RAPID APPRAISAL OF RIPARIAN CONDITION

2017-2022 Report

Abstract

Working with landholders, the Landscape Rehydration actions of The Mulloon Institute have significantly improved vegetation response during extremes of drought and floods providing resilience to such potentially damaging climatic events. When coupled with managing stock access and additional native plantings the results are multiplied and greatly assist regeneration of the riparian zone that have many benefits for flora, fauna, and water quantity and quality.

Luke Peel, Susie Miechels, and Peter Hazell

Acknowledgements

The Mulloon Rehydration Initiative (MRI) is jointly funded by The Mulloon Institute, the Australian Government's National Landcare Program, NSW Environmental Trust, with funding of initial baseline surveys by South East LLS. The author wishes to acknowledge the assistance of Ira Dudley-Bestow, Penny Cooper, Cam Wilson, and James Diack with collecting field data and preliminary analysis. Thanks to John Morton, Richard Campbell, and others at HydroTerra who assisted in the design and building of the digital data sheets and corresponding data management system. Thanks to The Mulloon Institute's Science Advisory Committee members who provide advice and support for the scientific monitoring.

Special thanks to the landholders involved with the MRI for their continued support and involvement: you are an integral part of the MRI, and we hope our combined efforts generate many benefits for you and your farm operations. This report is not intended to judge property management, but rather, endeavours to present the factual information gathered and explain the results while maintaining a level of anonymity.

The Mulloon Institute acknowledges the traditional custodians of the lands across Australia where we conduct our work. We acknowledge their deep understanding and connection to lands, rivers, and sea. We appreciate their important and ongoing contributions to caring for Country.

Executive Summary

The Mulloon Institute's (TMI) catchment scale project, the Mulloon Rehydration Initiative (MRI), aims to rehabilitate nearly 50 kilometers of waterways involving 23 properties and encompassing 23,000 hectares. Rapid Appraisal of Riparian Condition (RARC) baseline surveys were conducted in 2017 along lower Mulloon Creek. In 2020 the survey was expanded to include the upper Mulloon and main tributaries, Sandhills and Shiel Creeks, which continues to be surveyed in the subsequent 2021 and 2022 surveys. The aim of these surveys was to measure changes over time in the condition of riparian vegetation within the catchment, due to rehydration and rehabilitation actions. The RARC process involves quantifying different parameters such as width of riparian vegetation, canopy and ground cover, leaf litter and other debris to reflect functional aspects of the physical, plant community and landscape features of the riparian zone.

RARC scores in upper Mulloon were average (20) to excellent (>30). RARC scores in the lower Mulloon floodplain ranged from very poor (<15) to average. This is primarily a reflection of historical land use and management across the catchment, which itself was reflected in the initial native plant composition of the riparian zone (see Appendix B).

However, there is an emerging trend of improvements in the RARC Index for a majority of the transects along the entire length of Mulloon Creek. Much of this improvement can be attributed to rehydration and rehabilitation actions undertaken between 2006 and 2020 as part of the Mulloon Rehydration Initiative. The most prominent responses to rehydration actions were from aquatic plants, ground cover along the creek banks (aided by fencing), and recruitment due to plantings and natural germination. In addition, RARC scores also trended positively downstream of any instream works, suggesting that the rehydration actions upstream were having a positive downstream impact.

The original nineteen baseline RARC transects were surveyed in 2017. The rehydration works were implemented between 2018-2020. Therefore, these original nineteen transects provide a sound baseline for change in riparian vegetation condition, as a result of the works, over the following surveys in 2019, 2021 and 2022.

An analysis of surveys before and after the implementation of rehydration works also suggests a correlation with a RARC Index score increase during extreme drought conditions. The degree of response in RARC Index score can be affected by current management practices such as managing stock access to riparian zone.

Introduction

The Mulloon Institute (TMI) conducts Rapid Appraisal of Riparian Condition (RARC) surveys to help establish how the implementation of leaky weirs in waterways affects the condition of riparian vegetation along Mulloon Creek. RARC surveys are a component of TMI's scientific monitoring program, being conducted for the Mulloon Rehydration Initiative (MRI) (Peel and Hazell et al 2022).

Riparian zones are especially sensitive to conventional farming methods such as clearing of vegetation (Brierley et al. 1999). Such practices have compounding effects on the rate of erosion on the bank and bed of a waterway, resulting in deep creek incision and large amounts of surface erosion (Dobes et al. 2013). Erosion of the bed and bank has potential to cause water quality issues due to turbidity and silt, potential loss of productive land and lowering of groundwater aquifers (Dobes et al. 2013; Streeton et al. 2013).

However, appropriate management of riparian zones can ensure they provide both filtering, stability, and habitat functions for waterways. The riparian and aquatic vegetation provides a buffering effect on surface water flows, which can minimise soil loss, build organic matter, and filter nutrients and pollutants that enter the waterway. Riparian vegetation also plays an important role in moderating waterway temperatures, reducing evaporation, and providing food and shelter for a wide variety of terrestrial and aquatic flora and fauna. High functioning and hydrated riparian corridors throughout a catchment can also assist with slowing fire progress and reducing intensity, while at the same time providing refuge for fauna, and potential water supplies to fight fires.

