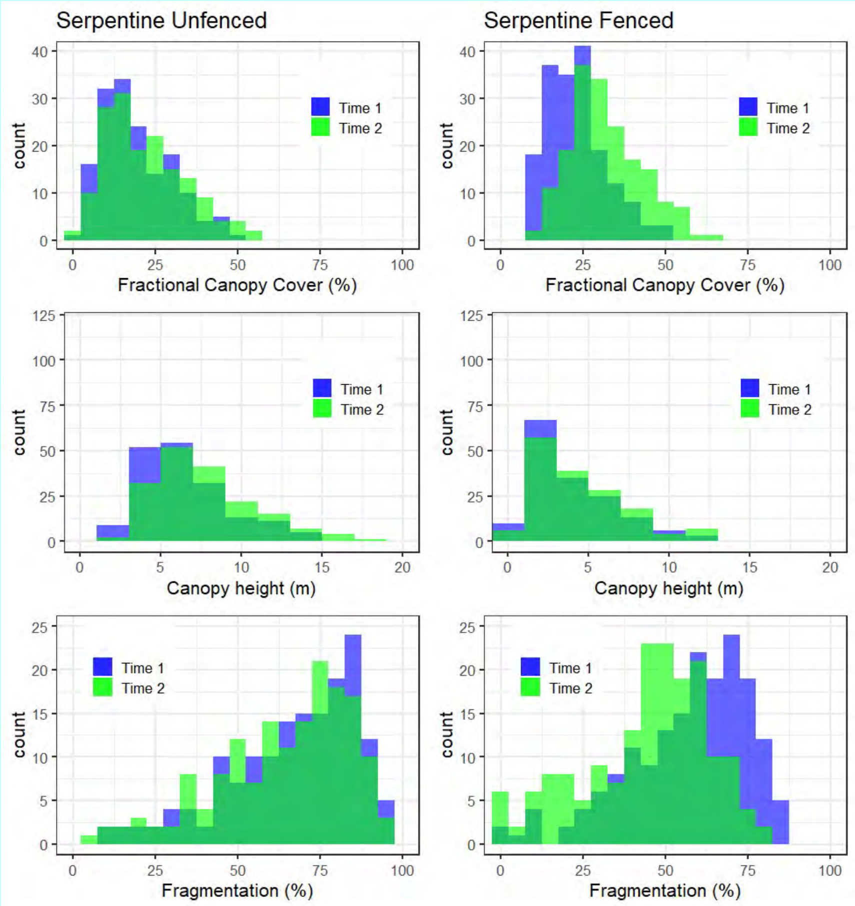
Summary of changes in vegetation metrics on Birch Creek

Metric	2010	2018	Diff
Fractional canopy cover (%)	21	12	-9
Canopy height (m)	2.4	2.0	-0.4
Fragmentation (%)	71	79	+8
Vegetation width (m)	14	9	-5

Box 7: Fencing on Serpentine Creek

A 7km section of Serpentine Creek (Basin 7 reach 11) extending north of the township of Serpentine shows the response of woody vegetation to fencing undertaken in 2009-10. This was followed up with revegetation in 2011-12. The site was revisited in 2019, as captured below.

In the fenced section of Serpentine Creek, canopy cover and canopy height increased by 8% and 2.2m and, fragmentation decreased by 12% whereas in an equivalent, unfenced section of Serpentine Creek, canopy cover and fragmentation both increased by 3% and canopy height increased by 1m. Therefore, canopy cover and canopy cover increased and fragmentation decreased more substantially (by ~5%, 1.2m and ~15%) within the fenced section between 2010 and 2018.



Summary of changes in vegetation metrics on Serpentine Creek

Mean changes	Serpentine unfenced			Serpentine fenced			Fenced-Unfenced
Metric	**2010**	**2018**	**Diff**	**2010**	**2018**	**Diff**	**Difference**
Fractional canopy cover (%)	19	22	+3	23	32	+9	+6
Canopy height (m)	3.8	4.3	1.0	6.5	7.8	+2.2	+1.2
Fragmentation (%)	67	64	+3	57	44	-13	-16

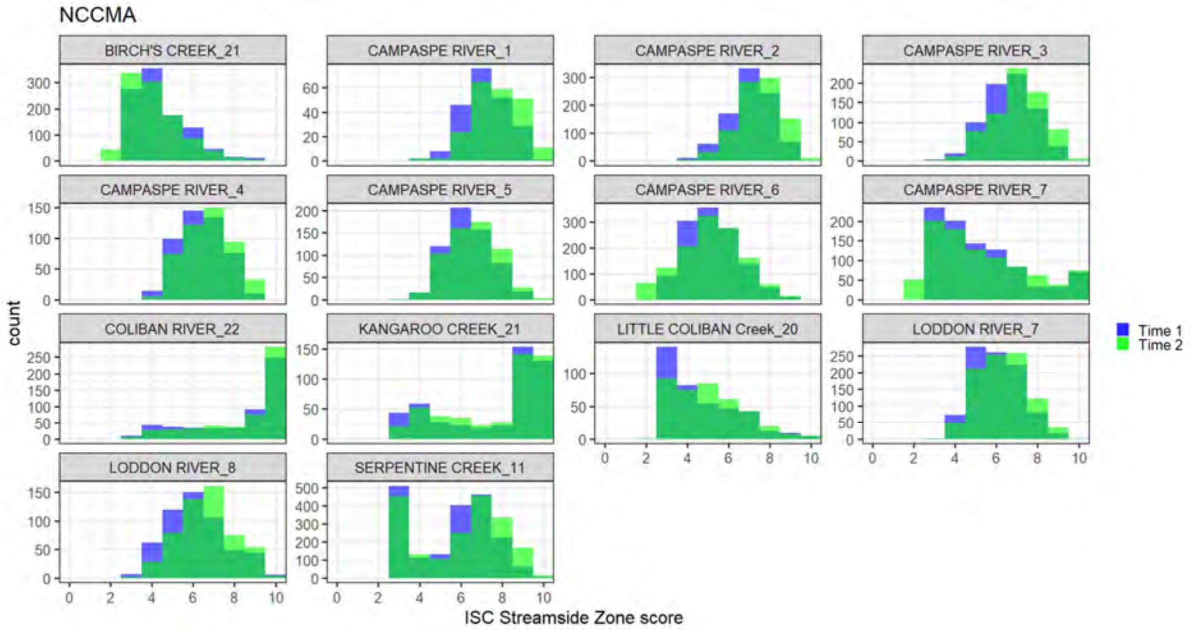


Figure 58 Streamside Zone ISC scores for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections.

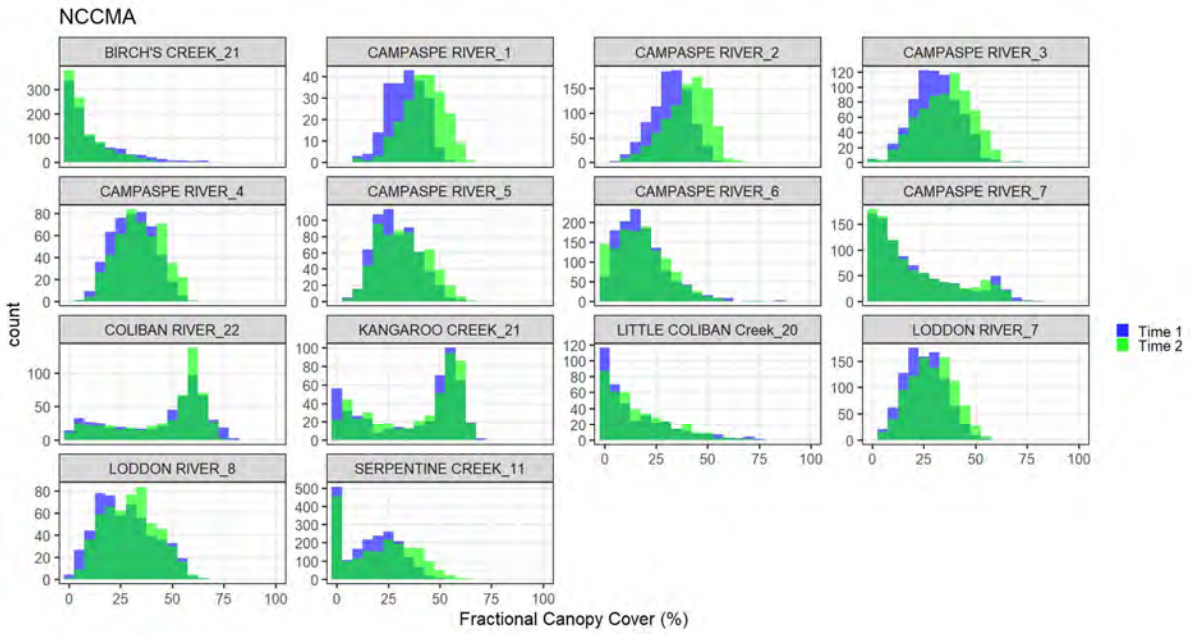


Figure 59 Fractional canopy cover for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections.

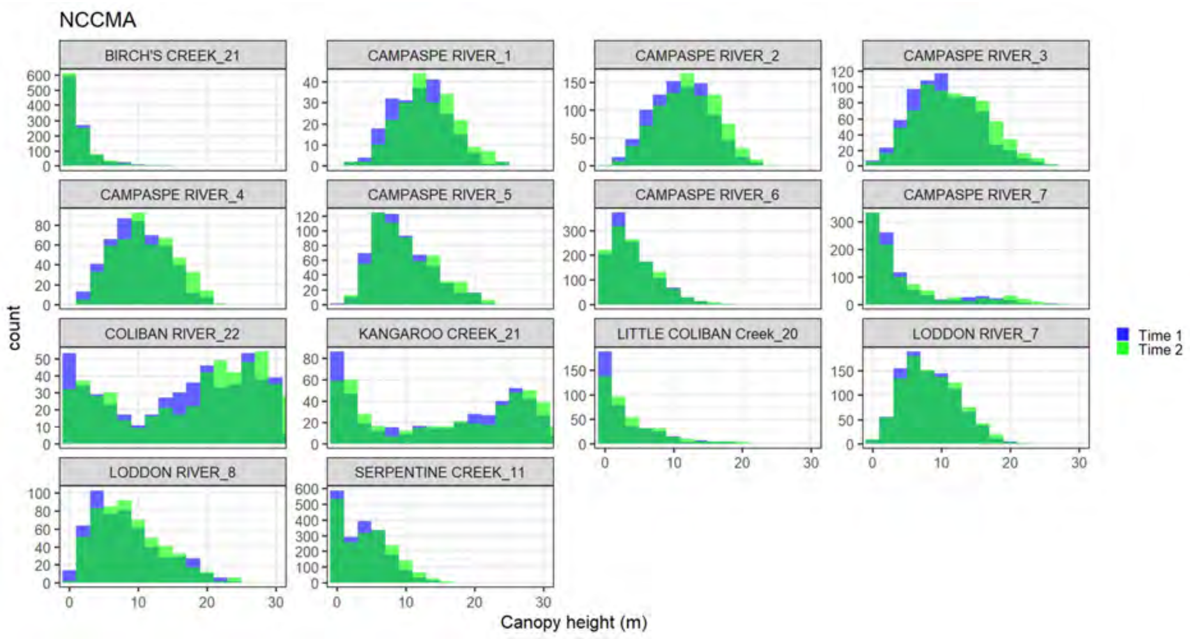


Figure 60 Canopy height for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections.

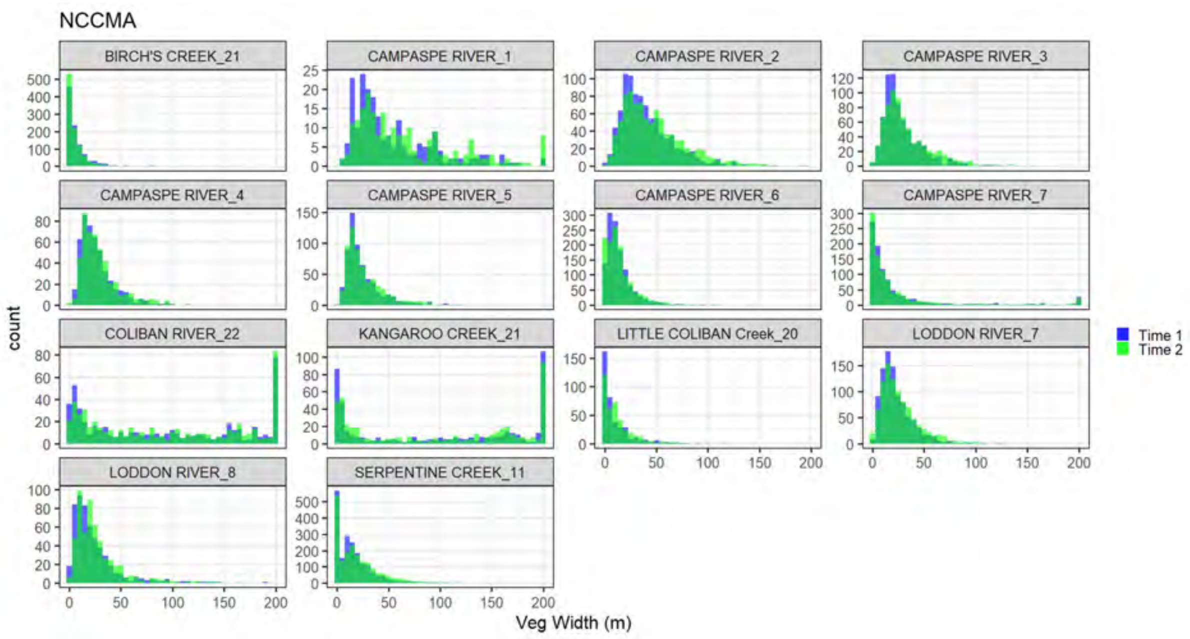


Figure 61 Vegetation width for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections.

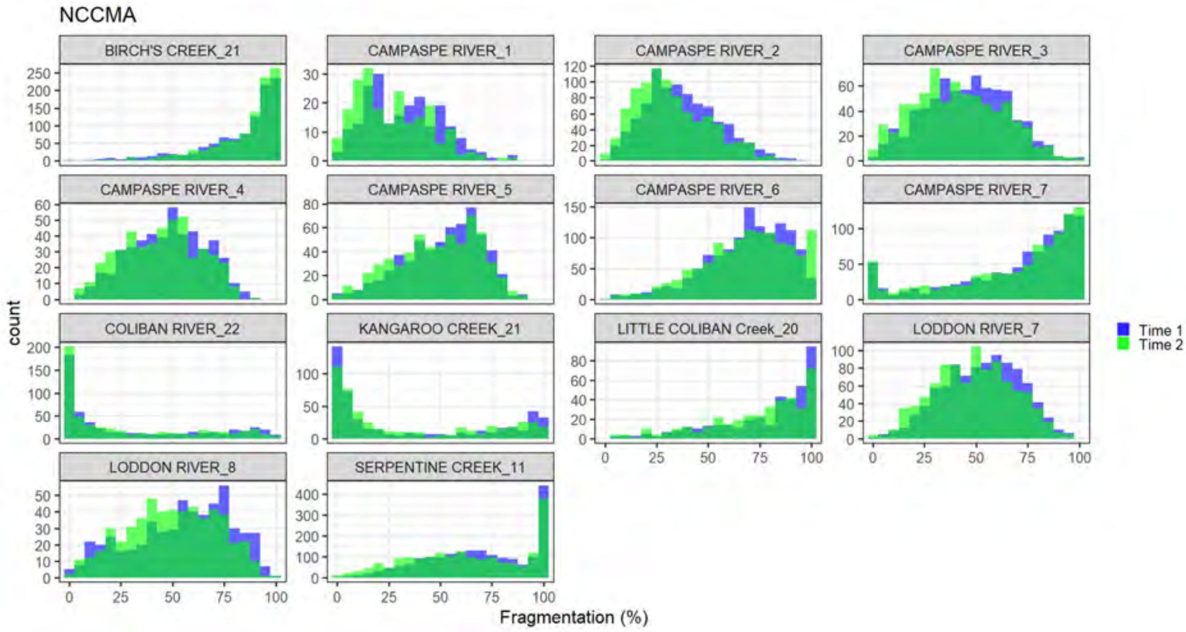


Figure 62 Fragmentation for locations in the NCCMA at the two assessment periods. The count on the y-axis is the number of sections.

4.3.8 Wimmera Region

The two assessment periods for the Wimmera region were in 2010 and 2018 (Table 9).

In general, ISC Streamside Zone scores and vegetation metrics were unchanged in the Wimmera region between 2010 and 2018 (Figure 63 - Figure 67; Table 10-Table 12).

Fractional canopy cover increased at more than 50% of sections across all reaches, but the largest changes were small i.e. ~4% increases at Wattle Creek Basin reach 53 and Wimmera River reach 10, and the mean change across all reaches was a 2% increase.

Changes in other metrics were similarly of very small magnitude – mean changes in canopy height, vegetation width and fragmentation and vegetation width were a 1% decrease, 1% decrease, and 3% increase respectively.

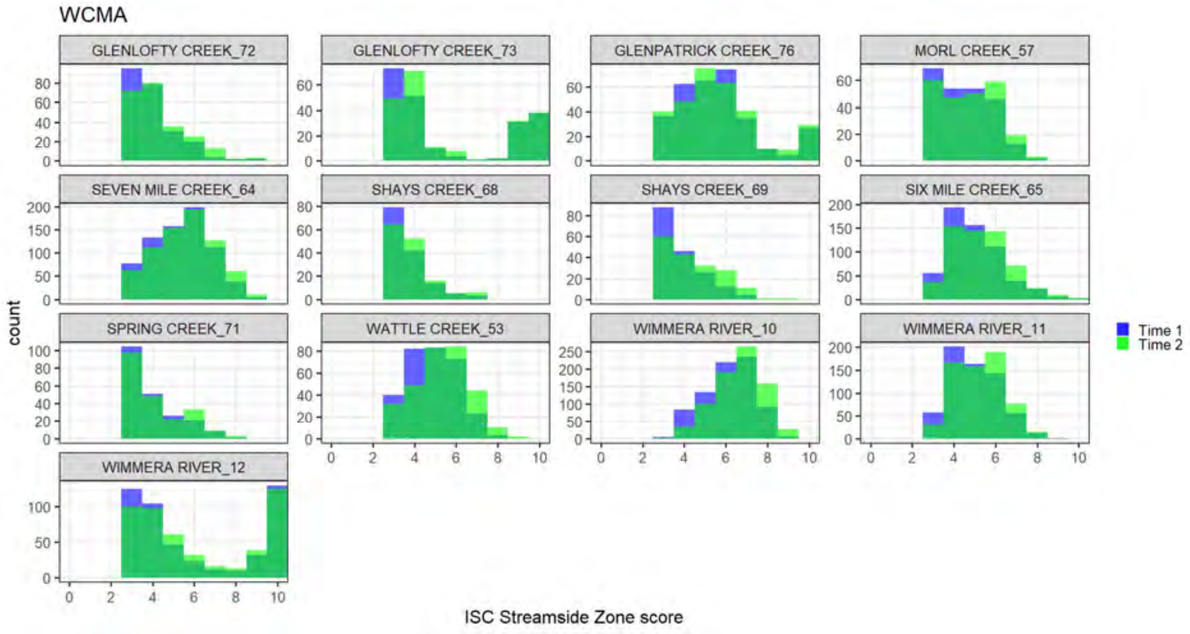


Figure 63 Streamside Zone ISC scores for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections.