To reduce the erosive force of water that pulses through the floodplain pockets of the Mulloon catchment, to date, TMI has implemented over 50 strategically located in-stream structures, colloquially known as leaky weirs, in Mulloon Creek. These structures are intended to raise the water level and slow stream flow, and during large flow events encourage the water to spread more gently across the floodplains in the catchment. These interventions are coupled with fencing of the riparian zone, and revegetation of the banks, ponds, and structures themselves.

Composed of rocks and logs, leaky weirs re-establish higher base water levels that support vegetation growth in the waterway and associated riparian zone. While the volume of water moving through the system is maintained on an annual basis, the rate of flow is slowed due to reduced stream gradient, greater cross-sectional area of flow and increased surface roughness caused by the vegetation. This reduces the scouring effect of fast-flowing water and provides a more reliable source of water for flora and fauna, especially during dry periods. These landscape rehydration actions promote riparian and aquatic vegetation, armouring the banks (riparian) and buffering the flow (emergent aquatic), which further reduces the rate of erosion. Other management strategies such as managing stock access to riparian zones and native plantings complement the construction of leaky weirs to maximise the rate of recovery.

To help determine whether the leaky weirs are having a positive effect on riparian and aquatic native vegetation, RARC surveys were conducted across the catchment in 2017 (baseline) prior to the installation of leaky weirs to generate a baseline measure, followed by subsequent surveys in 2019, 2021 and 2022.

Methodology

The RARC approach to assessing the condition of watercourses was developed for South-Eastern Australia by Dr Amy Jansen (Jansen et al 2005) and measures the departure of riparian condition from a semi-natural state. The approach generates an Index score based on field surveys. The Index is made up of five sub-indices: habitat, vegetation cover, native vegetation, woody debris, and indicative features. These sub-index scores are generated by several field observations such as the percentage of cover for ground, understorey, and canopy. See Appendix A for a complete listing of sub-index categories and components measured.

Historic bird survey transects were used as the location of RARC transects at the pilot project property (Property Management Area 2 – PMA2) and the lower Mulloon floodplain. This will help inform results from bird and frog surveys conducted at the same transects. Additional RARC transects for the remaining catchment areas were selected using satellite and aerial imagery, site accessibility and local knowledge to be representative of the landholder's property.

RARC survey methods (Jansen et al 2005) were conducted throughout the MRI along Mulloon Creek, and sub-catchments of Shiel and Sandhills Creeks. RARC surveys were conducted at 19 transects in 2017. These focused on the pilot project and lower Mulloon floodplain and captured baseline data for Stages 1 and 2 of the MRI, prior to in-stream actions to rehydrate the riparian zone and associated floodplains. RARC surveys were expanded to 49 transects in 2019 to include upper Mulloon, and the sub-catchments Sandhills and Shiel Creeks. Surveys were undertaken between 25th September and 16th October 2019 and included the initial 19 transects surveyed in 2017.

In 2021, following a review of all transects in the MRI, a decision was made to reduce transects to 34 to account for distribution, accessibility, and resources required to monitor these transects. Transects were surveyed between 27th October and 18th November 2021. Transects not surveyed in 2021 included four transects in Upper Mulloon (excess to needs), nine along the Sandhills Creek (unable to access), and two transects on Shiel Creek (unable to access). See Figure 1 for the location of transects across the MRI and the respective properties referred to as Property Management Area (PMA).

The survey in 2022 was conducted from 4 October and 4 November 2022. Three transects (T9, T50, T55) monitored in previous years were inaccessible in 2022 and consequently were not surveyed.

The 2021 and 2022 RARC surveys were conducted using a computer tablet with the ''Fast Fields'' program designed to link automatically to the digital data management system (DataStream™) administered by our partner HydroTerra. This digital field data collection reduces time to transcribe data from field sheets and potential data entry errors. Fast Fields allows customised setup to suit specific needs including setting expected range or type of input and use of drop-down lists to minimise errors and allows input of site photos. The field data collected is automatically uploaded to DataStream™ when the tablet is connected to the internet.

Background

Figure 1 presents locations of the RARC transects and respective PMA. PMA2 is the pilot project area where in-stream structures were implemented in 2006-07. Stage 1 of the MRI was implemented at PMA 3, 4 and 5 (2018-19), and Stage 2 of the MRI was implemented at PMA 7 and 8 (2019-current). Planning and design for landscape rehydration works is underway for PMA1 (Stage 3), with implementation expected in 2023. Transect 15 is referred to as the Gorge and located at the boundary of two properties and crown land.

The transects within PMA1 are the least historically degraded in the MRI catchment. This property has more remnant native plants than any other PMA and the riparian corridor has been fenced off for many years. Some non-native trees (willows) are present in the mid to lower sections of this PMA. It is important to note here, that a bushfire in 2019-20 severely burnt a large section of southern PMA1, including the riparian zone of transects 1 and 2, and less severe at transects 3 and 4.