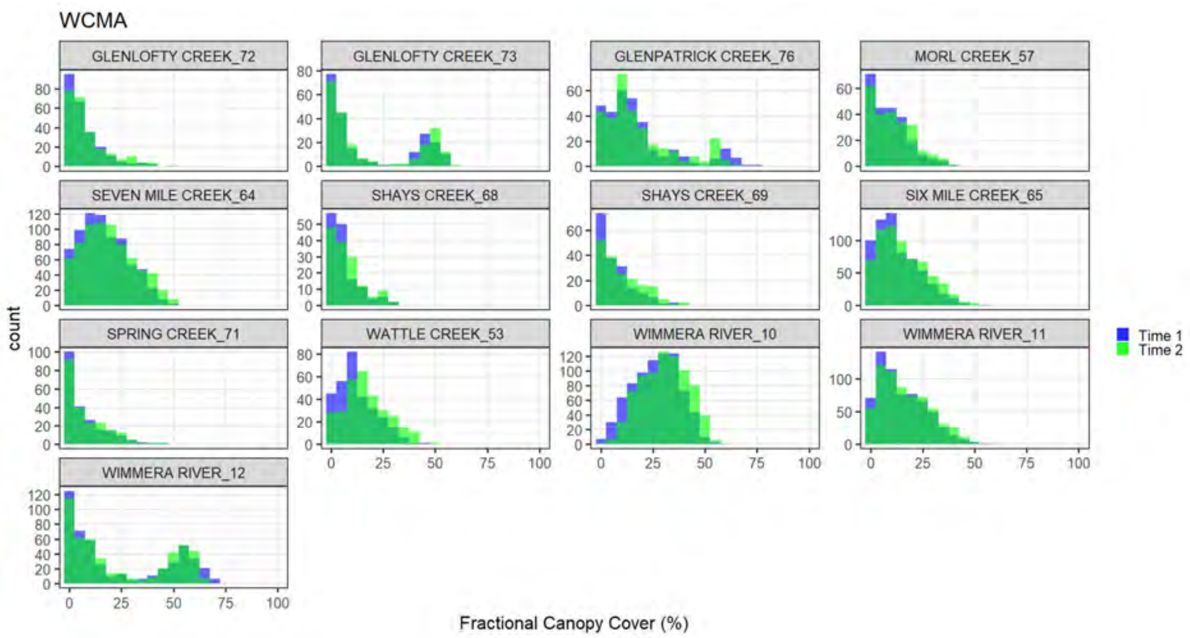


Figure 64 Fractional canopy cover for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections.

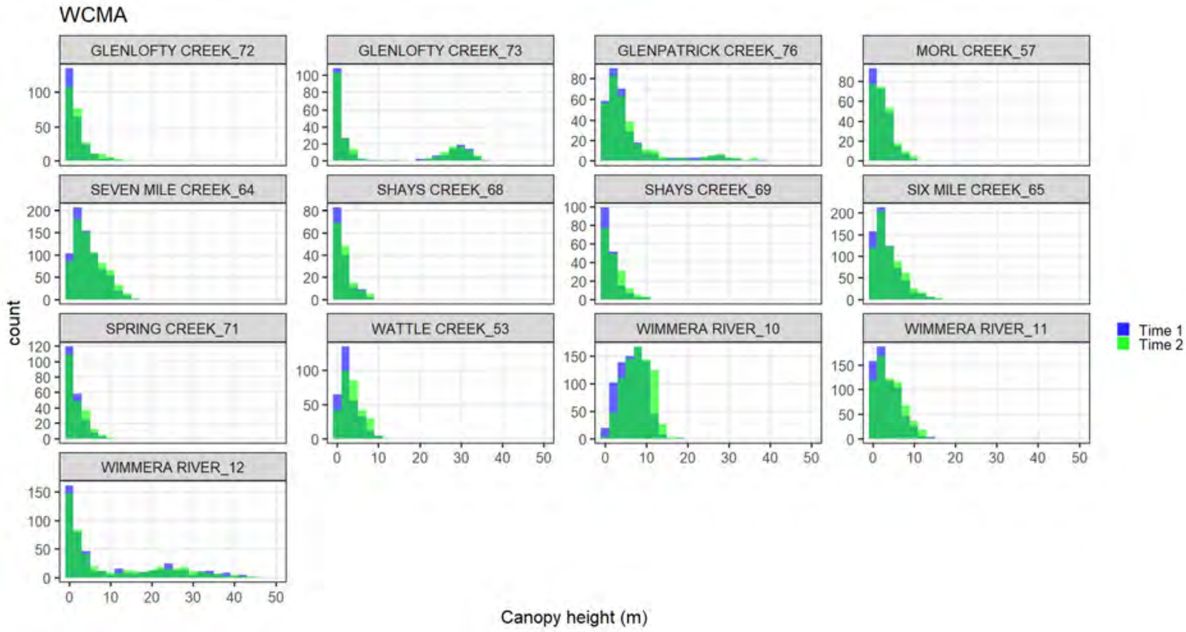


Figure 65 Canopy height for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections.

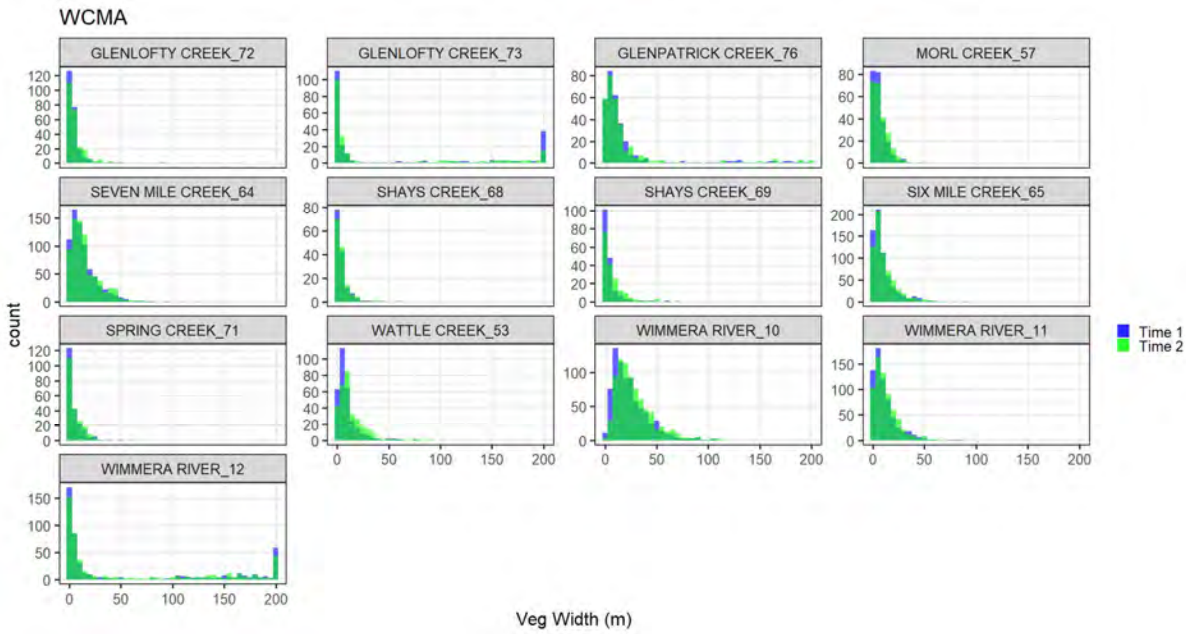


Figure 66 Vegetation width for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections.

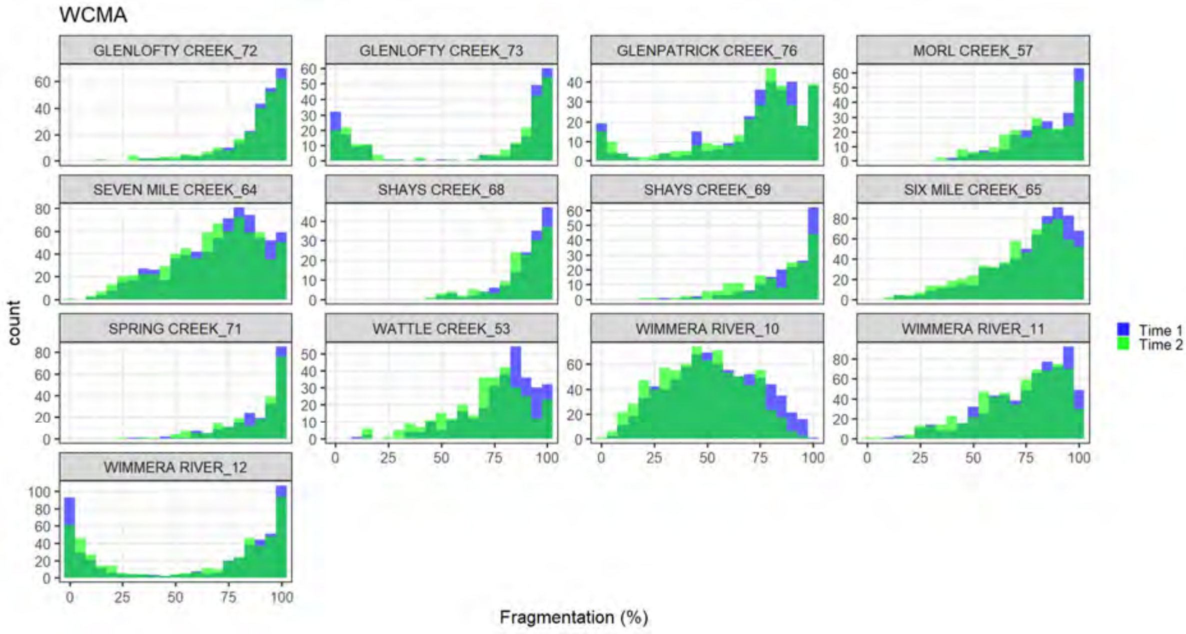


Figure 67 Fragmentation for locations in the WCMA at the two assessment periods. The count of the y-axis is the number of sections.

4.3.9 West Gippsland Region

The two assessment periods for the West Gippsland region were in 2010 and 2018.

ISC Streamside Zone scores increased at 11 of the 21 reaches assessed (Figure 68; Table 10). but at ten reaches, this increase was by one unit only. The exception was Macalister River reach 8, where a two unit increase was observed.

Canopy cover increased at more than 50% of sections at all reaches except the Jack River reach 32 (Table 11; Figure 69). At the Macalister River reach 8, for instance, cover increased on average by 20%, and 38% more sections had canopy cover greater than 40% in 2018 than in 2010. Five other reaches had average increases in canopy cover of 10% or more: Tarra River Basin reach 34, Thomson River reach 3, Avon River reach 20, Avon River reach 21 and Thomson River reach 4. In contrast, canopy cover decreased at 54% of sections at Jack River reach 32, on average by only 1%. Most reaches had either negligible or small reductions in the percentage of sections with canopy cover greater than 60 or 80%.

Canopy height increased at more than 60% of sections at all reaches. many reaches, especially in terms of the percentage of sections above 2 and 5m (Figure 70)). At the Macalister River reach 8, ~32 and 40% more sections had canopy heights above 2m and 5m in 2018 respectively. Across all reaches, the average increase in canopy cover was by 1.6m, with the largest increases at Macalister River reach 8 (3.1m), Franklin River reach 21 (2.9m) and Tarra River reach 4 (2.9m).

Vegetation width also increased across almost all reaches (Figure 71). For example, at Macalister River reach 8, 39% more sections were wider than 20m in 2018 than in 2010, and 21% more sections were wider than 40m. Similarly at Avon River Basin reach 20, 33% more sections had riparian widths above 40m in 2018.

Decreases in fragmentation were observed at more than 50% of sections at all but two reaches: Franklin River reach 22, and Jack River Basin reach 32 (Figure 72; Table 10, Table 12). At three reaches, fragmentation decreased on average by more than 15%: Avon River reach 20, Macalister River reach 8 and Thomson River reach 4.

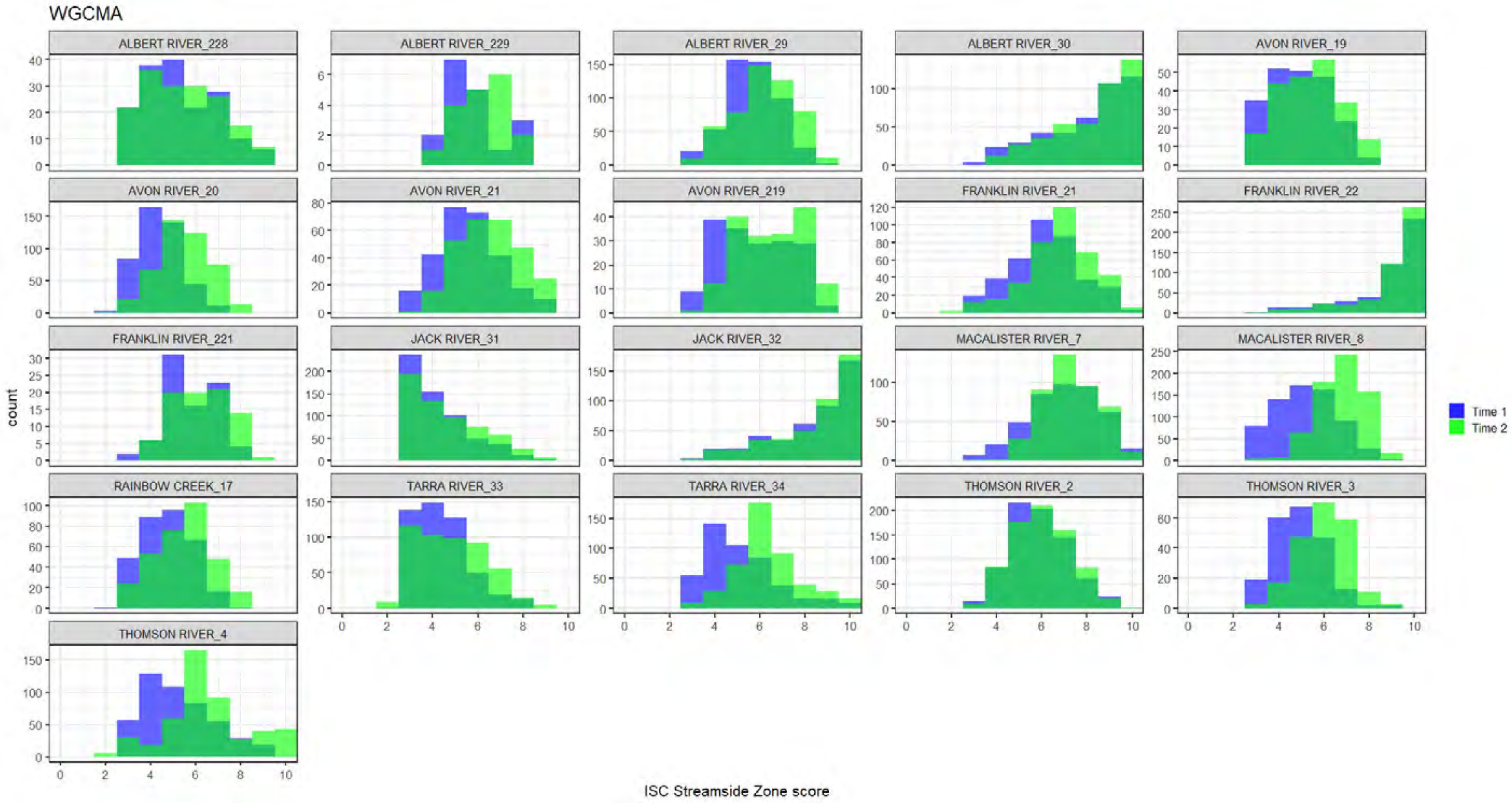


Figure 68 Streamside Zone ISC scores for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections.

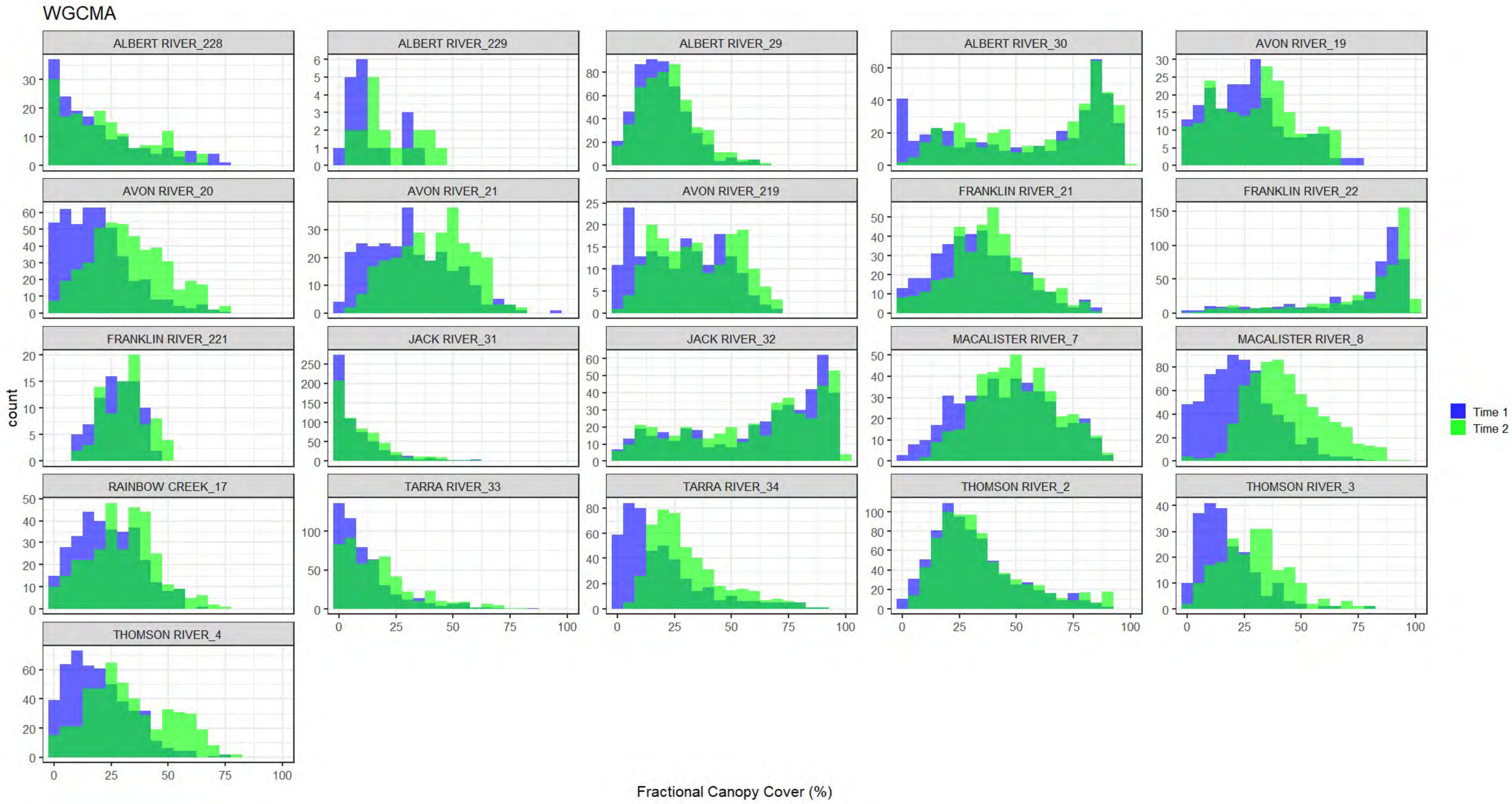


Figure 69 Fractional canopy cover for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections.

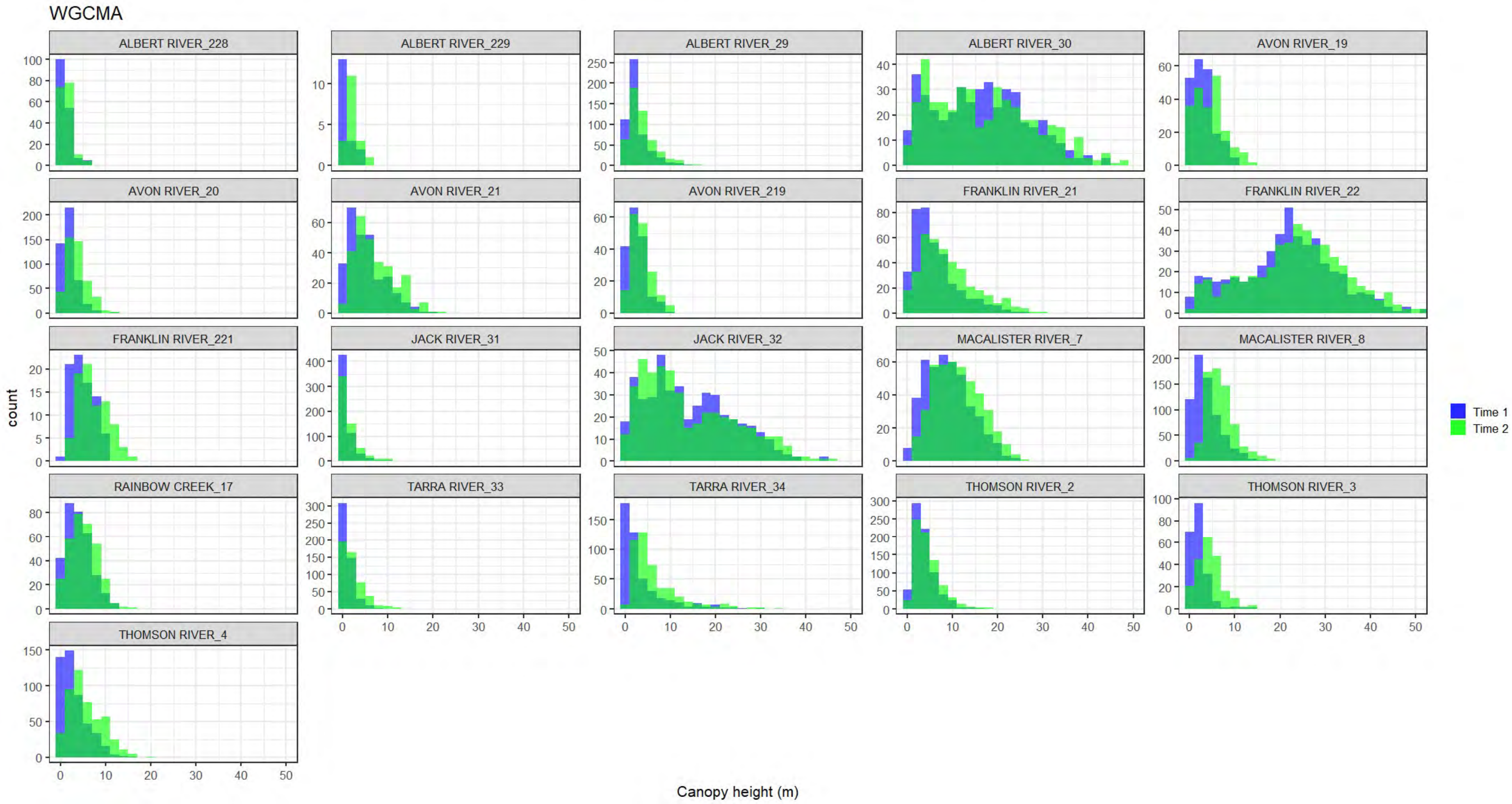


Figure 70 Canopy height for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections.

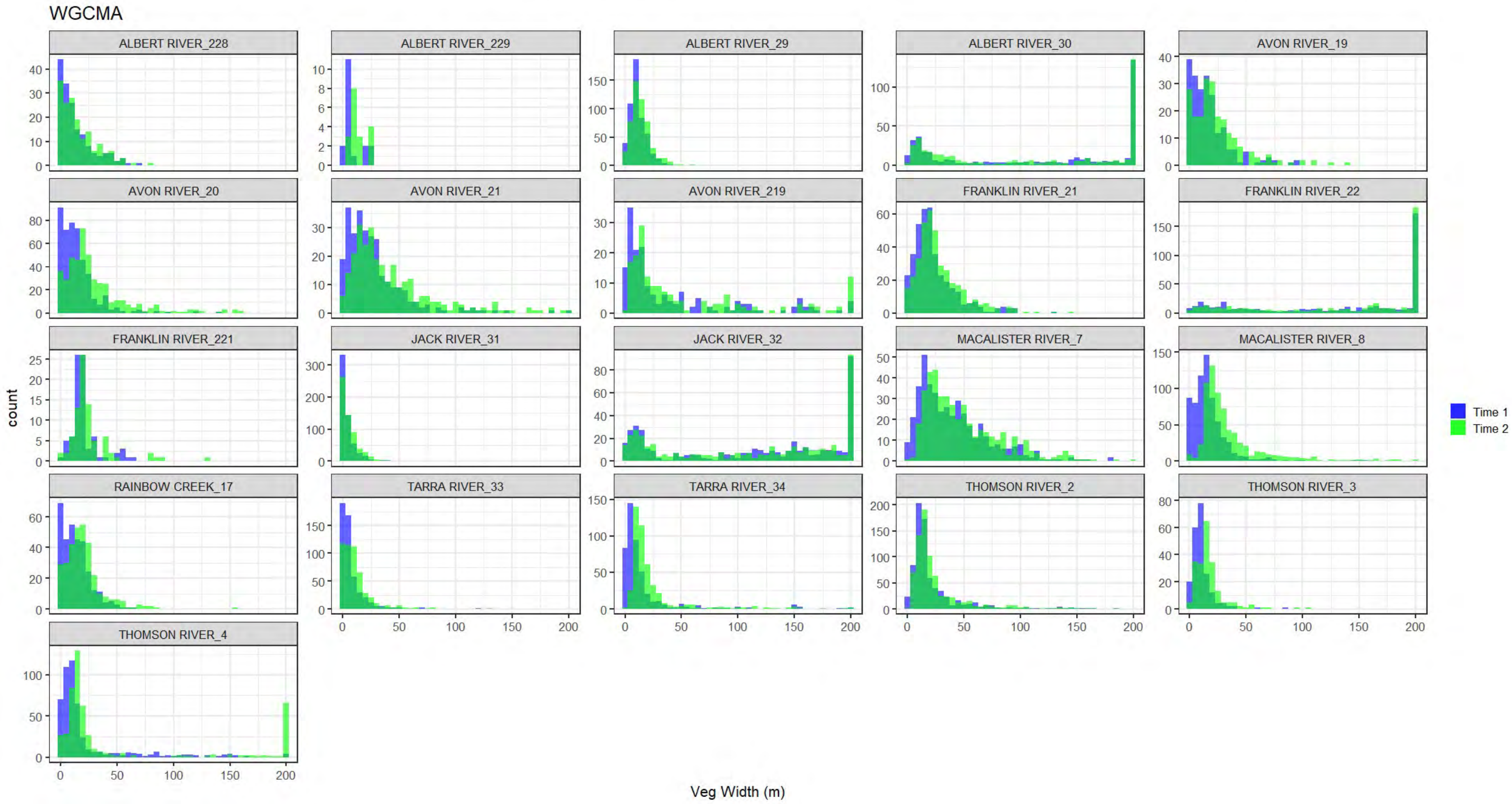


Figure 71 Vegetation width for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections.

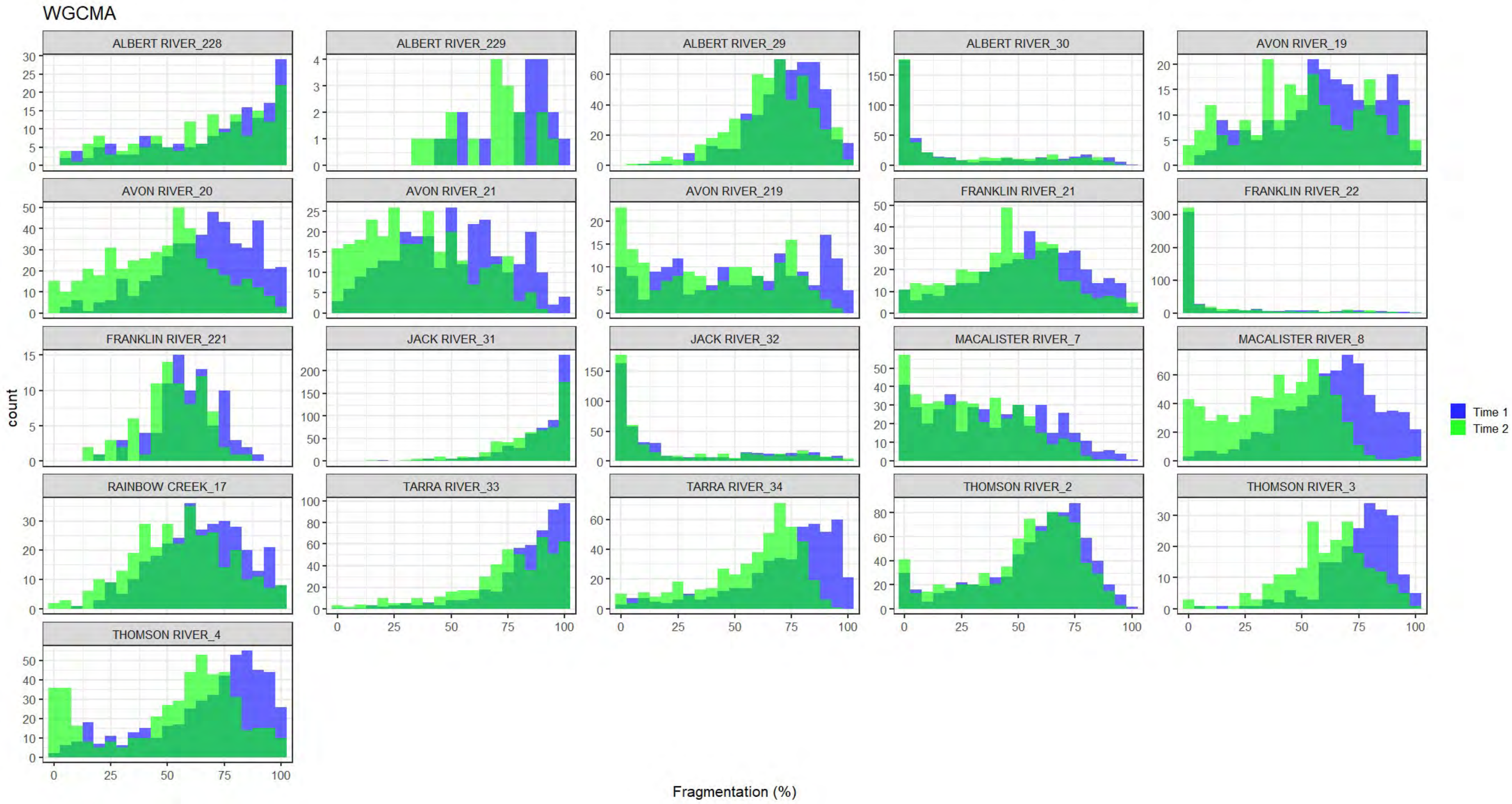


Figure 72 Fragmentation for locations in the WGCMA at the two assessment periods. The count on the y-axis is the number of sections.

4.4 Examining the potential influence of buffer width on assessments of riparian change

For this report, a buffer width of 40m was used to calculate vegetation metrics. A 40m buffer width was used for the ISC3 2010 Streamside Zone metric calculations and applied across all ISC reaches with the aim of characterising riparian condition at this spatial extent. Whilst this width may be a reasonable extent to assess condition it may not be as meaningful to assess and track changes related to management objectives, which are often at narrower buffer widths. Riparian metrics can now be calculated at widths ranging from 10m to 200m. However, it is important to note that assessments of change in riparian vegetation change will likely vary in relation to the buffer width that is used.

To illustrate, two examples are presented, from Cann River reach 14 in East Gippsland and Chalka Creek reach 39 in the Mallee (Figure 73; Figure 74; Table 8). At Cann River, riparian vegetation is narrow, and using a buffer wider than 40m would mean that cleared land adjacent to the riparian vegetation will also be sampled. The consequence of including cleared adjacent land is a reduction in the values observed at each time period and also the magnitude of change between time periods. For example, the average canopy cover in this reach in 2010 was 58% using a 10m buffer and 44% using a 40m buffer; using a 10m buffer, a 16% reduction in canopy cover was observed but this difference was reduced to 6% using the 40m buffer (Table 8).

In comparison to Cann River, riparian vegetation is more homogenous moving out laterally from the channel at Chalka Creek, and the choice of buffer width has less influence on assessments of riparian vegetation. Canopy cover increased by between 6 and 8% across all buffer widths (Table 8).

These two examples illustrate that assessments of vegetation will depend on buffer width in some instances, especially where riparian buffers are narrow so increasing buffer width increases the area that is sampled without woody vegetation. On expansive floodplains with relatively homogenous vegetation, results will be less sensitive to the buffer width chosen for the assessment.

The Victorian Waterway Management Strategy (DEPI 2013) outlines the aim for riparian fencing to be at least 20m wide on average from the top of the bank. Much of the management effort by CMAs is implemented at widths around 20m to comply with this policy. The results here highlight that it is important that future assessments of change consider the buffer width objectives of riparian management.

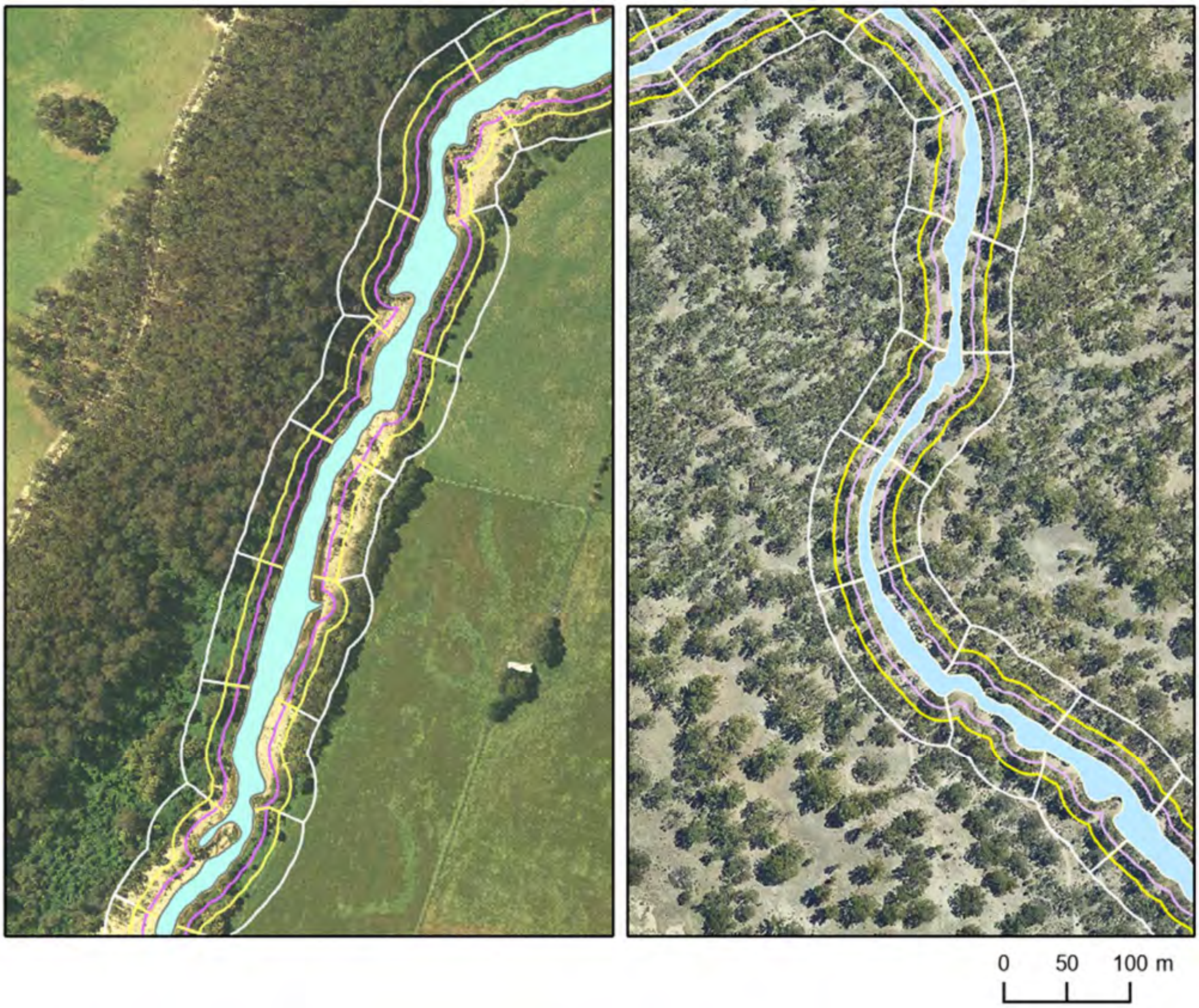


Figure 73 Two examples, from Cann River in the East Gippsland CMA (left) and Chalka Creek in the Mallee CMA (right), showing multiple buffer widths from the stream bed out laterally to 10m (purple line), 20m (yellow line) and 40m (white line).