For the context of this report, the vegetation of the Mulloon catchment has also been affected by climatic events: extreme drought from 2017 to Jan 2020, culminating in severe bushfires (2019-2020) that burnt much of the upper catchment, particularly Tallaganda National Park and State Conservation Areas. This was followed by two large floods (1-in-50-year events) in August 2020 and March 2021, which transported debris, ash, and sediment downstream from the fires. Only days before the August 2020 flood, the last of the in-stream structures at PMA8 were installed. For much of 2022, rainfall was above average, and saw at least 5 overbanking events in Mulloon Creek.

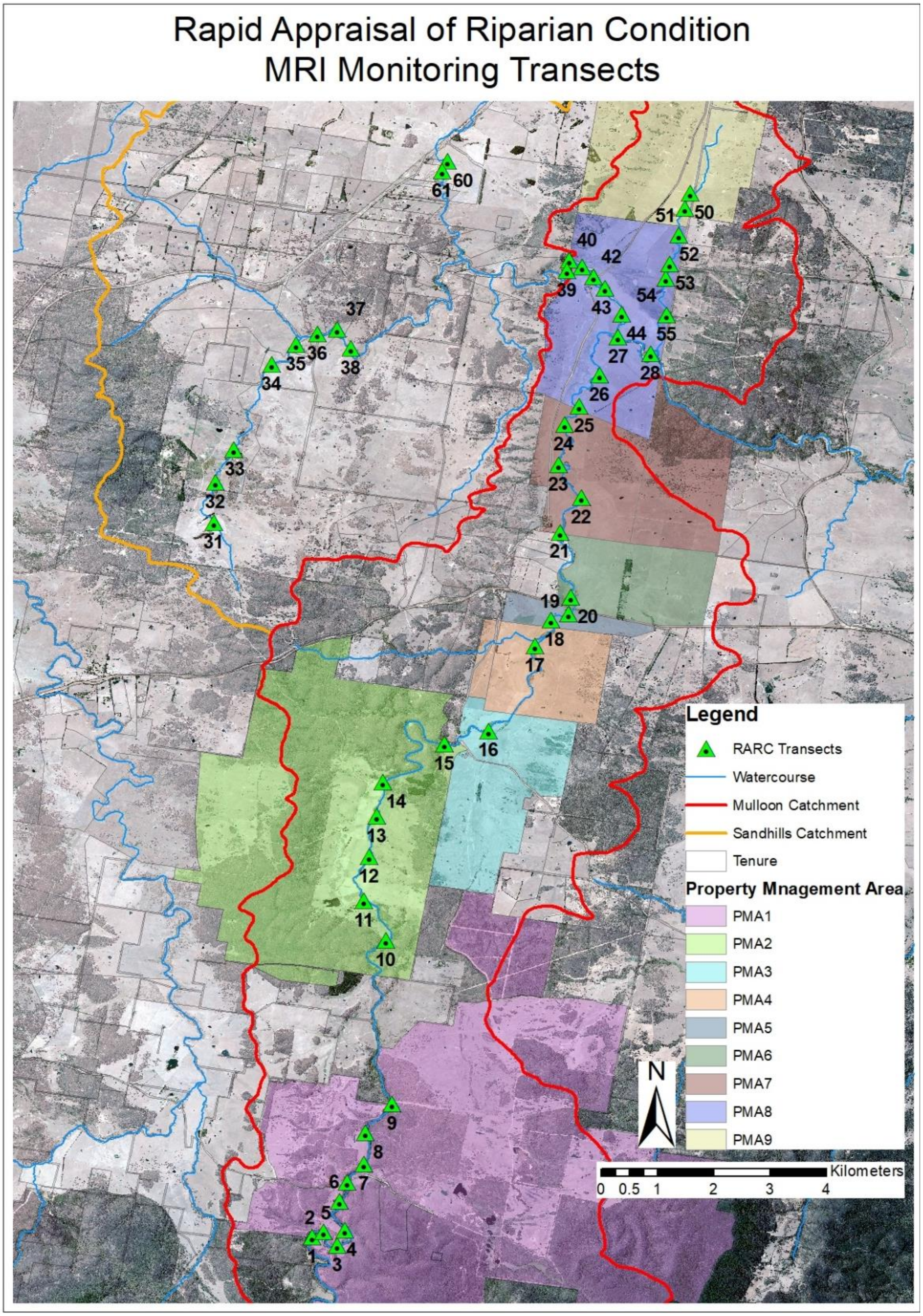

Figure 1: RARC transect locations in the MRI.

Results

This report will focus on the RARC results for the main Mulloon Creek riparian zone (not sub-catchments Sandhills and Shiel Creek) where rehydration works have occurred or soon to be implemented. The majority of these transects have had four RARC surveys conducted over the period 2017 – 2022, that can provide an assessment of trends. For more information and photos of the transect sites see Appendix C.