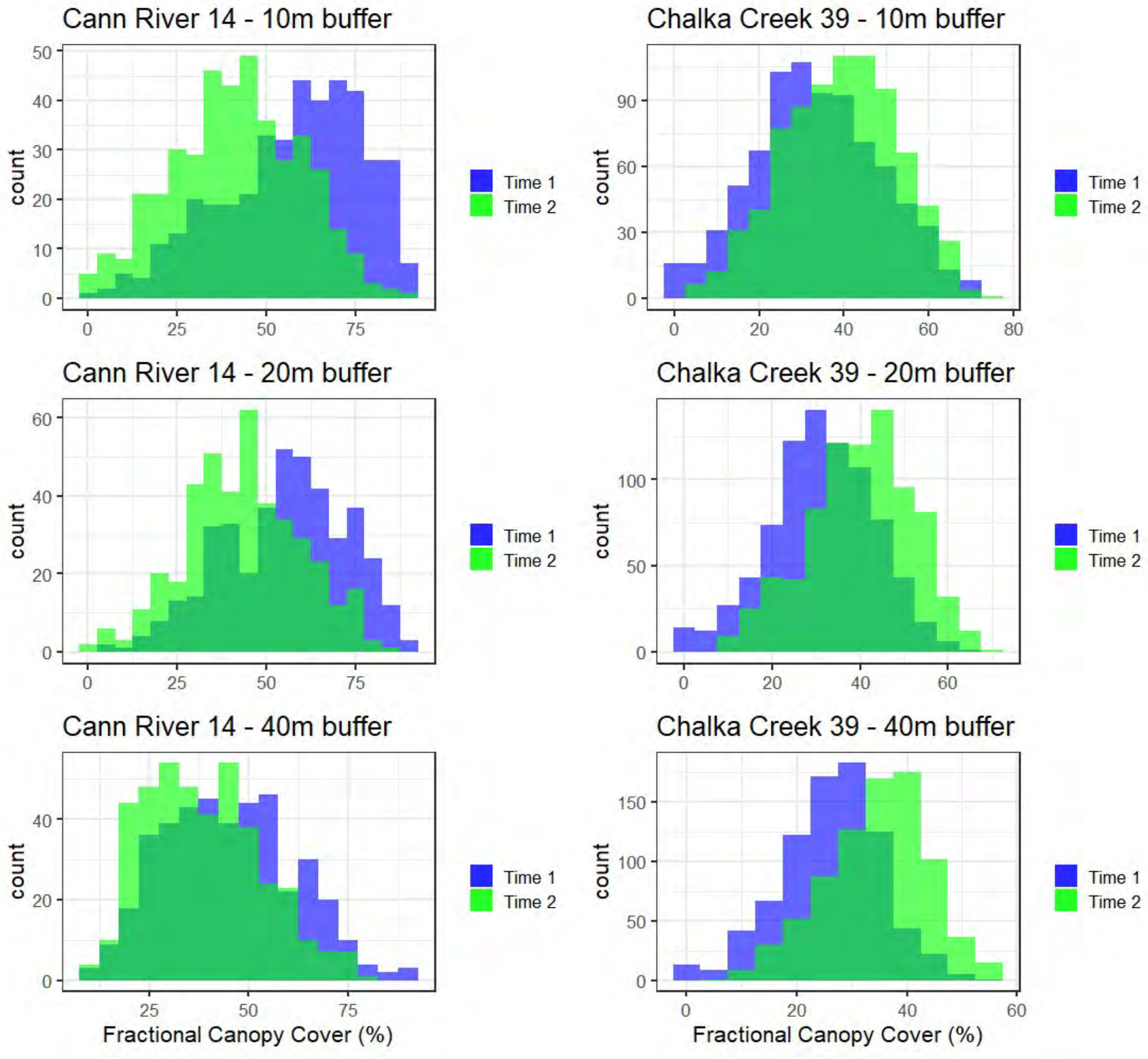


Figure 74 Canopy cover at Cann River 14 and Chalka Creek 30 across the two time periods and at three buffer widths.

Table 8 Summary of canopy cover (%) at Cann River 14 and Chalka Creek 39 across the two time periods and at three buffer widths.

	Cann River 14			Chalka Creek 39		
	Canopy cover 2010 (%)	Canopy cover 2018 (%)	Cover difference (2018-2010)	Canopy cover 2010 (%)	Canopy cover 2018 (%)	Cover difference (2018-2010)
10m	58	42	-16	33	39	6
20m	55	44	-11	31	39	8
40m	44	38	-6	26	34	8

4.5 Using fractional canopy cover at different height strata to interpret vegetation change

For this report, overall changes in fractional canopy cover have been used to describe changes in the cover of woody vegetation. However, data are also available for fractional canopy cover at various height intervals (described in Section 3.2.1). Examining changes in fractional canopy cover at different height intervals can be used to help interpret the causes of changes in overall fractional canopy and/or track expected changes in height intervals due to management actions.

For example, at Acheron River Reach 62, 89% of sections had total fractional cover of less than 50% in 2010, largely due to a bushfire that impacted much of the upper catchment prior to the first LiDAR assessment. Total fractional cover had increased substantially by 2018, with almost half of sections having cover of over 50% (Figure 75a). An examination of the mean cover of height intervals shows that most of this change was due to increases of height strata less than 15m, with the largest increase in the 5-10 interval coinciding with post-fire recruitment and regrowth in the intervening 8 years (Figure 75b).

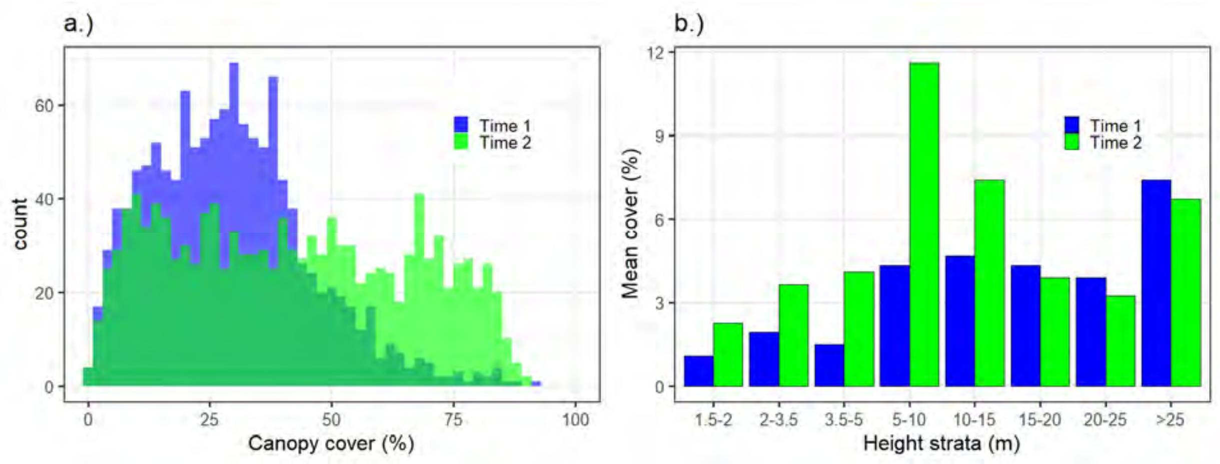


Figure 75 (a) overall canopy cover and (b) canopy cover at different height strata at Acheron River reach 62 in Time 1 (2010) and Time 2 (2018).

Alternatively at Snowy River reach 4, mean total canopy cover had increased from 29% in 2010 to 42% in 2018 (Figure 76a), however these increases were spread relatively evenly across all height intervals (Figure 76b). Increases in overall canopy cover were likely due to a sustained regime of re-vegetation across a longer time period.

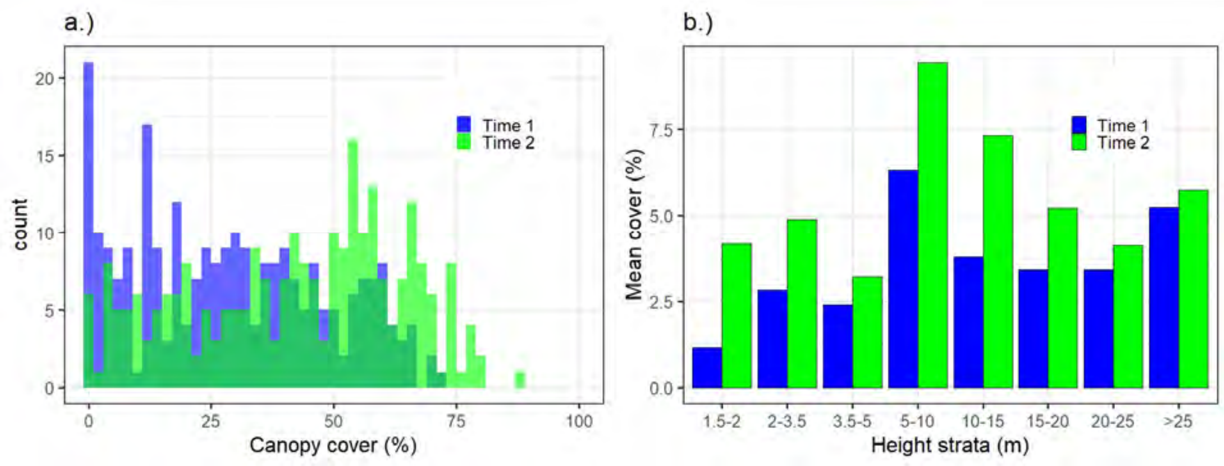


Figure 76 (a) overall canopy cover and (b) canopy cover at different height strata at Snowy River reach 4 in Time 1 (2010) and Time 2 (2018).

5. Next steps

Several key areas can be explored using the recently collected LiDAR data and will form the focus of further work.

Incorporation of woody weeds
Discriminating woody weeds from native woody vegetation within the recently collected data set and derived scores will facilitate improved interpretation of any observed changes in woody vegetation. Effort will be directed foremost at reaches and catchments where woody weeds represent a significant management issue. The geodatabase products derived as part of the SCA accommodate a woody weed assessment at the scale of each section (~100m, left and right bank). At present, the second assessment period contains identical scores to those collected as part of ISC3 assessment, so the primary task involves altering these values in sections where woody weed management has occurred or new infestations are observed. This will rely on a combination of CMA woody weed management data as well as manual interpretation of aerial imagery.

Attribution of change in riparian vegetation

There were many instances where changes in one of more woody vegetation metrics were observed between the two assessment periods. Reasons for these changes are varied and are likely to include the types and quantities of riparian management as well as environmental factors like rainfall, temperature and hydrology. Attributing changes to riparian management requires reliable information from CMAs about the characteristics of riparian management (e.g., location, timing, type of intervention) prior to and between the two assessment periods. DELWP Standard Output data in many cases is insufficient for this purpose as it does not extend far enough back in time, only includes outputs generated by state funding and/or is not of sufficient quality.

To explore the influence of environmental change or gradients, freely-available datasets (e.g. rainfall and temperature from the Bureau of Meteorology; hydrological information from gauges; hydrological and land use information from the Australian Hydrological Geospatial Fabric) could be utilised.

Changes in woody riparian vegetation metrics could plausibly be related to a set of predictors using statistical models, potentially employing an analogous hierarchical modelling framework to that previously used to examine the impacts of climatic variation and vegetation on stream biota (Thomson et al. 2012). This framework will enable the potential drivers of changes in riparian vegetation to be explored at different spatial scales (e.g. state-wide, CMA regions, biogeographical regions, EVC types, ISC reaches).

Should the requisite data on riparian management become available then this type of analysis will help identify when and where different management interventions lead to changes of a given rate and magnitude in riparian vegetation. Variability in responses could relate to the type of management (e.g. revegetation and fencing compared to fencing alone), the timing of management (e.g. recent management compared to management undertaken many years ago), and location of management (e.g. differences between vegetation types or elevations). The degree to which it is possible to explore the influence of these drivers will be dependent on the management data that is available to characterise past interventions. If sufficient data are available, decisions will then need to be made about how management interventions are considered in the analysis. The preliminary analysis presented in section 4.2 provides initial insights into some of the ‘maximum’ magnitudes of change that might be expected with a level of management effort. These magnitudes appear unsurprisingly related to some degree with rainfall, whereby the largest changes tend to have occurred in the wetter south east part of the state and the smaller changes in the drier north-west.

A key consideration in future analyses that looks at the effectiveness of riparian management interventions is to determine how to best isolate the effects of woody weed management from other management types. In this report, the influence of woody weed management has not been considered. It is likely that at some locations, reductions in canopy cover were due to willow removal and mask any increases in canopy cover due to revegetation or natural recruitment accruing elsewhere. Identifying whether sections contained woody weeds during the two capture periods is possible based on a combination of pre-existing spatial layers (ISC 2010 woody weeds layer) and woody weed management spatial data held by CMAs.

There is also the potential to explore the attribution of environmental changes on riparian change in the future. For instance, reaches that have experienced below or above average rainfall or stream flow might differ in terms of the condition of their riparian areas. Understanding the background drivers of riparian change is important, as these will likely influence responses to management interventions.

Comparing change detection of riparian vegetation with other available remotely sensed data sets

This project has provided relatively high resolution and broad spatial estimates of change in woody vegetation between two times using LiDAR. It should now be possible to compare these results with other remotely sensed methodologies, such as Sentinel and Landsat satellite imagery. Sentinel and Landsat are both coarser in their spatial resolutions but are freely available and collected more frequently than the data used for this report. Therefore, if these alternative datasets provide comparable ability to detect change in woody riparian vegetation, it may be possible to use them in some circumstances in lieu of LiDAR, which is of higher resolution but has higher costs associated with both collection and processing. By comparing different methods, it will be possible to rationalise how to best assess the status and track changes in riparian woody vegetation for a set of given purposes into the future.

Exploring changes using other riparian vegetation metrics

The focus of this report is describing changes in woody vegetation using a subset of the riparian metrics that could have been used – fractional canopy cover, canopy height, vegetation width and fragmentation. In the future, it will be possible to explore changes using the other metrics that are available but to this point have only been used as components of the Streamside Zone ISC scores – overhang, large trees, Structure 1 and Structure 2 (Table 3). This will help determine if these metrics describe additional aspects of change that are not being captured by the metrics presented in this report, and/or help identify redundancies between metrics.

6. References

Alluvium (2020) Identification and management of active meandering rivers in Victoria. Report for Department of Land, Water and Planning.

DSE (2005) Index of Stream Condition: The Second Benchmark of Victorian River Condition. The State of Victoria, Department of Sustainability and Environment, East Melbourne, Victoria.

DEPI (2013) Victorian Waterway Management Strategy. Department of Environment and Primary Industries. Melbourne.

DEPI (2014) ISC Streamside Zone sub-index fact sheet. Department of Environment and Primary Industries. Melbourne.

Fugro (2013) Final project report: Victorian State Wide Rivers LiDAR Project. Aerial remote sensing for physical channel form and riparian vegetation mapping. Prepared for Department of Environment and Primary Industries by Fugro Spatial Solutions and Department of Environment and Primary Industries.

Thomson J.R., Bond N.R., Cunningham S.C, Metzeling L, Reich P, Thompson R.M. and Mac Nally R. (2012) The influences of climatic variation and vegetation on stream biota: lessons from the Big Dry in south-eastern Australia. Global Change Biology 18. 1582-1596.

Appendix A Summary statistics of reaches included in report

Table 9 Summary showing the length of reaches, number of sections where LiDAR was captured, the number of sections included in our summaries (based on overlap between capture areas of greater than 50%), the percentage of captured sections that were included, and the dates of LiDAR capture in 2010 and 2018. LiDAR was captured at 150 ISC reaches but fewer than 40 sections were sampled at 9 reaches which were excluded from this report.

CMA	Basin	Reach	River	Reach length (km)	Sections	Sections included	Sections included (prop)	2010 capture date	2018 capture date
CCMA	35	28	Aire River	20.1	406	406	1.00	8/01/2010	7/03/2019
CCMA	35	56	Aire River	21.3	434	434	1.00	7/01/2010	7/03/2019
CCMA	33	2	Barwon River	16.6	332	332	1.00	4/12/2009	12/01/2017
CCMA	33	3	Barwon River	39.1	414	414	1.00	2/12/2009	12/01/2017
CCMA	33	27	Barwon River East Branch	22.6	457	442	0.97	16/12/2009	12/06/2020
CCMA	33	6	Barwon River West Branch	29.2	576	576	1.00	16/12/2009	12/06/2020
CCMA	33	25	Dewing Creek	9.2	184	184	1.00	25/01/2010	12/06/2020
CCMA	35	26	Ford River	20.2	410	402	0.98	8/01/2010	7/03/2019
CCMA	32	14	Lal Lal Creek	22.8	455	455	1.00	8/01/2010	27/02/2019
CCMA	32	1	Moorabool River	20.9	422	404	0.96	2/12/2009	27/02/2019
CCMA	32	2	Moorabool River	39.5	796	796	1.00	2/12/2009	27/02/2019
CCMA	32	3	Moorabool River	35.7	714	714	1.00	2/12/2009	27/02/2019
CCMA	32	4	Moorabool River	10.1	202	202	1.00	2/12/2009	27/02/2019
CCMA	32	10	Moorabool River East Branch	16.6	334	334	1.00	2/12/2009	27/02/2019
CCMA	32	11	Moorabool River East Branch	9.9	204	198	0.97	3/12/2009	27/02/2019
CCMA	32	12	Moorabool River East Branch	15.3	308	308	1.00	15/12/2009	27/02/2019
CCMA	32	5	Moorabool River West Branch	23.9	478	478	1.00	1/12/2009	27/02/2019
CCMA	32	6	Moorabool River West Branch	33	608	608	1.00	1/12/2009	27/02/2019
CCMA	32	13	Spring Creek	8.5	170	170	1.00	2/12/2009	27/02/2019

CCMA	32	7	Sutherland Creek West Branch	30	600	600	1.00	2/12/2009	7/03/2019
CCMA	32	8	Sutherland Creek West Branch	15.9	318	318	1.00	2/12/2009	7/03/2019
CCMA	35	36	Thompson Creek	15.8	316	316	1.00	6/01/2010	27/02/2019
CCMA	35	37	Thompson Creek	35.5	710	710	1.00	15/12/2009	27/02/2019
CCMA	35	38	Unnamed Creek	11.5	230	230	1.00	6/01/2010	27/02/2019
CCMA	35	39	Unnamed Creek	13.3	266	266	1.00	6/01/2010	27/02/2019
EGCMA	22	11	Buchan River	21.8	436	436	1.00	9/12/2009	9/04/2018
EGCMA	21	13	Cann River	11	220	220	1.00	28/10/2010	8/04/2018
EGCMA	21	14	Cann River	21.2	424	424	1.00	6/11/2010	8/04/2018
EGCMA	24	5	Mitchell River	24.1	502	472	0.94	1/02/2010	10/04/2018
EGCMA	24	6	Mitchell River	14.5	290	290	1.00	2/02/2010	10/04/2018
EGCMA	24	204	Mitchell River	15.8	316	316	1.00	3/02/2010	10/04/2018
EGCMA	24	205	Mitchell River	4.1	82	82	1.00	3/02/2010	10/04/2018
EGCMA	22	3	Snowy River	6.3	126	126	1.00	9/12/2009	10/04/2018
EGCMA	22	4	Snowy River	13.7	280	270	0.96	9/12/2009	10/04/2018
EGCMA	22	203	Snowy River	11.4	227	225	0.99	8/12/2009	10/04/2018
EGCMA	23	4	Tambo River	2.7	54	54	1.00	1/02/2010	9/04/2018
EGCMA	23	5	Tambo River	10.6	212	212	1.00	20/02/2010	9/04/2018
EGCMA	23	204	Tambo River	17.2	344	344	1.00	20/02/2010	9/04/2018
GBCMA	5	62	Acheron River	61.8	1240	1235	1.00	2/05/2010	23/04/2018
GBCMA	4	4	Broken River	35.7	742	742	1.00	24/03/2010	20/04/2018
GBCMA	4	5	Broken River	22.1	442	442	1.00	24/03/2010	20/04/2018
GBCMA	5	21	Faithfulls Creek	53.7	1076	1072	1.00	16/12/2010	21/04/2018
GBCMA	5	14	Goulburn River	51.3	1004	997	0.99	2/05/2010	23/04/2018
GBCMA	4	14	Holland Creek	41.3	832	824	0.99	13/02/2010	20/04/2018
GBCMA	5	37	Hughes Creek	23.6	482	470	0.98	4/05/2010	22/04/2018
GBCMA	5	38	Hughes Creek	16.3	332	322	0.97	4/05/2010	22/04/2018
GBCMA	5	39	Hughes Creek	44.7	900	891	0.99	4/05/2010	22/04/2018

GBCMA	5	51	King Parrot Creek	45	927	887	0.96	18/05/2010	23/04/2018
GBCMA	5	17	Seven Creeks	40.7	822	816	0.99	16/12/2010	21/04/2018
GBCMA	5	18	Seven Creeks	27.5	552	552	1.00	16/12/2010	21/04/2018
GBCMA	5	19	Seven Creeks	31	624	624	1.00	17/03/2010	21/04/2018
GBCMA	5	20	Seven Creeks	38	764	756	0.99	17/03/2010	21/04/2018
GHCMA	36	19	Battle Creek	29	580	580	1.00	24/11/2009	16/02/2019
GHCMA	38	31	Bryans Creek	17.8	360	354	0.98	7/11/2009	13/03/2019
GHCMA	38	32	Bryans Creek	13.8	276	276	1.00	14/11/2009	13/03/2019
GHCMA	38	33	Bryans Creek	28.7	574	574	1.00	14/11/2009	13/03/2019
GHCMA	38	47	Chetwynd River	42.4	848	848	1.00	14/11/2009	14/03/2019
GHCMA	38	7	Glenelg River	33.9	678	678	1.00	1/11/2009	14/03/2019
GHCMA	38	9	Glenelg River	22	439	427	0.97	14/11/2009	15/03/2019
GHCMA	38	10	Glenelg River	57.8	1154	1154	1.00	17/11/2009	16/03/2019
GHCMA	38	11	Glenelg River	52.8	987	960	0.97	17/11/2009	17/03/2019
GHCMA	38	34	Konong Wootong Creek	23.6	476	466	0.98	14/11/2009	17/03/2019
GHCMA	36	38	Merri River	9.5	190	190	1.00	7/11/2009	13/03/2019
GHCMA	36	39	Merri River	18.5	372	372	1.00	7/11/2009	14/03/2019
GHCMA	36	238	Merri River	6.4	128	128	1.00	7/11/2009	16/02/2019
GHCMA	36	18	Mt Emu Creek	62.7	696	696	1.00	19/11/2009	16/02/2019
GHCMA	36	22	Mt Emu Creek	57.9	1158	1158	1.00	24/11/2009	16/02/2019
GHCMA	38	48	Pigeon Ponds Creek	16	320	320	1.00	14/11/2009	14/03/2019
GHCMA	38	46	Steep Bank Rivulet	31.4	630	630	1.00	1/11/2009	14/03/2019
GHCMA	36	23	Trewalla Creek	21.9	82	82	1.00	24/11/2009	13/03/2019
GHCMA	38	44	Wando River	3.5	70	70	1.00	1/11/2009	14/03/2019
GHCMA	38	45	Wando River	41.4	828	828	1.00	1/11/2009	14/03/2019
MCMA	14	40	Cantala Creek	8.3	176	140	0.80	18/07/2010	14/02/2019
MCMA	14	39	Chalka Creek	42.2	846	823	0.97	18/07/2010	14/02/2019
MCMA	14	41	Chalka Creek	9	182	176	0.97	18/07/2010	14/02/2019

MCMA	14	67	Lindsay River	12.5	260	260	1.00	2/08/2010	11/02/2019
MCMA	14	68	Lindsay River	9.5	194	194	1.00	2/08/2010	11/02/2019
MCMA	14	69	Lindsay River	11.8	240	240	1.00	5/08/2010	11/02/2019
MCMA	14	10	Murray River	71	1444	1426	0.99	1/12/2009	11/02/2019
MCMA	14	11	Murray River	38.5	773	773	1.00	25/07/2010	11/02/2019
MCMA	14	12	Murray River	38.3	778	778	1.00	25/07/2010	11/02/2019
MCMA	14	65	Potterwalkagee Creek	11.5	230	230	1.00	2/08/2010	12/02/2019
MCMA	14	64	Potterwallkagee Creek	16.2	330	330	1.00	27/07/2010	13/02/2019
MCMA	14	20	Unnamed Creek	2.5	50	50	1.00	25/07/2010	14/02/2019
MCMA	14	66	Unnamed Creek	2.3	46	46	1.00	27/07/2010	14/02/2019
NCCMA	7	21	Birch's Creek	51	1020	1012	0.99	13/05/2010	21/06/2018
NCCMA	6	1	Campaspe River	10.6	214	214	1.00	19/05/2010	24/05/2018
NCCMA	6	2	Campaspe River	44.8	898	898	1.00	19/05/2010	24/05/2018
NCCMA	6	3	Campaspe River	36.3	726	726	1.00	19/05/2010	24/05/2018
NCCMA	6	4	Campaspe River	24	484	478	0.99	30/08/2010	24/05/2018
NCCMA	6	5	Campaspe River	30.1	602	602	1.00	30/08/2010	24/05/2018
NCCMA	6	6	Campaspe River	61.1	1228	1228	1.00	31/08/2010	24/05/2018
NCCMA	6	7	Campaspe River	46.9	943	934	0.99	4/01/2010	24/05/2018
NCCMA	6	22	Coliban River	28.2	566	530	0.94	4/12/2009	27/05/2018
NCCMA	6	21	Kangaroo Creek	24.4	492	486	0.99	9/10/2010	27/05/2018
NCCMA	6	20	Little Coliban Creek	19.5	390	390	1.00	4/01/2010	27/05/2018
NCCMA	7	7	Loddon River	46.7	936	936	1.00	19/12/2009	21/06/2018
NCCMA	7	8	Loddon River	30.1	650	550	0.85	19/12/2009	21/06/2018
NCCMA	7	11	Serpentine Creek	95.7	1916	1916	1.00	13/05/2010	26/05/2018
NECMA	3	22	King River	20.5	410	409	1.00	11/03/2010	17/04/2018
NECMA	3	23	King River	26.3	558	504	0.90	16/02/2010	17/04/2018
NECMA	3	24	King River	13.8	276	270	0.98	16/02/2010	17/04/2018
NECMA	3	53	King River West Branch	18.4	372	366	0.98	16/02/2010	17/04/2018

NECMA	3	4	Ovens River	52.2	1058	1040	0.98	15/02/2010	13/04/2018
NECMA	3	5	Ovens River	34.8	718	682	0.95	15/02/2010	13/04/2018
NECMA	3	6	Ovens River	38.8	832	736	0.88	17/02/2010	13/04/2018
NECMA	3	7	Ovens River	15.7	314	314	1.00	24/02/2010	13/04/2018
WCMA	15	72	Glenlofty Creek	12	242	242	1.00	6/01/2010	10/02/2019
WCMA	15	73	Glenlofty Creek	11	220	220	1.00	6/01/2010	10/02/2019
WCMA	15	76	Glenpatrick Creek	16	322	316	0.98	5/01/2010	10/02/2019
WCMA	15	57	Morl Creek	12	244	238	0.98	14/01/2010	10/02/2019
WCMA	15	64	Seven Mile Creek	36	720	720	1.00	14/01/2010	10/02/2019
WCMA	15	68	Shays Creek	7.1	146	146	1.00	13/01/2010	10/02/2019
WCMA	15	69	Shays Creek	8.8	176	176	1.00	13/01/2010	10/02/2019
WCMA	15	65	Six Mile Creek	32.3	646	646	1.00	13/01/2010	10/02/2019
WCMA	15	71	Spring Creek	10.6	214	214	1.00	13/01/2010	10/02/2019
WCMA	15	53	Wattle Creek	15.2	304	304	1.00	20/10/2010	10/02/2019
WCMA	15	10	Wimmera River	38.6	772	772	1.00	20/10/2010	10/02/2019
WCMA	15	11	Wimmera River	32.4	648	648	1.00	13/01/2010	10/02/2019
WCMA	15	12	Wimmera River	24.1	484	484	1.00	6/01/2010	10/02/2019
WGCMA	27	29	Albert River	25.6	514	514	1.00	19/02/2010	13/04/2018
WGCMA	27	30	Albert River	21.3	428	428	1.00	19/02/2010	13/04/2018
WGCMA	27	228	Albert River	8.3	166	166	1.00	19/02/2010	13/04/2018
WGCMA	27	229	Albert River	0.9	18	18	1.00	19/02/2010	13/04/2018
WGCMA	25	19	Avon River	10.7	214	214	1.00	1/03/2010	11/04/2018
WGCMA	25	20	Avon River	24	534	486	0.91	1/03/2010	11/04/2018
WGCMA	25	21	Avon River	14.3	292	282	0.97	2/03/2010	11/04/2018
WGCMA	25	219	Avon River	8.7	174	174	1.00	1/03/2010	11/04/2018
WGCMA	27	21	Franklin River	19.2	384	384	1.00	20/02/2010	23/04/2018
WGCMA	27	22	Franklin River	23.9	484	478	0.99	20/02/2010	23/04/2018
WGCMA	27	221	Franklin River	4.1	82	82	1.00	20/02/2010	23/04/2018

WGCMA	27	31	Jack River	29.8	596	596	1.00	19/02/2010	13/04/2018
WGCMA	27	32	Jack River	22	446	440	0.99	19/02/2010	13/04/2018
WGCMA	25	7	Macalister River	21.6	432	432	1.00	1/03/2010	11/04/2018
WGCMA	25	8	Macalister River	33.9	678	678	1.00	22/02/2010	11/04/2018
WGCMA	25	17	Rainbow Creek	15.9	320	320	1.00	2/03/2010	11/04/2018
WGCMA	27	33	Tarra River	25.8	508	507	1.00	19/02/2010	13/04/2018
WGCMA	27	34	Tarra River	23.1	464	464	1.00	18/02/2010	13/04/2018
WGCMA	25	2	Thomson River	37.5	744	744	1.00	2/03/2010	11/04/2018
WGCMA	25	3	Thomson River	10.5	210	210	1.00	2/03/2010	11/04/2018
WGCMA	25	4	Thomson River	69.8	480	480	1.00	2/03/2010	11/04/2018

Appendix B Summary of changes in riparian vegetation

Table 10 Summary of changes in riparian vegetation for ISC reaches. The percentage of sections at each reach that increased, did not change, or decreased is shown for the ISC Streamside Zone score, along with the mean change ("Change").

		ISC Streamside Zone score						ISC Streamside Zone score			
Catchment	ISC Reach	Increase	No change	Decrease	Change	Catchment	ISC Reach	Increase	No change	Decrease	Change
CCMA	AIRE RIVER_28	4.7	88.9	6.4	0	MCMA	CANTALA CREEK_40	35.6	54.8	9.6	0
CCMA	AIRE RIVER_56	7.4	90.5	2.1	0	MCMA	CHALKA CREEK_39	41.4	46.0	12.6	0
CCMA	BARWON RIVER EAST BRANCH_27	12.0	60.9	27.1	0	MCMA	CHALKA CREEK_41	47.2	49.4	3.4	0
CCMA	BARWON RIVER WEST BRANCH_6	14.8	55.5	29.7	0	MCMA	LINDSAY RIVER_67	31.3	54.4	14.3	0
CCMA	BARWON RIVER_2	19.4	57.4	23.2	0	MCMA	LINDSAY RIVER_68	67.5	25.7	6.8	1
CCMA	BARWON RIVER_3	16.9	63.3	19.8	0	MCMA	LINDSAY RIVER_69	28.3	65.4	6.3	0
CCMA	DEWING CREEK_25	21.7	61.4	16.8	0	MCMA	MURRAY RIVER_10	48.5	46.2	5.3	1
CCMA	FORD RIVER_26	9.4	82.8	7.8	0	MCMA	MURRAY RIVER_11	53.5	40.1	6.4	1
CCMA	LAL LAL CREEK_14	25.3	60.3	14.4	0	MCMA	MURRAY RIVER_12	37.0	56.7	6.3	0
CCMA	MOORABOOL RIVER EAST BRANCH_10	23.7	53.6	22.8	0	MCMA	POTTERWALKAGEE CREEK_65	18.9	49.8	31.3	0
CCMA	MOORABOOL RIVER EAST BRANCH_11	27.8	47.0	25.3	0	MCMA	POTTERWALLKAGEE CREEK_64	33.3	58.3	8.4	0
CCMA	MOORABOOL RIVER EAST BRANCH_12	14.6	58.1	27.3	0	MCMA	UNNAMED CREEK_20	2.0	93.9	4.1	0
CCMA	MOORABOOL RIVER WEST BRANCH_5	19.0	68.4	12.6	0	MCMA	UNNAMED CREEK_66	76.1	21.7	2.2	1
CCMA	MOORABOOL RIVER WEST BRANCH_6	26.3	64.0	9.7	0	NCCMA	BIRCH'S CREEK_21	19.9	50.9	29.2	0
CCMA	MOORABOOL RIVER_1	26.8	59.3	13.9	0	NCCMA	CAMPASPE RIVER_1	52.3	43.9	3.7	1
CCMA	MOORABOOL RIVER_2	14.9	72.2	12.8	0	NCCMA	CAMPASPE RIVER_2	42.7	53.0	4.2	0

CCMA	MOORABOOL RIVER_3	11.1	71.7	17.2	0	NCCMA	CAMPASPE RIVER_3	42.8	50.8	6.4	0
CCMA	MOORABOOL RIVER_4	34.7	59.4	5.9	0	NCCMA	CAMPASPE RIVER_4	36.4	58.4	5.2	0
CCMA	SPRING CREEK_13	21.8	72.4	5.9	0	NCCMA	CAMPASPE RIVER_5	28.9	61.5	9.6	0
CCMA	SUTHERLAND CREEK WEST BRANCH_7	27.7	62.7	9.7	0	NCCMA	CAMPASPE RIVER_6	26.5	49.3	24.2	0
CCMA	SUTHERLAND CREEK WEST BRANCH_8	25.5	63.2	11.3	0	NCCMA	CAMPASPE RIVER_7	34.3	44.4	21.3	0
CCMA	THOMPSON CREEK_36	36.3	58.0	5.7	0	NCCMA	COLIBAN RIVER_22	25.9	66.9	7.2	0
CCMA	THOMPSON CREEK_37	41.8	53.8	4.4	1	NCCMA	KANGAROO CREEK_21	27.7	58.8	13.4	0
CCMA	UNNAMED CREEK_38	41.3	51.3	7.4	0	NCCMA	LITTLE COLIBAN Creek_20	35.1	53.6	11.3	0
CCMA	UNNAMED CREEK_39	38.0	58.6	3.4	0	NCCMA	LODDON RIVER_7	36.1	53.6	10.3	0
EGCMA	BUCHAN RIVER_11	49.0	41.1	9.9	1	NCCMA	LODDON RIVER_8	43.0	49.3	7.7	0
EGCMA	CANN RIVER_13	11.7	55.1	33.2	0	NCCMA	SERPENTINE CREEK_11	35.4	63.4	1.3	0
EGCMA	CANN RIVER_14	13.1	43.6	43.3	0	NECMA	KING RIVER WEST BRANCH_53	26.8	65.7	7.5	0
EGCMA	MITCHELL RIVER_204	59.5	38.3	2.2	1	NECMA	KING RIVER_22	32.4	51.5	16.1	0
EGCMA	MITCHELL RIVER_205	31.7	52.4	15.9	0	NECMA	KING RIVER_23	21.5	54.2	24.3	0
EGCMA	MITCHELL RIVER_5	48.5	41.2	10.3	0	NECMA	KING RIVER_24	23.7	55.7	20.6	0
EGCMA	MITCHELL RIVER_6	48.1	45.3	6.6	1	NECMA	OVENS RIVER_4	37.5	53.1	9.4	0
EGCMA	SNOWY RIVER_203	47.3	48.3	4.3	1	NECMA	OVENS RIVER_5	27.2	49.0	23.8	0
EGCMA	SNOWY RIVER_3	60.2	35.0	4.9	1	NECMA	OVENS RIVER_6	20.7	54.8	24.5	0
EGCMA	SNOWY RIVER_4	58.0	30.7	11.3	1	NECMA	OVENS RIVER_7	45.5	42.0	12.4	0
EGCMA	TAMBO RIVER_204	54.1	41.0	4.9	1	WCMA	GLENLOFTY CREEK_72	27.0	68.3	4.8	0
EGCMA	TAMBO RIVER_4	46.3	35.2	18.5	0	WCMA	GLENLOFTY CREEK_73	24.4	67.0	8.6	0
EGCMA	TAMBO RIVER_5	43.8	49.3	6.9	0	WCMA	GLENPATRICK CREEK_76	22.9	64.8	12.4	0
GBCMA	ACHERON RIVER_62	46.2	38.0	15.8	0	WCMA	MORL CREEK_57	23.5	71.8	4.6	0

GBCMA	BROKEN RIVER_4	41.7	49.7	8.7	0	WCMA	SEVEN MILE CREEK_64	27.5	66.8	5.7	0
GBCMA	BROKEN RIVER_5	31.9	63.1	5.0	0	WCMA	SHAYS CREEK_68	21.7	72.7	5.6	0
GBCMA	FAITHFULLS CREEK_21	51.5	44.0	4.5	1	WCMA	SHAYS CREEK_69	42.6	56.3	1.1	1
GBCMA	GOULBURN RIVER_14	41.9	47.3	10.8	0	WCMA	SIX MILE CREEK_65	33.8	62.2	4.0	0
GBCMA	HOLLAND CREEK_14	35.8	57.0	7.1	0	WCMA	SPRING CREEK_71	18.9	76.4	4.7	0
GBCMA	HUGHES CREEK_37	43.3	50.8	5.9	0	WCMA	WATTLE CREEK_53	38.5	58.2	3.3	0
GBCMA	HUGHES CREEK_38	23.3	62.9	13.8	0	WCMA	WIMMERA RIVER_10	44.8	52.2	3.0	0
GBCMA	HUGHES CREEK_39	31.1	55.3	13.6	0	WCMA	WIMMERA RIVER_11	32.2	60.5	7.2	0
GBCMA	KING PARROT CREEK_51	49.7	43.6	6.8	1	WCMA	WIMMERA RIVER_12	20.9	71.6	7.5	0
GBCMA	SEVEN CREEKS_17	58.2	39.7	2.1	1	WGCMA	ALBERT RIVER_228	23.5	66.3	10.2	0
GBCMA	SEVEN CREEKS_18	41.5	53.2	5.3	0	WGCMA	ALBERT RIVER_229	50.0	38.9	11.1	0
GBCMA	SEVEN CREEKS_19	42.8	45.8	11.4	0	WGCMA	ALBERT RIVER_29	47.5	40.9	11.7	1
GBCMA	SEVEN CREEKS_20	28.7	60.2	11.1	0	WGCMA	ALBERT RIVER_30	32.8	59.0	8.2	0
GHCMA	BATTLE CREEK_19	4.5	94.0	1.6	0	WGCMA	AVON RIVER_19	45.8	50.9	3.3	0
GHCMA	BRYANS CREEK_31	21.0	73.9	5.1	0	WGCMA	AVON RIVER_20	70.8	26.1	3.1	1
GHCMA	BRYANS CREEK_32	33.1	60.2	6.7	0	WGCMA	AVON RIVER_21	62.7	31.2	6.1	1
GHCMA	BRYANS CREEK_33	21.1	58.9	20.0	0	WGCMA	AVON RIVER_219	64.4	30.5	5.2	1
GHCMA	CHETWYND RIVER_47	26.2	61.4	12.4	0	WGCMA	FRANKLIN RIVER_21	53.9	37.2	8.9	1
GHCMA	GLENELG RIVER_10	12.9	69.7	17.4	0	WGCMA	FRANKLIN RIVER_22	20.1	78.2	1.7	0
GHCMA	GLENELG RIVER_11	20.4	59.7	20.0	0	WGCMA	FRANKLIN RIVER_221	45.1	52.4	2.4	0
GHCMA	GLENELG RIVER_7	10.3	73.9	15.8	0	WGCMA	JACK RIVER_31	34.2	57.7	8.1	0
GHCMA	GLENELG RIVER_9	12.2	62.4	25.4	0	WGCMA	JACK RIVER_32	22.0	67.0	10.9	0
GHCMA	KONONG WOOTONG CREEK_34	26.3	66.6	7.1	0	WGCMA	MACALISTER RIVER_7	30.3	51.6	18.1	0
GHCMA	MERRI RIVER_238	20.3	68.8	10.9	0	WGCMA	MACALISTER RIVER_8	79.9	19.4	0.7	2
GHCMA	MERRI RIVER_38	20.5	62.7	16.8	0	WGCMA	RAINBOW CREEK_17	53.1	35.3	11.6	1

GHCMA	MERRI RIVER_39	33.2	55.0	11.9	0	WGCMA	TARRA RIVER_33	39.8	49.0	11.2	0
GHCMA	MT EMU CREEK_18	18.6	59.1	22.3	0	WGCMA	TARRA RIVER_34	73.9	19.6	6.5	1
GHCMA	MT EMU CREEK_22	16.4	75.1	8.6	0	WGCMA	THOMSON RIVER_2	30.9	47.2	21.9	0
GHCMA	PIGEON PONDS CREEK_48	13.8	64.1	22.0	0	WGCMA	THOMSON RIVER_3	59.0	32.9	8.1	1
GHCMA	STEEP BANK RIVULET_46	16.2	58.8	25.0	0	WGCMA	THOMSON RIVER_4	74.0	17.9	8.1	1
GHCMA	TREWALLA CREEK_23	6.4	74.4	19.2	0						
GHCMA	WANDO RIVER_44	21.4	70.0	8.6	0						
GHCMA	WANDO RIVER_45	30.6	60.4	9.1	0						

Table 11 Summary of changes in riparian vegetation for ISC reaches. The percentage of sections at each reach that increased ("INC"), did not change ("NC"), or decreased ("DEC") is shown for fractional canopy cover, canopy height, fragmentation and vegetation width, along with the mean change ("Change").