For detailed results and discussion of surveys in 2017, 2019 and 2021, please refer to the earlier RARC Reports.

Total RARC Index Scores

Total RARC Index scores were calculated using the prescribed methods taken from Jansen et al 2015 with a possible maximum RARC Index score of 50 and assessed for transects on Mulloon Creek. Figure 2 presents total RARC Index scores for each transect and identifies the PMA in which the transect is located. Note that PMA1 is furthest upstream and PMA8 is furthest downstream.

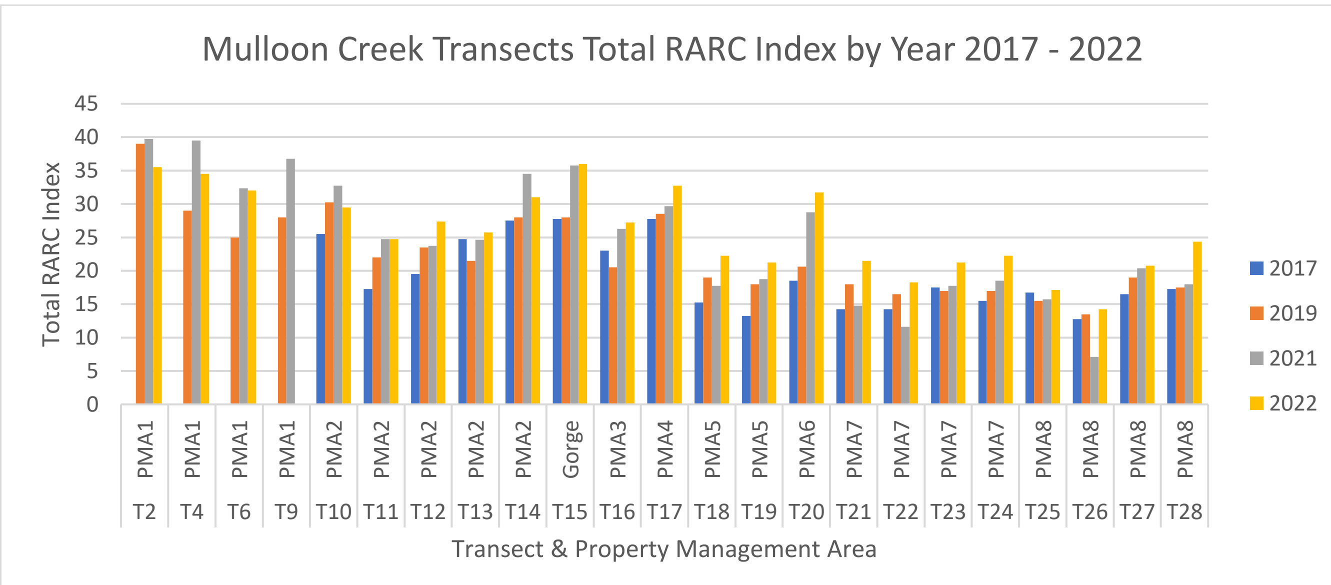

Figure 2: Total RARC Index scores for Mulloon Creek transects 2017, 2019, 2021 and 2022.

Across the twenty-three transects monitored along Mulloon Creek since 2017 to 2022, there is an evident trend of improvement in total RARC score. In the period 2021 to 2022, eighteen (78%) transects increased RARC Index scores despite overbank flow events in the La Nina period of 2022. Four (17%) transects (2, 4, 6, 10) experienced a decrease in RARC Index for the same period (Figures 2 & 3), one transect remained stable (0.05%) (T11) and one transect (0.05%) was not surveyed in 2022 (T9).

A decline in total RARC index score from 2021-2022 is seen at the top of the catchment (PMA 1), while there is a general trend in improvement across the rest of the catchment (PMA2 – PMA8), with the largest gains seen downstream of PMA4.

Figure 3 presents the change in RARC Index score for each survey period, plus total change since transect was monitored. A 2nd y-axis indicating the average RARC Index score across the three surveys has been included for context and comparison with other transects.

Since the baseline survey, we see that only T2 has regressed, while all other transects have improved (Total Change).

In the period 2021 to 2022, there is a decline in PMA 1, along with T10 and T14, however overall change remains positive. The largest positive changes are seen in PMA 5, 7 and 8 – it is noted here that these transects were those that had the lowest baseline scores (see Figure 2).