		Fractional canopy cover				Canopy height				Fragmentation				Vegetation width			
Catchment	ISC Reach	INC	NC	DEC	Change	INC	NC	DEC	Change	INC	NC	DEC	Change	INC	NC	DEC	Change
CCMA	AIRE RIVER_28	18.7	0.0	81.3	-1.8	53.0	0.0	47.0	-0.1	53.2	6.9	39.9	0.4	55.9	0.0	44.1	-1.2
CCMA	AIRE RIVER_56	40.4	0.0	59.6	0.4	73.2	0.0	26.8	1.2	14.8	55.9	29.3	-0.7	52.4	0.0	47.6	4.5
CCMA	BARWON RIVER EAST BRANCH_27	43.0	6.3	50.7	-0.5	61.8	6.1	32.1	0.6	41.9	2.5	55.7	-1.6	46.8	14.7	38.5	1.1
CCMA	BARWON RIVER WEST BRANCH_6	39.5	4.9	55.7	-1.5	55.8	4.5	39.7	0.4	43.8	0.2	56.0	-0.7	47.1	13.4	39.5	1.7
CCMA	BARWON RIVER_2	68.4	1.2	30.4	3.4	76.8	1.2	22.0	0.4	40.7	1.2	58.1	-2.2	50.9	11.7	37.3	1.6
CCMA	BARWON RIVER_3	60.4	0.0	39.6	1.3	71.0	0.0	29.0	0.4	48.8	0.0	51.2	-1.0	51.4	0.2	48.3	0.7
CCMA	DEWING CREEK_25	67.4	2.2	30.4	4.7	59.8	2.2	38.0	0.6	47.8	0.5	51.6	-5.3	48.4	9.2	42.4	1.7
CCMA	FORD RIVER_26	37.8	6.5	55.7	-2.0	73.4	6.5	20.1	0.2	24.6	35.1	40.3	0.5	49.8	10.0	40.3	-3.8
CCMA	LAL LAL CREEK_14	63.2	6.9	29.9	1.5	65.0	6.4	28.6	0.1	35.3	0.0	64.7	-1.5	48.6	25.1	26.4	0.7
CCMA	MOORABOOL RIVER EAST BRANCH_10	67.1	0.0	32.9	2.2	54.8	0.0	45.2	-0.1	50.3	0.0	49.7	-1.0	55.7	5.4	38.9	-1.9
CCMA	MOORABOOL RIVER EAST BRANCH_11	63.6	0.0	36.4	1.5	68.2	0.0	31.8	0.5	42.9	0.0	57.1	-1.0	53.0	5.6	41.4	0.2
CCMA	MOORABOOL RIVER EAST BRANCH_12	77.3	0.6	22.1	2.9	51.0	0.6	48.4	0.0	63.0	0.3	36.7	1.6	51.0	1.9	47.1	-1.5
CCMA	MOORABOOL RIVER WEST BRANCH_5	54.4	0.0	45.6	0.7	45.6	0.0	54.4	-0.2	63.6	1.7	34.7	2.1	43.3	0.0	56.7	-6.7

CCMA	MOORABOOL RIVER WEST BRANCH_6	65.8	1.2	33.1	1.7	74.8	1.0	24.2	0.5	29.9	1.0	69.1	-2.7	61.5	7.2	31.3	1.3
CCMA	MOORABOOL RIVER_1	64.0	0.0	36.0	1.7	76.2	0.0	23.8	0.5	39.5	0.0	60.5	-1.3	52.9	0.7	46.4	-0.5
CCMA	MOORABOOL RIVER_2	48.0	0.0	52.0	-0.1	62.7	0.0	37.3	0.3	51.4	0.1	48.5	0.3	45.9	0.0	54.1	0.4
CCMA	MOORABOOL RIVER_3	41.7	0.0	58.3	-2.3	54.5	0.0	45.5	0.1	62.5	0.8	36.7	2.2	41.9	0.0	58.1	-6.2
CCMA	MOORABOOL RIVER_4	71.8	0.0	28.2	3.7	90.1	0.0	9.9	0.7	26.7	0.0	73.3	-5.3	68.3	0.0	31.7	3.3
CCMA	SPRING CREEK_13	53.5	9.4	37.1	0.4	68.8	8.2	22.9	0.2	33.5	0.0	66.5	-1.4	42.4	31.2	26.5	0.4
CCMA	SUTHERLAND CREEK WEST BRANCH_7	78.3	0.2	21.5	2.2	81.5	0.2	18.3	0.4	27.7	0.0	72.3	-2.6	65.0	4.7	30.3	1.4
CCMA	SUTHERLAND CREEK WEST BRANCH_8	78.0	0.0	22.0	5.3	54.1	0.0	45.9	0.1	35.5	0.3	64.2	-3.6	69.8	0.0	30.2	15.7
CCMA	THOMPSON CREEK_36	74.5	2.2	23.2	2.9	84.4	2.2	13.4	0.6	21.7	0.0	78.3	-5.4	51.9	22.6	25.5	2.5
CCMA	THOMPSON CREEK_37	74.4	8.0	17.6	4.4	79.6	8.2	12.3	0.9	19.4	4.4	76.2	-8.1	57.9	26.5	15.6	4.2
CCMA	UNNAMED CREEK_38	77.0	4.3	18.7	2.9	82.2	4.3	13.5	0.7	20.4	0.0	79.6	-5.0	63.9	17.4	18.7	3.1
CCMA	UNNAMED CREEK_39	73.7	16.5	9.8	3.8	77.8	17.7	4.5	0.9	19.9	0.0	80.1	-6.3	50.8	41.4	7.9	4.0
EGCMA	BUCHAN RIVER_11	77.1	0.0	22.9	5.4	87.5	0.0	12.5	1.0	16.4	0.0	83.6	-9.8	70.0	6.7	23.3	4.4
EGCMA	CANN RIVER_13	22.4	0.0	77.6	-4.4	62.6	0.0	37.4	0.6	63.1	3.3	33.6	2.3	55.6	0.0	44.4	-1.2
EGCMA	CANN RIVER_14	23.7	0.0	76.3	-6.2	59.6	0.0	40.4	0.3	59.6	0.0	40.4	3.0	47.0	0.0	53.0	-5.3
EGCMA	MITCHELL RIVER_204	95.3	0.0	4.7	9.5	96.2	0.0	3.8	1.5	4.1	0.0	95.9	-13.1	86.7	0.0	13.3	7.2
EGCMA	MITCHELL RIVER_205	61.0	1.2	37.8	3.6	73.2	1.2	25.6	0.7	42.7	0.0	57.3	-4.7	56.1	1.2	42.7	4.7
EGCMA	MITCHELL RIVER_5	79.6	0.0	20.4	5.8	83.5	0.0	16.5	1.3	18.7	0.0	81.3	-8.5	76.0	0.9	23.2	4.0

EGCMA	MITCHELL RIVER_6	81.2	1.0	17.8	7.8	84.0	1.0	15.0	1.1	17.1	0.0	82.9	-11.6	72.5	4.9	22.6	6.9
EGCMA	SNOWY RIVER_203	76.0	5.1	18.9	6.8	84.1	5.1	10.7	1.5	23.0	0.0	77.0	-6.6	57.1	17.5	25.3	3.4
EGCMA	SNOWY RIVER_3	84.6	0.0	15.4	13.0	95.9	0.0	4.1	3.1	17.1	0.0	82.9	-15.6	72.4	0.0	27.6	8.3
EGCMA	SNOWY RIVER_4	86.4	0.0	13.6	13.6	89.9	0.0	10.1	2.9	12.5	0.0	87.5	-18.5	74.3	6.6	19.1	10.5
EGCMA	TAMBO RIVER_204	85.5	0.6	14.0	5.1	92.2	0.6	7.3	1.1	12.5	0.0	87.5	-8.6	80.8	0.6	18.6	4.5
EGCMA	TAMBO RIVER_4	68.5	0.0	31.5	-0.2	83.3	0.0	16.7	0.7	31.5	0.0	68.5	-1.0	61.1	0.0	38.9	2.4
EGCMA	TAMBO RIVER_5	72.4	2.0	25.6	3.9	82.8	1.5	15.8	1.1	21.2	0.0	78.8	-7.0	67.0	14.3	18.7	4.4
GBCMA	ACHERON RIVER_62	71.9	0.1	28.0	12.6	62.1	0.1	37.8	0.6	28.7	0.5	70.8	-7.8	70.3	0.2	29.6	17.0
GBCMA	BROKEN RIVER_4	75.3	0.1	24.5	3.8	81.1	0.1	18.7	1.4	22.2	0.4	77.4	-6.0	67.5	0.1	32.3	5.7
GBCMA	BROKEN RIVER_5	76.6	2.8	20.6	3.6	83.3	2.3	14.4	0.7	19.3	0.0	80.7	-6.4	49.1	26.1	24.8	2.4
GBCMA	FAITHFULLS CREEK_21	90.2	0.4	9.4	5.3	92.1	0.3	7.6	1.3	13.3	0.2	86.5	-8.2	75.5	0.8	23.6	7.0
GBCMA	GOULBURN RIVER_14	64.2	0.1	35.7	5.2	74.0	0.1	25.8	1.3	34.6	0.3	65.1	-6.6	62.3	1.0	36.7	6.0
GBCMA	HOLLAND CREEK_14	74.5	0.0	25.5	2.8	84.0	0.0	16.0	1.0	20.5	0.0	79.5	-4.4	63.8	0.0	36.2	3.1
GBCMA	HUGHES CREEK_37	84.9	0.0	15.1	4.5	88.3	0.0	11.7	1.3	17.4	0.0	82.6	-6.5	66.8	0.0	33.2	4.4
GBCMA	HUGHES CREEK_38	69.5	0.0	30.5	2.0	86.8	0.0	13.2	1.1	34.3	0.6	65.1	-2.3	60.7	0.0	39.3	5.1
GBCMA	HUGHES CREEK_39	70.2	0.7	29.1	2.0	80.2	0.6	19.3	0.9	31.6	0.2	68.1	-2.6	60.1	1.8	38.1	1.8
GBCMA	KING PARROT CREEK_51	77.5	0.0	22.5	6.6	85.5	0.0	14.5	1.6	18.2	0.5	81.4	-9.1	75.3	0.0	24.7	7.6
GBCMA	SEVEN CREEKS_17	97.1	0.0	2.9	7.9	94.2	0.0	5.8	1.8	6.0	0.0	94.0	-9.7	79.5	0.0	20.5	12.6
GBCMA	SEVEN CREEKS_18	84.2	0.0	15.8	3.9	85.9	0.0	14.1	1.3	15.8	0.2	84.1	-6.8	69.0	0.0	31.0	5.4
GBCMA	SEVEN CREEKS_19	70.8	0.2	29.1	2.0	91.2	0.0	8.8	1.2	22.0	0.0	78.0	-4.9	69.2	0.3	30.5	5.3

GBCMA	SEVEN CREEKS_20	65.7	0.5	33.8	1.6	84.9	0.5	14.6	1.0	31.5	3.1	65.4	-2.5	58.7	1.3	39.9	1.9
GHCMA	BATTLE CREEK_19	35.3	50.2	14.5	0.3	38.1	49.1	12.8	0.1	40.3	0.0	59.7	-0.6	11.2	84.0	4.8	0.3
GHCMA	BRYANS CREEK_31	73.1	2.3	24.6	1.7	79.6	2.3	18.1	0.4	28.3	0.0	71.7	-2.1	45.0	29.5	25.5	0.9
GHCMA	BRYANS CREEK_32	71.4	5.9	22.7	2.3	87.4	2.6	10.0	0.9	28.6	0.0	71.4	-3.7	48.0	25.7	26.4	1.3
GHCMA	BRYANS CREEK_33	70.6	0.7	28.7	1.9	77.0	0.7	22.3	0.7	47.7	0.0	52.3	-0.2	56.6	2.4	40.9	0.8
GHCMA	CHETWYND RIVER_47	56.6	0.7	42.7	0.5	81.0	0.7	18.3	0.6	43.0	0.0	57.0	-1.2	54.2	6.3	39.5	0.7
GHCMA	GLENELG RIVER_10	57.5	0.0	42.5	0.4	59.2	0.0	40.8	0.1	60.5	0.0	39.5	1.6	46.5	0.1	53.4	-1.3
GHCMA	GLENELG RIVER_11	60.6	0.0	39.4	1.1	58.7	0.0	41.3	0.2	61.9	0.7	37.4	1.4	45.4	0.0	54.6	-3.9
GHCMA	GLENELG RIVER_7	34.5	0.0	65.5	-1.0	45.7	0.0	54.3	-0.1	75.4	0.0	24.6	2.2	37.3	0.0	62.7	-2.7
GHCMA	GLENELG RIVER_9	57.3	0.0	42.7	0.8	49.3	0.0	50.7	-0.1	73.9	0.0	26.1	3.9	34.9	0.0	65.1	-3.0
GHCMA	KONONG WOOTONG CREEK_34	67.5	6.5	26.1	1.5	73.5	6.5	20.0	0.5	35.8	0.0	64.2	-2.4	42.5	33.0	24.6	0.8
GHCMA	MERRI RIVER_238	64.1	14.8	21.1	1.9	67.2	15.6	17.2	0.3	43.0	0.0	57.0	-1.7	25.0	46.9	28.1	0.8
GHCMA	MERRI RIVER_38	53.7	9.5	36.8	1.5	62.6	8.4	28.9	0.5	47.4	0.0	52.6	-2.0	39.5	25.8	34.7	1.1
GHCMA	MERRI RIVER_39	60.4	1.9	37.7	2.1	77.4	1.9	20.8	0.8	38.0	0.0	62.0	-3.9	55.8	7.5	36.7	2.1
GHCMA	MT EMU CREEK_18	66.1	0.0	33.9	1.0	74.3	0.0	25.7	0.3	46.4	0.0	53.6	-0.2	60.1	3.3	36.6	0.5
GHCMA	MT EMU CREEK_22	61.0	18.2	20.9	0.3	66.9	15.5	17.6	0.1	33.5	0.0	66.5	0.3	45.1	40.1	14.8	0.7
GHCMA	PIGEON PONDS CREEK_48	51.6	0.0	48.4	-0.3	71.6	0.0	28.4	0.3	59.4	0.0	40.6	1.6	47.8	0.6	51.6	-1.6
GHCMA	STEEP BANK RIVULET_46	33.4	0.0	66.6	-2.3	54.2	0.0	45.8	-0.1	57.6	0.2	42.3	2.7	45.3	1.0	53.7	-4.1
GHCMA	TREWALLA CREEK_23	37.2	29.5	33.3	-2.4	41.0	26.9	32.1	-0.6	48.7	0.0	51.3	5.2	14.1	79.5	6.4	-1.0

GHCMA	WANDO RIVER_44	78.6	0.0	21.4	1.6	95.7	0.0	4.3	0.7	14.3	0.0	85.7	-2.8	60.0	10.0	30.0	0.4
GHCMA	WANDO RIVER_45	69.3	0.6	30.1	1.4	80.6	0.4	19.1	0.4	36.0	0.0	64.0	-1.5	54.5	8.3	37.2	0.0
MCMA	CANTALA CREEK_40	88.9	0.0	11.1	4.5	65.9	0.0	34.1	0.3	23.7	0.0	76.3	-5.3	60.0	0.0	40.0	3.2
MCMA	CHALKA CREEK_39	96.1	0.0	3.9	8.3	83.1	0.0	16.9	1.2	15.8	0.0	84.2	-6.2	69.2	0.2	30.6	3.2
MCMA	CHALKA CREEK_41	97.2	0.0	2.8	6.8	90.3	0.0	9.7	0.9	7.4	0.0	92.6	-6.2	66.5	0.6	33.0	6.4
MCMA	LINDSAY RIVER_67	91.1	0.0	8.9	4.8	76.4	0.0	23.6	0.8	27.4	0.4	72.2	-3.7	61.0	0.0	39.0	4.9
MCMA	LINDSAY RIVER_68	95.3	0.0	4.7	11.6	93.7	0.0	6.3	1.8	6.3	0.0	93.7	-17.2	82.7	0.0	17.3	17.0
MCMA	LINDSAY RIVER_69	92.1	0.0	7.9	3.7	82.1	0.0	17.9	0.5	25.8	0.0	74.2	-3.2	57.9	0.0	42.1	1.4
MCMA	MURRAY RIVER_10	91.3	0.0	8.7	6.2	85.2	0.0	14.8	1.4	20.3	0.0	79.7	-5.3	68.5	1.4	30.1	15.8
MCMA	MURRAY RIVER_11	87.8	0.0	12.2	5.6	77.1	0.0	22.9	0.9	27.3	0.0	72.7	-4.2	57.2	0.0	42.8	7.0
MCMA	MURRAY RIVER_12	91.9	0.0	8.1	6.1	88.6	0.0	11.4	1.0	19.2	0.0	80.8	-4.8	65.6	0.3	34.2	6.8
MCMA	POTTERWALKAGEE CREEK_65	84.2	0.0	15.8	3.3	89.0	0.0	11.0	0.9	26.3	0.0	73.7	-3.1	65.4	0.0	34.6	3.2
MCMA	POTTERWALLKAGEE CREEK_64	87.2	0.0	12.8	3.5	66.4	0.0	33.6	0.4	25.5	0.0	74.5	-4.3	55.1	4.4	40.5	3.9
MCMA	UNNAMED CREEK_20	10.0	80.0	10.0	-0.3	10.0	80.0	10.0	0.0	56.0	0.0	44.0	1.4	4.0	90.0	6.0	-2.9
MCMA	UNNAMED CREEK_66	95.7	0.0	4.3	7.4	91.3	0.0	8.7	0.8	6.5	0.0	93.5	-14.5	78.3	4.3	17.4	6.4
NCCMA	BIRCH'S CREEK_21	38.8	2.1	59.1	-3.5	58.2	1.7	40.1	0.0	50.5	0.0	49.5	3.0	44.6	11.5	43.8	-1.8
NCCMA	CAMPASPE RIVER_1	97.2	0.0	2.8	8.4	93.5	0.0	6.5	1.2	15.9	0.0	84.1	-5.5	68.7	0.0	31.3	13.3
NCCMA	CAMPASPE RIVER_2	96.5	0.0	3.5	7.9	86.8	0.0	13.2	1.0	17.4	0.0	82.6	-5.0	64.6	0.0	35.4	7.5
NCCMA	CAMPASPE RIVER_3	84.2	0.0	15.8	4.8	85.4	0.0	14.6	1.2	22.5	0.0	77.5	-4.3	67.8	0.3	31.9	5.0