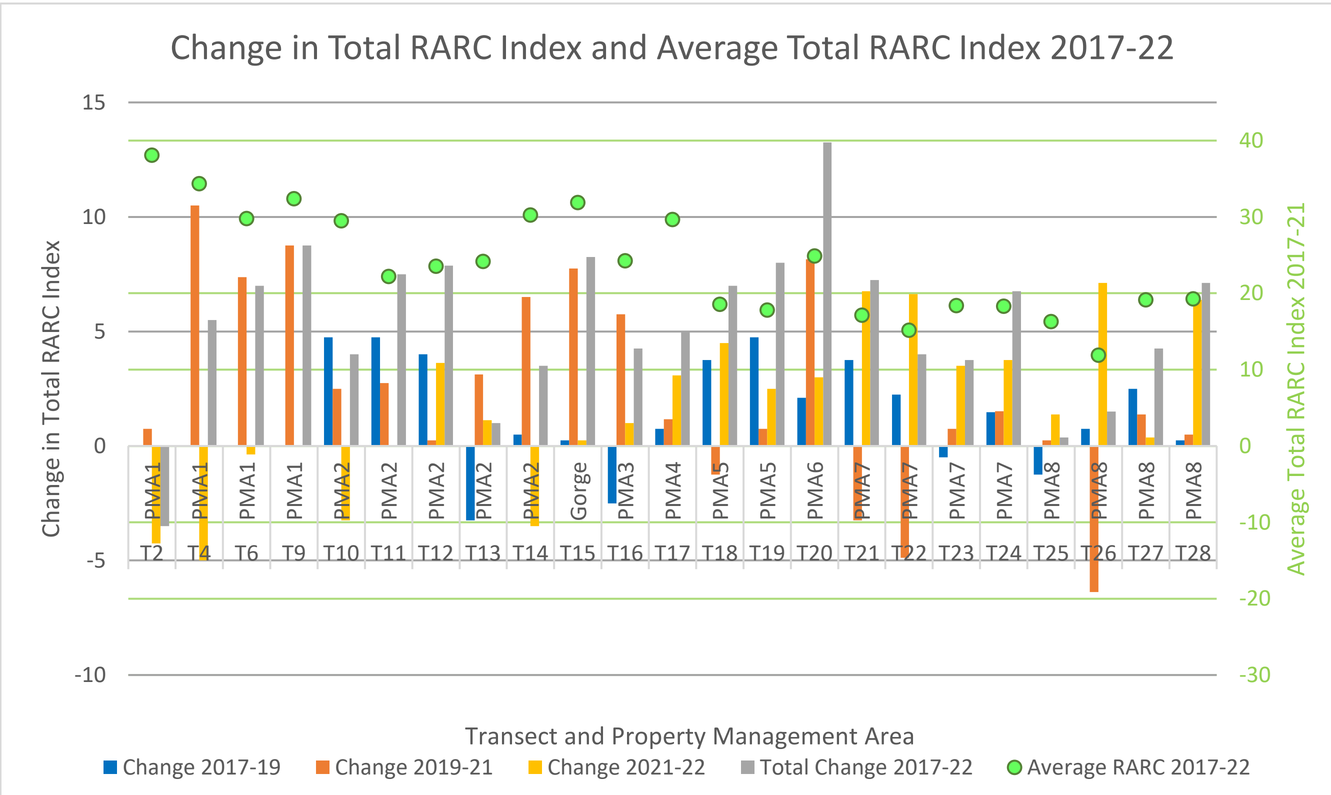

Figure 3: Mulloon Creek transects change in RARC Index score (Y-axis on left) and Average RARC Index score 2017-22 (Y-axis on right)

The above results can also be expressed as a box and whisker plot of RARC Index scores for each PMA and survey period (Figure 4). The plots centre, X, represents the median value or 50^{th} percentile of the data set and is derived using the lower and upper quartile (25%) values for where there is more than one transects assessed. The maximum and minimum values are displayed with vertical lines ("whiskers") connecting the points to the centre box.

The results in Figure 4 provide confirmation that the RARC Index has improved for all PMA's since monitoring commenced, with the exception of PMA1. At first sight PMA 2 also looks to have declined in the 2022 survey, however the median value has increased from 2021. Consistent with Figures 2 and 3, the largest gains are in the lower half of Mulloon Catchment, PMA4 - PMA8.

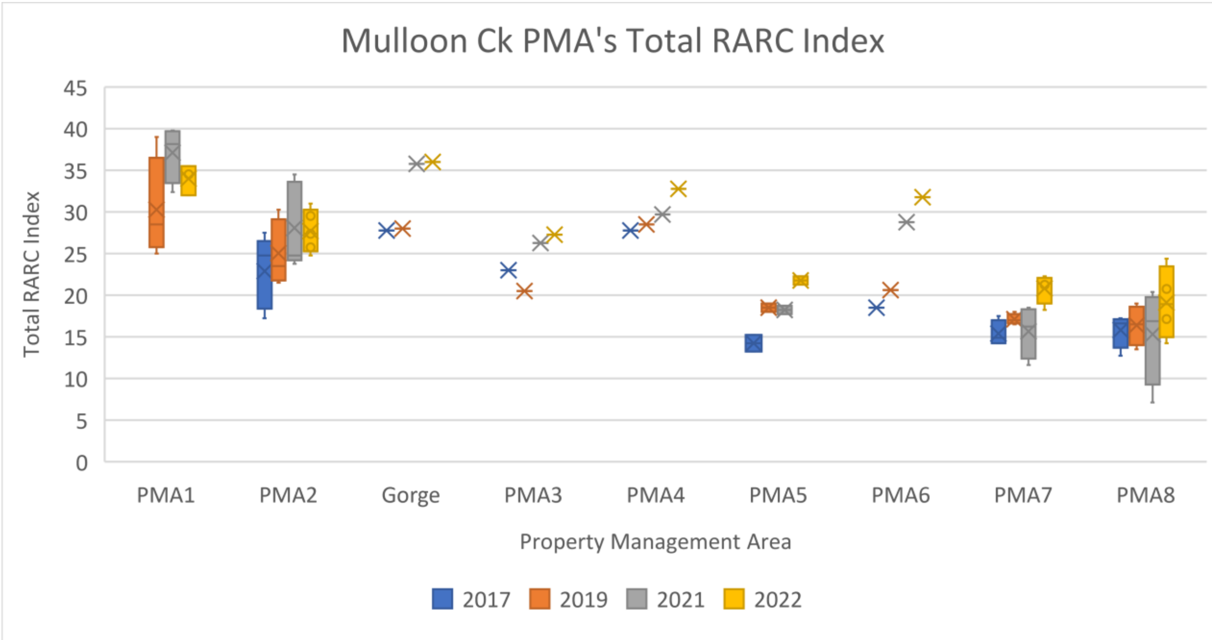

Figure 4: Total RARC Index score for each Property Management Area and survey year

RARC Sub-Index Scores

RARC Index scores are comprised of five sub-indices as described in the methodology section. When assessed individually, they provide detail of when and how much change has occurred that can be linked to timing of landscape rehydration actions such as installation of leaky weirs, riparian fencing, planting of vegetation.

Figure 5 provides a visual summary of the changes in the sub-index values over the four survey periods. As with the pervious figures, a trend of improvement can be seen in all sub-indices, as the median score has increased sequentially from 2017 – 2022, bar Cover and Natives in the most recent 2022 survey.

Additional insights to the variations in score is indicated by the maximum and minimum values (range). It shows that in general, the range of all sub-indices has narrowed with time, suggesting that within a PMA, vegetation along the riparian zone is becoming more similar. Minimum scores across all PMAs have improved, which demonstrates a universal improvement in riparian conditions across the catchment.

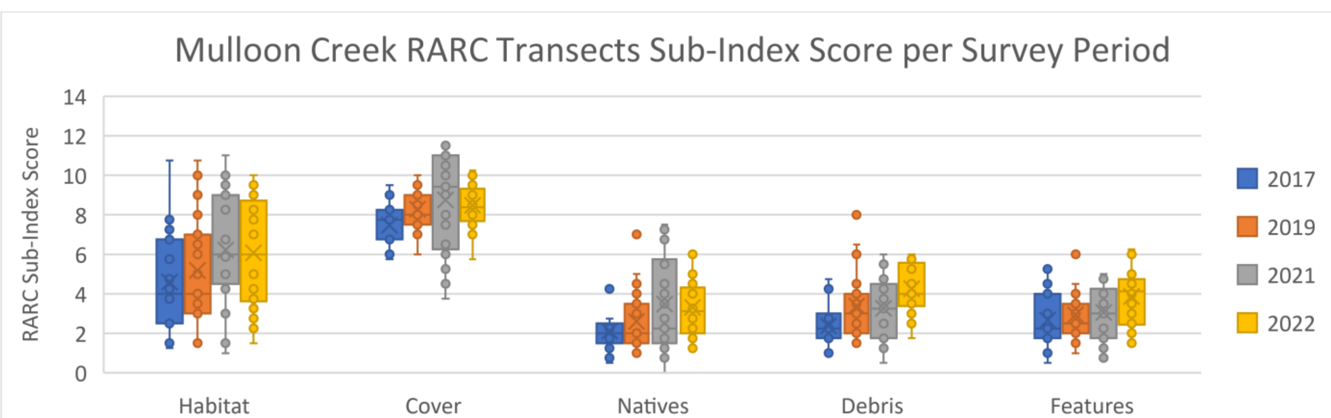

Figure 5: Box and Whisker plots for RARC Sub-Index Scores for all Mulloon Creek transects

To assess these RARC sub-Index score results at a catchment scale, the following sections analyse the five RARC sub-index scores for each PMA along Mulloon Creek.

Habitat

The RARC sub-index Habitat measures vegetation continuity, extent (as a ratio of channel width to vegetation width), and distance to nearest patch (>10 ha) of remnant native native woodland or forest, with a maximum potential score of 11.