NCCMA	CAMPASPE RIVER_4	84.9	0.0	15.1	3.4	86.2	0.0	13.8	1.1	22.8	0.0	77.2	-3.5	64.9	0.0	35.1	2.9
NCCMA	CAMPASPE RIVER_5	77.7	0.0	22.3	3.0	72.8	0.0	27.2	0.6	36.9	0.0	63.1	-2.7	52.8	0.0	47.2	2.2
NCCMA	CAMPASPE RIVER_6	61.6	0.2	38.3	0.0	65.4	0.2	34.4	0.2	38.8	0.0	61.2	-0.2	55.5	2.0	42.4	0.8
NCCMA	CAMPASPE RIVER_7	57.7	0.2	42.1	-0.4	75.2	0.3	24.5	0.8	33.8	4.6	61.6	-0.9	55.8	7.0	37.2	0.5
NCCMA	COLIBAN RIVER_22	54.1	0.0	45.9	1.3	86.2	0.0	13.8	1.7	28.2	15.7	56.1	-2.6	56.9	0.9	42.2	2.7
NCCMA	KANGAROO CREEK_21	65.1	0.4	34.5	1.4	78.2	0.2	21.6	0.8	41.2	8.8	50.0	-0.9	56.1	4.4	39.5	-0.1
NCCMA	LITTLE COLIBAN CREEK_20	53.8	4.9	41.3	0.8	77.2	4.9	17.9	0.7	31.3	0.0	68.7	-4.0	60.3	16.2	23.6	2.4
NCCMA	LODDON RIVER_7	79.5	0.0	20.5	3.6	67.3	0.0	32.7	0.3	33.2	0.0	66.8	-3.9	60.6	0.0	39.4	3.8
NCCMA	LODDON RIVER_8	68.8	0.0	31.2	2.5	74.5	0.0	25.5	0.6	33.6	0.0	66.4	-4.5	62.0	0.2	37.8	3.2
NCCMA	SERPENTINE CREEK_11	89.7	6.8	3.4	4.6	88.9	6.6	4.4	0.7	12.0	0.1	87.9	-5.6	61.9	25.3	12.8	4.1
NECMA	KING RIVER WEST BRANCH_53	76.5	0.0	23.5	7.7	82.9	0.0	17.1	1.3	30.9	5.2	63.8	-2.6	60.8	0.0	39.2	12.1
NECMA	KING RIVER_22	58.0	0.0	42.0	0.9	84.0	0.0	16.0	1.7	30.0	0.0	70.0	-4.1	65.8	0.0	34.2	4.5
NECMA	KING RIVER_23	36.9	0.0	63.1	-3.5	69.8	0.0	30.2	0.8	47.6	0.2	52.2	0.8	52.9	0.2	46.9	-0.8
NECMA	KING RIVER_24	54.6	0.0	45.4	0.7	80.9	0.0	19.1	1.3	48.5	0.0	51.5	-0.7	54.2	0.0	45.8	4.4
NECMA	OVENS RIVER_4	71.9	0.0	28.1	3.1	87.9	0.0	12.1	2.1	24.2	0.0	75.8	-4.9	65.7	3.0	31.3	6.3
NECMA	OVENS RIVER_5	54.0	0.0	46.0	0.3	82.6	0.0	17.4	1.6	42.7	0.0	57.3	-0.8	55.3	0.0	44.7	-2.3
NECMA	OVENS RIVER_6	39.0	0.0	61.0	-3.8	67.5	0.0	32.5	0.5	48.6	0.6	50.8	1.6	50.1	0.0	49.9	-3.0
NECMA	OVENS RIVER_7	56.4	0.0	43.6	2.4	42.7	0.0	57.3	-0.7	28.7	1.0	70.4	-8.9	69.4	0.0	30.6	29.2
WCMA	GLENLOFTY CREEK_72	68.6	2.9	28.5	1.7	76.0	4.1	19.8	0.5	26.4	0.0	73.6	-3.0	54.1	22.3	23.6	1.3

WCMA	GLENLOFTY CREEK_73	67.1	5.0	27.9	1.1	64.8	4.6	30.6	0.1	35.6	1.4	63.0	-0.3	41.6	21.5	37.0	-4.7
WCMA	GLENPATRICK CREEK_76	54.3	6.0	39.7	0.4	68.3	5.4	26.3	0.5	34.3	1.6	64.1	-1.7	55.2	10.2	34.6	2.6
WCMA	MORL CREEK_57	69.7	10.9	19.3	1.7	72.3	10.9	16.8	0.4	22.7	0.0	77.3	-3.2	57.6	21.0	21.4	1.5
WCMA	SEVEN MILE CREEK_64	80.4	3.1	16.5	2.2	81.8	2.9	15.3	0.6	19.6	0.0	80.4	-2.9	58.3	7.2	34.4	1.6
WCMA	SHAYS CREEK_68	75.2	2.1	22.8	1.4	75.2	0.7	24.1	0.3	28.3	0.0	71.7	-2.6	46.2	22.8	31.0	1.3
WCMA	SHAYS CREEK_69	78.4	10.2	11.4	3.1	83.0	8.5	8.5	0.7	14.2	0.0	85.8	-5.9	55.1	29.5	15.3	3.5
WCMA	SIX MILE CREEK_65	89.0	2.3	8.7	2.6	85.1	2.5	12.4	0.6	11.3	0.0	88.7	-4.0	65.9	7.9	26.2	1.8
WCMA	SPRING CREEK_71	65.7	8.0	26.3	0.9	71.4	8.5	20.2	0.3	32.4	0.0	67.6	-1.6	44.6	35.7	19.7	0.7
WCMA	WATTLE CREEK_53	94.1	0.3	5.6	4.3	93.8	0.3	5.9	0.9	4.9	0.0	95.1	-7.4	75.3	9.2	15.5	3.8
WCMA	WIMMERA RIVER_10	93.0	0.0	7.0	4.3	93.9	0.0	6.1	1.3	11.7	0.0	88.3	-5.7	74.0	0.1	25.9	4.2
WCMA	WIMMERA RIVER_11	73.7	1.1	25.2	1.9	80.4	0.9	18.7	0.6	24.1	0.0	75.9	-3.1	63.7	4.2	32.1	1.2
WCMA	WIMMERA RIVER_12	53.4	5.4	41.2	0.4	62.9	5.0	32.1	0.2	43.3	6.4	50.3	-0.8	44.1	17.4	38.5	-3.1
WGCMA	ALBERT RIVER_228	73.5	0.6	25.9	2.2	89.2	1.2	9.6	0.3	16.9	0.0	83.1	-4.4	71.1	10.8	18.1	2.5
WGCMA	ALBERT RIVER_229	100.0	0.0	0.0	8.4	100.0	0.0	0.0	1.0	0.0	0.0	100.0	-10.3	94.4	0.0	5.6	3.8
WGCMA	ALBERT RIVER_29	66.1	0.0	33.9	2.8	80.4	0.0	19.6	1.2	21.4	0.0	78.6	-6.2	74.5	0.4	25.1	2.9
WGCMA	ALBERT RIVER_30	68.4	0.0	31.6	7.6	76.1	0.0	23.9	0.8	28.1	16.4	55.5	-1.0	54.6	0.0	45.4	-1.9
WGCMA	AVON RIVER_19	72.9	0.0	27.1	3.4	92.5	0.0	7.5	1.4	16.4	0.0	83.6	-8.1	77.1	5.6	17.3	7.0
WGCMA	AVON RIVER_20	89.8	0.2	10.0	13.7	94.7	0.2	5.1	1.7	7.3	0.0	92.7	-19.4	81.6	3.1	15.3	15.5
WGCMA	AVON RIVER_21	82.4	0.0	17.6	10.0	88.5	0.0	11.5	1.9	14.7	0.0	85.3	-14.6	77.4	0.4	22.2	15.7
WGCMA	AVON RIVER_219	83.9	0.0	16.1	7.5	93.1	0.0	6.9	1.1	6.3	0.0	93.7	-12.7	83.9	0.6	15.5	15.5

WGCMA	FRANKLIN RIVER_21	75.3	0.0	24.7	4.7	91.7	0.0	8.3	2.9	16.7	0.5	82.8	-7.8	74.2	0.3	25.5	4.9
WGCMA	FRANKLIN RIVER_22	75.9	0.0	24.1	4.1	94.4	0.0	5.6	2.4	11.9	42.1	46.0	-2.7	55.4	0.2	44.4	5.8
WGCMA	FRANKLIN RIVER_221	91.5	0.0	8.5	3.6	98.8	0.0	1.2	2.2	2.4	0.0	97.6	-6.8	80.5	1.2	18.3	4.5
WGCMA	JACK RIVER_31	66.7	11.3	22.1	2.1	78.6	10.6	10.8	0.7	24.1	0.0	75.9	-4.2	58.2	26.9	14.8	1.8
WGCMA	JACK RIVER_32	46.8	0.0	53.2	-1.2	68.4	0.0	31.6	0.0	29.5	22.7	47.7	-1.2	52.3	0.2	47.5	0.4
WGCMA	MACALISTER RIVER_7	62.5	0.0	37.5	4.7	91.4	0.0	8.6	2.1	20.4	0.7	78.9	-7.9	68.1	0.0	31.9	8.5
WGCMA	MACALISTER RIVER_8	93.5	0.0	6.5	19.8	96.4	0.0	3.6	3.1	4.0	0.0	96.0	-23.6	91.1	0.7	8.1	18.8
WGCMA	RAINBOW CREEK_17	73.8	0.0	26.3	6.6	73.8	0.0	26.3	1.0	25.3	0.0	74.7	-9.3	71.3	3.4	25.3	6.9
WGCMA	TARRA RIVER_33	74.7	2.2	23.0	5.7	85.4	2.4	12.2	1.1	15.0	0.0	85.0	-8.7	76.6	10.2	13.2	4.5
WGCMA	TARRA RIVER_34	85.6	0.0	14.4	11.4	95.7	0.0	4.3	2.8	8.8	0.0	91.2	-14.2	89.0	0.0	11.0	8.1
WGCMA	THOMSON RIVER_2	59.7	0.0	40.3	3.4	63.2	0.0	36.8	0.9	32.9	1.5	65.6	-4.4	60.3	0.0	39.7	2.5
WGCMA	THOMSON RIVER_3	74.8	0.0	25.2	11.8	74.8	0.0	25.2	2.4	22.9	0.0	77.1	-14.0	72.4	0.0	27.6	6.8
WGCMA	THOMSON RIVER_4	85.8	0.0	14.2	13.3	90.8	0.0	9.2	2.5	12.5	0.0	87.5	-15.4	86.9	0.4	12.7	25.7

Table 12 Summary of changes in riparian vegetation at ISC reaches in each CMA. For fractional canopy cover, canopy height and vegetation width, values greater than zero (i.e. an increase in 2018 versus 2010) are highlighted in green, and values less than zero highlighted in red. For fragmentation, values lower than zero are highlighted in green, and values greater than zero in red.

		Fractional canopy cover				Canopy height				Fragmentation				Vegetation width	
Catchment	Location	>20%	>40%	>60%	>80%	Catchment	Location	>20%	>40%	>60%	>80%	Catchment	Location	>20%	>40%
CCMA	AIRE RIVER_28	0.0	-0.2	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.2
CCMA	AIRE RIVER_56	0.0	0.0	0.7	3.5	0.0	0.0	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.7
CCMA	BARWON RIVER EAST BRANCH_27	-1.1	0.9	-0.7	-1.8	4.5	3.6	2.9	-0.9	-2.9	-4.8	0.0	3.2	2.5	0.0
CCMA	BARWON RIVER WEST BRANCH_6	-3.0	-2.4	-0.3	-0.2	1.4	1.9	1.9	-0.7	0.2	0.7	-4.0	1.4	1.7	1.6
CCMA	BARWON RIVER_2	7.8	4.2	0.6	0.0	6.9	4.5	1.5	-2.1	-1.8	-1.5	-4.2	3.3	0.9	0.9
CCMA	BARWON RIVER_3	4.1	1.4	0.5	0.0	2.9	6.3	2.4	-1.0	-1.4	-0.7	0.2	-2.9	0.0	1.9
CCMA	DEWING CREEK_25	9.8	-0.5	1.1	0.0	9.2	3.3	0.5	0.0	-2.7	-14.7	-14.7	11.4	1.6	-1.1
CCMA	FORD RIVER_26	0.2	-1.0	-2.0	-3.7	1.0	1.2	-0.2	1.5	0.5	-0.2	-1.5	0.7	-0.7	-1.0
CCMA	LAL LAL CREEK_14	2.9	2.7	0.2	-0.2	1.8	2.2	-0.4	-0.4	-1.8	-2.7	-3.8	2.0	0.7	0.0
CCMA	MOORABOOL RIVER EAST BRANCH_10	3.9	4.5	0.0	0.0	5.4	3.3	-4.8	2.7	-2.7	-6.0	-4.8	5.1	4.2	0.0
CCMA	MOORABOOL RIVER EAST BRANCH_11	3.0	0.5	0.0	0.0	4.0	4.5	2.5	0.0	-1.0	-3.0	-4.5	0.5	2.0	1.0
CCMA	MOORABOOL RIVER EAST BRANCH_12	2.3	9.7	0.0	0.0	0.3	0.0	-0.3	4.5	-0.6	-0.3	-1.0	1.6	-1.0	0.0
CCMA	MOORABOOL RIVER WEST BRANCH_5	1.0	2.3	0.0	0.0	0.4	0.4	-3.6	3.6	-0.2	0.0	0.0	1.3	-0.6	-2.3
CCMA	MOORABOOL RIVER WEST BRANCH_6	4.6	1.6	2.0	0.0	5.8	3.6	1.6	0.0	-3.8	-4.1	-5.8	4.4	4.6	1.8
CCMA	MOORABOOL RIVER_1	3.0	3.2	-0.5	-0.2	4.6	2.6	2.4	-1.7	-1.2	-3.7	-3.5	2.7	-1.7	-1.7
CCMA	MOORABOOL RIVER_2	-1.3	1.3	-0.1	0.0	0.1	1.8	2.1	-1.0	0.4	2.0	0.3	-2.9	1.8	0.8
CCMA	MOORABOOL RIVER_3	0.7	-0.3	-8.7	-0.3	0.6	-0.1	0.3	5.3	0.1	-0.4	0.3	-1.0	-0.6	-0.8
CCMA	MOORABOOL RIVER_4	9.9	7.4	1.5	0.0	9.4	8.9	1.5	-5.9	-9.4	-6.4	-0.5	4.0	10.4	6.9
CCMA	SPRING CREEK_13	0.0	0.6	0.0	0.0	3.5	4.1	0.0	-0.6	-4.1	-1.8	-2.9	-1.8	1.2	0.6
CCMA	SUTHERLAND CREEK WEST BRANCH_7	5.3	1.2	0.0	0.0	11.7	4.8	0.2	-0.5	-2.7	-9.2	-6.0	4.2	3.8	0.3
CCMA	SUTHERLAND CREEK WEST BRANCH_8	5.0	23.6	-1.6	0.0	1.3	0.9	-1.9	-5.3	-1.9	-1.9	-0.3	2.8	1.6	4.1
CCMA	THOMPSON CREEK_36	9.9	0.0	0.0	0.0	16.6	1.3	0.0	0.6	-4.5	-14.0	-9.9	10.2	4.8	0.6
CCMA	THOMPSON CREEK_37	9.4	4.1	-0.7	0.0	15.9	6.2	1.4	-2.4	-5.4	-17.5	-19.2	17.2	5.9	3.0
CCMA	UNNAMED CREEK_38	11.7	2.6	0.0	0.0	18.3	6.1	1.7	-1.3	-5.7	-10.4	-6.5	10.0	7.8	2.2
CCMA	UNNAMED CREEK_39	12.0	1.9	0.0	0.0	19.5	7.9	2.3	-1.9	-5.3	-17.7	-9.8	13.5	7.1	3.0
EGCMA	BUCHAN RIVER_11	15.0	2.8	-2.3	0.0	12.5	11.1	2.5	-2.5	-8.5	-18.5	-21.0	19.6	9.0	4.2
EGCMA	CANN RIVER_13	-1.9	-3.3	-5.1	-12.1	0.0	0.5	-1.9	1.4	0.0	0.5	0.0	-1.4	-1.4	-0.9
EGCMA	CANN RIVER_14	-2.2	-14.5	-9.4	-1.9	-0.5	-2.2	4.6	7.3	3.1	-0.5	0.0	-4.1	-4.8	-3.9
EGCMA	MITCHELL RIVER_204	35.8	11.7	0.9	0.3	29.4	16.8	1.9	-5.4	-20.9	-27.5	-5.7	25.6	20.9	4.1
EGCMA	MITCHELL RIVER_205	11.0	6.1	0.0	0.0	18.3	9.8	1.2	-1.2	-8.5	-6.1	0.0	7.3	7.3	4.9
EGCMA	MITCHELL RIVER_5	13.7	11.2	2.8	0.0	17.2	20.4	2.4	-3.0	-13.3	-14.2	-6.9	13.3	11.6	3.4
EGCMA	MITCHELL RIVER_6	18.5	12.2	1.7	0.3	24.7	9.4	1.0	-5.9	-17.1	-18.8	-12.2	19.9	13.9	6.6
EGCMA	SNOWY RIVER_203	10.6	12.4	6.5	0.0	5.3	14.8	11.9	-8.8	-7.4	-6.9	-7.8	8.3	10.1	0.9
EGCMA	SNOWY RIVER_3	24.4	28.5	8.9	0.8	17.9	38.2	22.0	-10.6	-30.9	-22.0	-5.7	21.1	20.3	6.5
EGCMA	SNOWY RIVER_4	17.1	27.6	14.8	1.2	14.8	20.6	16.7	-21.0	-29.2	-20.2	-10.9	19.1	26.5	13.2