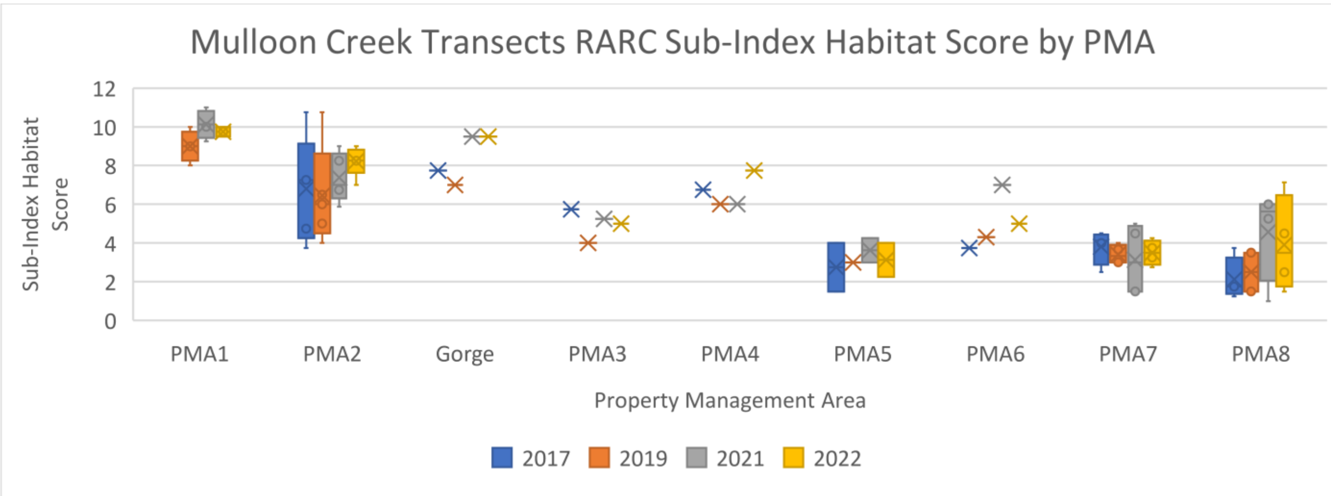

Figure 6: Box and Whisker plot for RARC sub-index Habitat score for each survey period by Property Management Area (PMA)

The Habitat score shows a general stability in scores across all scores and all years (Figure 6), which is reflective of the long-term features this index measures. The median value remained stable or showed insignificant change in 5 transects (PMA1, Gorge, PMA3, PMA5 and PMA7), while PMA6 and PMA8 decreased slightly. Slight increases were seen in PMA2 and PMA4.

PMA1 transects experienced a slight decrease in Habitat median score (Figure 6) due to having a high level of existing native vegetation that has been fenced off for over a decade and has extensive remnant woodlands in proximity. Since surveys began, it has consistently approached the upper limit of 11 possible for Habitat score.

Pilot project (PMA2) transects experienced a moderate increase in Habitat median score (Figure 6) due to increased riparian vegetation continuity and extent. There was a minor decline in 2019 due to the extreme drought, but the transects recovered in 2021 to a higher score than 2017 (baseline) despite the two flood events. A slight further increase is seen in 2022, as vegetation continuity continued to improve. Also a standout, is the smaller range of values indicating consistency in Habitat throughout the this PMA.

The Gorge transect experienced a small decline in 2019 due to extreme drought, followed by a significant increase in 2021 following the flood events (Figure 6). It remained stable in 2022, neither improving or declining.

PMA3 transect experienced a minor decline from 2017 to 2021 (Figure 6), with an initial moderate decline in 2019 (drought), and a moderate increase in Habitat score following the flood events (2021). The decline indicated by the 2022 survey is minimal.

PMA4 transect experienced a minor decline from 2017 to 2019 (Figure 6). This is possibly due to initial overestimation by the observer in 2017. The transect is relatively stable with good amounts of native shrub (acacia and tea tree) but is isolated from nearest remnant native woodland or forest. An improvement in 2022 is seen relating to the sites longitudinal connectivity in the 2022 survey.

PMA5 transect experienced small increases for each survey period from 2017 to 2021 (Figure 6) with minor increases in vegetation extent and connectivity. This transect is isolated from its nearest remnant native woodland or forest, so increases scores in this component are unlikely to be seen in the future. A very slight decline is seen in 2022.

The transect at PMA6 experienced a significant increase in Habitat score from 2017 to 2021 (Figure 6) related to good increases in vegetation extent and connectivity. The transect potentially benefited from the rehydration works upstream during the drought to generate a small increase in 2019. The increase in 2021 could be attributed to both land management (native plantings and reduced stock access) and upstream rehydration works that moderated creek flows. Both of which in turn reduced flood impact and promoted further native vegetation growth to increase extent and continuity observation scores. The decline in the 2022 could be attributed to an overestimation by the surveyor in 2021.

PMA7 transects experienced minor declines for the survey periods (Figure 6), but has been relatively stable since surveying began. The extreme drought caused a minor decline in vegetation extent, and rehydration works completed in late 2019 didn’t have enough time to regenerate vegetation prior to floods. The slight break in climatic conditions since the last major flood in 2020 have allowed time for growth, reflected in the slightly higher median value.

PMA8 transects experienced a moderate increase in Habitat score from 2017 to 2021 (Figure 6). A potential difference between PMA7 and PMA8 response can be attributed to restriction of stock access to the riparian area of PMA8. The overall increase in Habitat score can possibly be attributed to a combination of restricting stock access and rehydration works implemented locally and upstream throughout 2021 and 2022.