EGCMA	TAMBO RIVER_204	16.9	3.8	1.2	0.0	20.6	9.9	2.3	-2.3	-10.2	-19.2	-7.3	23.0	10.5	2.0
EGCMA	TAMBO RIVER_4	-5.6	1.9	-1.9	0.0	-7.4	3.7	11.1	-14.8	0.0	5.6	11.1	-5.6	-1.9	5.6
EGCMA	TAMBO RIVER_5	10.8	3.9	-1.0	0.0	17.2	11.8	2.0	-2.0	-10.3	-13.8	-5.9	15.3	10.3	2.5
GBCMA	ACHERON RIVER_62	7.2	28.7	22.8	5.3	3.6	0.8	2.8	-12.3	-7.1	-4.1	-1.6	6.6	9.1	11.1
GBCMA	BROKEN RIVER_4	4.4	11.7	0.5	0.0	0.4	8.0	11.1	-10.6	-9.7	-3.4	-0.3	5.3	10.5	8.9
GBCMA	BROKEN RIVER_5	9.2	0.0	0.0	0.0	15.8	3.2	0.0	0.0	-2.1	-17.2	-17.2	11.5	3.2	0.2
GBCMA	FAITHFULLS CREEK_21	16.9	8.2	0.5	0.0	4.9	11.5	7.9	-5.0	-12.9	-12.1	-3.8	12.6	15.1	7.9
GBCMA	GOULBURN RIVER_14	7.5	13.1	4.7	0.4	3.1	9.0	10.1	-6.1	-12.4	-4.7	-2.2	8.3	10.7	6.5
GBCMA	HOLLAND CREEK_14	7.9	4.8	0.5	0.1	2.8	7.2	7.3	-4.3	-7.4	-5.0	-2.4	7.9	8.4	4.1
GBCMA	HUGHES CREEK_37	9.4	16.6	0.6	0.0	1.7	6.4	11.7	-8.9	-11.5	-6.0	-0.6	5.5	10.6	8.7
GBCMA	HUGHES CREEK_38	3.5	6.3	-0.6	0.0	0.3	2.5	9.7	-1.6	-5.3	-1.6	0.0	0.0	4.7	5.3
GBCMA	HUGHES CREEK_39	4.5	6.0	0.1	0.0	2.2	5.9	8.4	-1.7	-4.4	-2.3	-1.5	4.0	4.8	1.8
GBCMA	KING PARROT CREEK_51	14.5	15.7	3.9	-0.1	11.4	11.6	10.0	-8.9	-15.1	-11.3	-1.8	14.0	14.7	8.2
GBCMA	SEVEN CREEKS_17	9.9	27.2	0.4	0.0	0.1	3.6	19.9	-17.3	-19.0	-2.9	0.0	4.4	14.0	18.6
GBCMA	SEVEN CREEKS_18	10.0	12.7	0.0	0.0	1.3	8.2	10.3	-12.1	-12.5	-4.7	-0.4	3.3	8.9	8.3
GBCMA	SEVEN CREEKS_19	7.7	4.5	-0.2	0.0	7.5	9.5	7.1	-3.0	-7.9	-7.7	-3.2	7.1	10.0	4.5
GBCMA	SEVEN CREEKS_20	3.6	4.0	-0.9	0.0	3.5	5.3	5.3	-1.9	-3.2	-2.8	-1.9	2.4	6.4	2.1
GHCMA	BATTLE CREEK_19	0.9	0.0	0.0	0.0	1.9	0.2	0.0	-0.2	-0.5	-2.1	-0.2	1.4	0.5	0.0
GHCMA	BRYANS CREEK_31	4.0	1.7	0.0	0.0	4.8	4.2	1.7	-0.3	-3.7	-2.3	-2.0	1.4	2.8	0.6
GHCMA	BRYANS CREEK_32	7.4	3.0	0.0	0.0	7.4	14.1	1.5	-0.7	-4.1	-5.2	-5.6	4.8	2.6	0.0
GHCMA	BRYANS CREEK_33	5.4	3.8	0.0	0.0	2.3	9.2	5.4	1.2	-1.4	-1.9	-0.7	3.3	3.8	2.3
GHCMA	CHETWYND RIVER_47	2.5	-1.7	-0.1	0.0	5.3	6.8	3.5	0.7	-0.2	-4.2	-3.9	3.7	2.6	-1.1
GHCMA	GLENELG RIVER_10	4.2	-2.3	-0.3	0.0	0.1	2.2	0.3	3.1	0.9	-0.5	0.0	-0.2	-3.4	-2.1
GHCMA	GLENELG RIVER_11	5.7	-0.3	1.8	-0.3	-0.1	0.4	0.9	3.6	1.7	-0.4	-0.3	1.8	-2.2	-5.6
GHCMA	GLENELG RIVER_7	-3.2	-3.2	-0.1	0.0	-0.1	-0.3	0.7	1.6	4.0	2.9	0.0	-2.1	-4.6	-3.5
GHCMA	GLENELG RIVER_9	0.2	2.4	0.0	0.0	-2.6	-2.7	1.2	5.1	7.1	4.6	1.5	-6.1	-5.9	-1.5
GHCMA	KONONG WOOTONG CREEK_34	5.0	0.2	-0.6	0.0	7.5	3.4	1.1	-0.6	-3.4	-2.8	-5.6	4.5	2.8	-0.4
GHCMA	MERRI RIVER_238	8.6	0.8	0.0	0.0	10.2	0.0	0.0	0.0	-0.8	-6.3	0.0	6.3	2.3	0.0
GHCMA	MERRI RIVER_38	5.8	3.2	0.0	0.0	11.1	5.3	1.1	-0.5	-2.1	-4.7	0.5	2.6	2.6	1.6
GHCMA	MERRI RIVER_39	4.9	2.2	-0.3	0.0	13.7	6.5	1.9	-1.6	-5.1	-9.7	-1.3	8.9	4.0	1.3
GHCMA	MT EMU CREEK_18	2.3	-0.3	0.0	0.0	6.9	2.6	0.1	0.4	1.4	0.3	-2.9	3.3	-1.4	-0.1
GHCMA	MT EMU CREEK_22	-0.6	0.4	0.0	0.0	3.5	-0.1	0.6	-0.3	0.5	0.7	1.2	2.7	0.1	0.2
GHCMA	PIGEON PONDS CREEK_48	0.9	-2.2	0.0	0.0	3.4	1.9	1.3	2.2	4.7	-0.6	-0.3	2.5	-2.5	-3.1
GHCMA	STEEP BANK RIVULET_46	-6.0	-5.9	-0.8	0.0	-0.8	-2.2	-0.3	2.5	4.3	4.0	-0.2	-3.0	-3.5	-4.6
GHCMA	TREWALLA CREEK_23	-5.1	-1.3	0.0	0.0	-9.0	-6.4	0.0	0.0	6.4	7.7	14.1	-1.3	-2.6	-2.6
GHCMA	WANDO RIVER_44	0.0	-1.4	0.0	0.0	12.9	5.7	1.4	0.0	-1.4	-4.3	-10.0	1.4	4.3	0.0
GHCMA	WANDO RIVER_45	4.7	0.6	0.0	0.0	6.9	3.3	1.0	0.1	-0.6	-3.7	-4.0	5.1	1.6	-0.7
MCMA	CANTALA CREEK_40	25.9	0.7	0.0	0.0	4.4	3.0	2.2	0.0	-10.4	-9.6	-0.7	5.2	6.7	3.7
MCMA	CHALKA CREEK_39	16.0	23.6	0.0	0.0	1.9	4.7	15.3	-6.7	-15.3	-3.0	-0.9	1.9	9.2	10.1
MCMA	CHALKA CREEK_41	13.6	19.3	0.0	0.0	0.0	1.7	10.2	-11.9	-8.0	-1.1	0.0	5.1	11.9	11.9

MCMA	LINDSAY RIVER_67	10.4	11.6	1.2	0.0	0.0	0.0	7.7	-4.2	-8.1	-1.2	0.0	2.7	6.9	6.6
MCMA	LINDSAY RIVER_68	27.2	33.5	0.0	0.0	1.0	6.8	22.5	-24.6	-40.3	-2.1	0.0	13.1	29.8	27.2
MCMA	LINDSAY RIVER_69	14.6	3.3	0.0	0.0	0.0	5.4	2.1	0.0	-11.3	-1.7	-0.4	3.3	3.3	0.0
MCMA	MURRAY RIVER_10	6.4	17.6	5.2	0.0	2.4	3.0	4.9	-11.4	-4.8	-2.2	-1.7	4.7	6.8	12.2
MCMA	MURRAY RIVER_11	10.9	17.6	1.6	0.0	0.1	2.8	11.0	-9.1	-6.0	-1.1	-0.1	2.9	3.6	7.1
MCMA	MURRAY RIVER_12	8.2	18.6	1.0	0.0	0.5	6.2	8.0	-9.0	-8.5	-1.5	0.0	5.1	7.7	7.6
MCMA	POTTERWALKAGEE CREEK_65	8.3	5.3	0.0	0.0	0.9	6.6	13.2	0.0	-8.8	-0.9	-0.4	3.5	6.6	6.6
MCMA	POTTERWALLKAGEE CREEK_64	11.8	9.0	0.0	0.0	1.9	3.1	3.4	-7.5	-9.7	-5.6	-1.6	5.0	5.6	3.7
MCMA	UNNAMED CREEK_20	-2.0	2.0	0.0	0.0	-2.0	0.0	2.0	0.0	0.0	4.0	4.0	-4.0	-4.0	-4.0
MCMA	UNNAMED CREEK_66	26.1	0.0	0.0	0.0	10.9	10.9	6.5	0.0	-23.9	-32.6	-8.7	26.1	13.0	6.5
NCCMA	BIRCH'S CREEK_21	-8.7	-4.3	-1.1	0.0	-0.2	-0.4	0.0	1.2	3.6	4.9	5.6	-5.7	-3.2	-1.5
NCCMA	CAMPASPE RIVER_1	3.7	36.4	1.4	0.0	0.5	0.9	9.3	-11.2	-5.6	0.0	0.0	1.9	7.0	14.0
NCCMA	CAMPASPE RIVER_2	5.7	35.4	0.9	0.0	0.1	2.1	8.4	-12.3	-6.5	-1.0	-0.1	1.5	4.4	10.6
NCCMA	CAMPASPE RIVER_3	4.6	19.2	0.1	0.0	0.3	2.6	10.2	-7.7	-8.9	-0.6	0.3	1.0	7.8	7.7
NCCMA	CAMPASPE RIVER_4	5.2	11.7	0.0	0.0	0.2	3.3	8.2	-6.1	-7.3	-1.7	-0.2	1.9	5.4	2.9
NCCMA	CAMPASPE RIVER_5	2.7	10.0	0.2	0.0	0.0	2.0	5.6	-4.8	-7.5	-0.5	-0.2	0.2	6.1	4.7
NCCMA	CAMPASPE RIVER_6	3.5	-0.2	-0.1	-0.2	2.6	2.3	0.5	0.0	-2.0	0.1	4.3	1.4	2.4	2.1
NCCMA	CAMPASPE RIVER_7	-1.0	0.4	-1.7	-0.1	3.1	6.4	2.6	-1.3	-2.2	-0.1	-0.1	2.2	2.4	1.5
NCCMA	COLIBAN RIVER_22	2.5	2.5	1.1	0.0	3.2	3.6	3.2	-2.8	-3.6	-3.8	-2.1	5.3	4.3	1.7
NCCMA	KANGAROO CREEK_21	2.3	-0.4	0.0	0.0	5.0	1.1	0.4	0.8	-0.2	-4.0	-5.5	5.3	1.7	0.0
NCCMA	LITTLE COLIBAN Creek_20	2.1	-2.1	-1.0	0.0	11.3	3.6	2.3	-1.5	-2.1	-6.7	-11.5	9.0	4.6	0.0
NCCMA	LODDON RIVER_7	10.4	9.0	0.0	0.0	0.6	2.3	3.1	-4.8	-7.9	-2.7	-0.5	2.7	7.9	6.3
NCCMA	LODDON RIVER_8	8.9	2.6	-0.4	0.0	4.4	8.3	5.5	1.5	-9.8	-8.7	-3.1	9.2	10.5	4.2
NCCMA	SERPENTINE CREEK_11	12.2	9.9	0.2	0.0	3.1	8.7	4.2	-5.3	-9.5	-5.4	-2.5	4.5	8.6	6.2
NECMA	KING RIVER WEST BRANCH_53	0.0	6.9	32.6	2.8	0.3	1.1	2.5	-1.1	-1.9	-0.3	0.3	0.3	0.0	2.2
NECMA	KING RIVER_22	2.9	4.7	-4.7	-0.2	-0.7	3.2	12.5	-5.4	-9.6	-0.7	0.2	1.5	8.4	4.7
NECMA	KING RIVER_23	-2.0	-5.7	-9.2	-2.4	-0.2	2.2	4.3	0.8	1.6	0.6	0.4	-1.8	-1.2	-2.7
NECMA	KING RIVER_24	2.7	5.0	-0.8	-0.8	0.8	4.6	13.7	0.4	-1.1	-2.7	-0.8	1.9	-0.8	0.8
NECMA	OVENS RIVER_4	4.0	8.0	2.8	-0.1	1.4	7.7	11.7	-7.7	-8.8	-2.6	-0.9	4.7	10.6	7.2
NECMA	OVENS RIVER_5	3.2	1.5	-2.9	-0.5	2.6	8.0	9.3	0.0	-1.7	-2.1	-0.9	2.3	3.8	1.2
NECMA	OVENS RIVER_6	0.3	-6.2	-12.3	-0.4	0.6	1.0	3.0	5.1	1.7	-0.1	0.0	0.1	-1.7	-2.8
NECMA	OVENS RIVER_7	2.2	15.3	-6.7	-0.3	0.0	0.6	-3.8	-27.4	-5.4	0.0	0.0	2.9	8.3	18.5
WCMA	GLENLOFTY CREEK_72	5.4	1.7	0.0	0.0	9.1	5.0	0.4	-0.4	-2.9	-7.0	-8.3	7.9	3.3	-0.4
WCMA	GLENLOFTY CREEK_73	0.9	0.5	0.0	0.0	2.7	0.5	0.5	0.0	-0.5	-0.9	-4.6	0.9	0.0	-0.5
WCMA	GLENPATRICK CREEK_76	3.5	1.3	-4.4	0.0	1.9	5.1	2.5	-1.9	-1.0	-1.9	-1.6	3.5	2.2	2.5
WCMA	MORL CREEK_57	4.6	0.4	0.0	0.0	5.0	3.8	0.0	0.0	-2.9	-9.7	-7.1	6.7	3.4	0.8
WCMA	SEVEN MILE CREEK_64	6.5	3.6	0.0	0.0	6.4	6.5	4.6	-1.5	-4.2	-6.3	-3.3	4.3	3.1	2.2
WCMA	SHAYS CREEK_68	4.1	0.0	0.0	0.0	6.2	1.4	0.0	0.0	-0.7	-3.4	-12.4	4.1	2.8	2.1
WCMA	SHAYS CREEK_69	9.1	0.0	0.0	0.0	11.4	5.1	1.1	-0.6	-1.1	-17.0	-11.4	16.5	6.3	2.3
WCMA	SIX MILE CREEK_65	9.3	1.2	0.0	0.0	8.4	7.6	0.8	-0.6	-4.3	-8.7	-5.4	9.4	3.6	1.4

WCMA	SPRING CREEK_71	1.4	0.0	0.0	0.0	9.9	3.3	0.0	0.0	0.0	-5.6	-1.9	4.7	0.0	0.0
WCMA	WATTLE CREEK_53	10.5	2.6	0.0	0.0	18.8	9.5	0.7	-1.0	-7.9	-20.7	-9.9	16.8	8.6	0.7
WCMA	WIMMERA RIVER_10	10.4	10.9	0.0	0.0	6.2	13.0	13.3	-4.8	-9.5	-7.8	-2.7	10.8	10.4	4.7
WCMA	WIMMERA RIVER_11	4.5	2.0	0.0	0.0	7.7	8.3	2.3	-0.9	-2.9	-6.5	-5.3	5.1	4.0	0.8
WCMA	WIMMERA RIVER_12	2.1	0.6	-5.0	0.0	5.0	3.1	0.8	-0.4	-0.8	-3.1	-3.7	3.7	1.2	0.4
WGCMA	ALBERT RIVER_228	10.2	3.0	-2.4	0.0	8.4	-0.6	0.0	-3.6	-4.2	-11.4	-6.6	10.8	7.8	1.2
WGCMA	ALBERT RIVER_229	22.2	5.6	0.0	0.0	5.6	5.6	0.0	0.0	-11.1	-33.3	-22.2	33.3	0.0	0.0
WGCMA	ALBERT RIVER_29	9.5	3.5	0.2	0.0	20.4	11.9	2.7	-1.8	-8.2	-15.6	-1.6	13.6	10.5	1.6
WGCMA	ALBERT RIVER_30	14.3	10.5	6.8	4.4	2.8	0.7	-0.7	2.1	-2.1	-3.0	-2.6	2.6	2.3	-1.6
WGCMA	AVON RIVER_19	5.1	10.3	2.8	0.0	9.3	26.6	6.5	-7.0	-17.3	-5.6	-2.3	15.0	16.8	7.5
WGCMA	AVON RIVER_20	35.1	23.3	4.9	0.0	38.2	18.0	0.7	-16.9	-30.4	-26.0	-9.6	27.6	32.7	14.9
WGCMA	AVON RIVER_21	17.2	23.7	6.1	-0.7	15.1	15.8	9.7	-19.0	-21.9	-12.9	-3.9	15.1	17.2	18.3
WGCMA	AVON RIVER_219	12.1	13.8	6.9	0.0	20.1	13.8	1.7	-10.3	-12.1	-17.2	-13.2	21.8	14.9	6.9
WGCMA	FRANKLIN RIVER_21	11.5	9.9	2.9	-0.3	10.4	22.4	17.7	-5.7	-16.9	-8.6	-2.6	8.1	15.9	6.5
WGCMA	FRANKLIN RIVER_22	1.9	2.3	2.9	2.3	1.3	2.3	3.8	-4.8	-3.3	-2.1	-1.3	1.5	3.1	4.0
WGCMA	FRANKLIN RIVER_221	11.0	8.5	0.0	0.0	8.5	25.6	20.7	-4.9	-19.5	-8.5	0.0	2.4	8.5	2.4
WGCMA	JACK RIVER_31	4.7	0.8	-0.2	0.0	11.4	4.2	0.8	0.2	-2.2	-9.3	-13.8	8.8	2.9	0.8
WGCMA	JACK RIVER_32	0.2	-0.2	-4.8	-5.2	1.8	-1.8	-3.9	0.0	-2.0	-0.7	-0.5	2.5	3.4	0.0
WGCMA	MACALISTER RIVER_7	7.9	10.0	4.2	0.0	4.6	14.1	15.0	-10.0	-12.3	-5.1	-2.1	8.1	13.7	6.7
WGCMA	MACALISTER RIVER_8	39.1	37.6	16.1	2.4	31.8	40.4	9.6	-21.0	-37.0	-28.1	-9.5	30.9	37.9	19.5
WGCMA	RAINBOW CREEK_17	16.6	11.9	3.1	0.0	11.3	15.3	1.6	-6.3	-18.8	-13.1	-5.9	21.9	15.3	5.6
WGCMA	TARRA RIVER_33	15.2	6.0	1.6	0.0	24.0	9.4	1.8	-3.0	-6.6	-20.6	-19.2	24.0	7.0	2.4
WGCMA	TARRA RIVER_34	33.0	9.3	1.3	-0.4	45.7	23.1	7.3	-5.2	-12.9	-34.9	-22.6	42.0	14.4	3.0
WGCMA	THOMSON RIVER_2	6.6	3.4	2.8	2.6	8.3	11.6	3.0	-4.0	-6.2	-9.3	-1.3	6.6	9.1	2.6
WGCMA	THOMSON RIVER_3	37.1	14.8	2.4	-0.5	41.0	31.9	3.3	-3.3	-15.2	-37.1	-9.0	34.3	13.8	4.3
WGCMA	THOMSON RIVER_4	29.4	25.2	9.0	0.2	29.4	26.0	12.9	-12.3	-12.5	-29.0	-11.5	31.9	14.0	6.9