Cover

The RARC sub-index Cover measures vegetation cover (tree, shrub, ground) and structural complexity, with a maximum potential score of 12.

It should be noted that the floodplain pockets in which the rehydration works have taken place are traditionally grassland environments, with grass, sedge, reed and rush dominated riparian zones. As such, the RARC cover score method which gives half of the total score to canopy and understory, may give a false indication of what is or isn’t good cover.

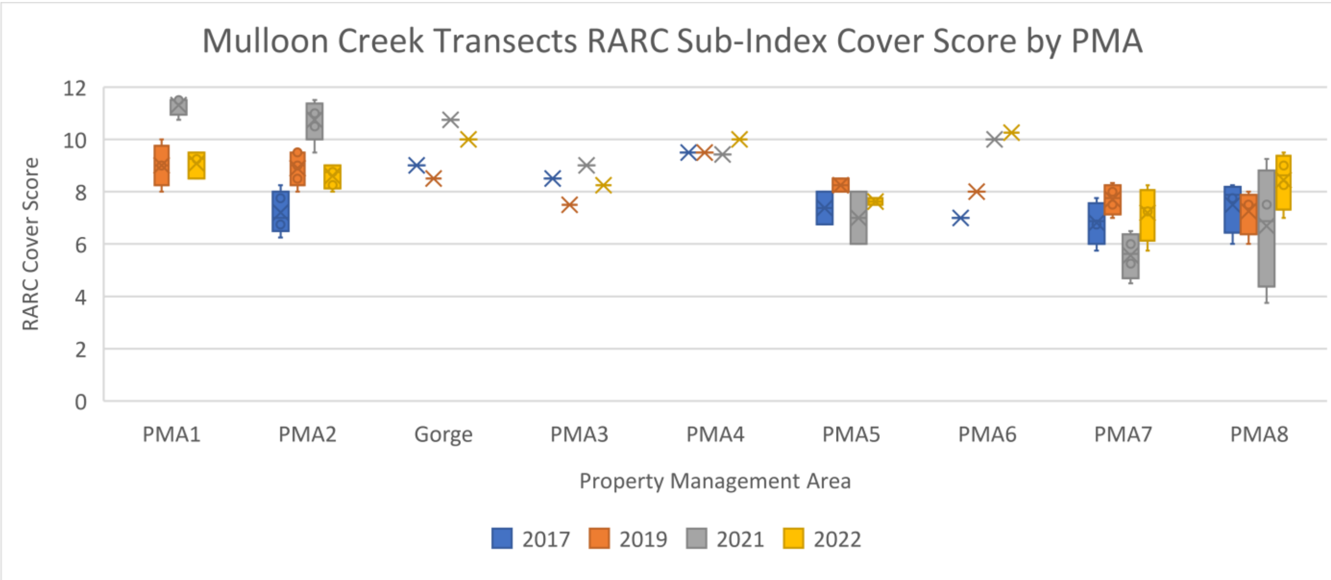

Figure 7: Box and Whisker plot RARC sub-index Cover score for each survey period by Property Management Area (PMA)

The Cover score has tended to vary over the four survey periods (Figure 7), with declines and improvements seen through time within many of the transects. The four upper transects of the Mulloon Catchment declined in Cover scores, while the lower five transects improved. A more detailed look at the raw data show the decline in the upper catchment is in canopy cover, whilst the improvement in the lower catchment is in understory.

The decline seen in the upper four transects relates to the decline in scores for canopy cover, and subsequently, the lower scores for number of layers of vegetation. As there are no significant visual differences in the photos between 2021 and 2022, it is suggested that the decline is due to overestimation of the previous surveyor or underestimation of the recent surveyor.

PMA4 Cover scores remained relatively stable for all survey periods due to stable and high cover of shrubs (Figure 7). It also had the highest initial Cover score of all PMA's. The score shows a slight improvement due to emergent understory supported by wet conditions in the 2021-2022 period.

PMA5 and 7 initially had a small increase in Cover scores during the drought that could be attributed to rehydration works locally and upstream respectively, which encouraged an increase in riparian vegetation cover. However, the significant flood events had some impact on the aquatic vegetation to cause a small to moderate decline in Cover from 2019-2021.

Riparian soil along PMA7 is often coarse sand, which explains the significant decline in the 2021 survey, as the powerful floods would have moved the sand bars and the grass/reed vegetation on it. However, a significant recovery is seen in PMA7 in the 2022 survey, and the higher score is due to substantial undercover (grass) growth.

Transects in PMA8 experienced on average a minor decline in Cover scores during the drought (2019) and again following the floods (2021). However, an improvement has been seen in 2022, with significant gains in the understory component, and subsequently in the number of vegetation layers.

Natives

The RARC sub-index Natives measures dominance of natives versus exotic vegetation species, with a maximum potential score of 9.

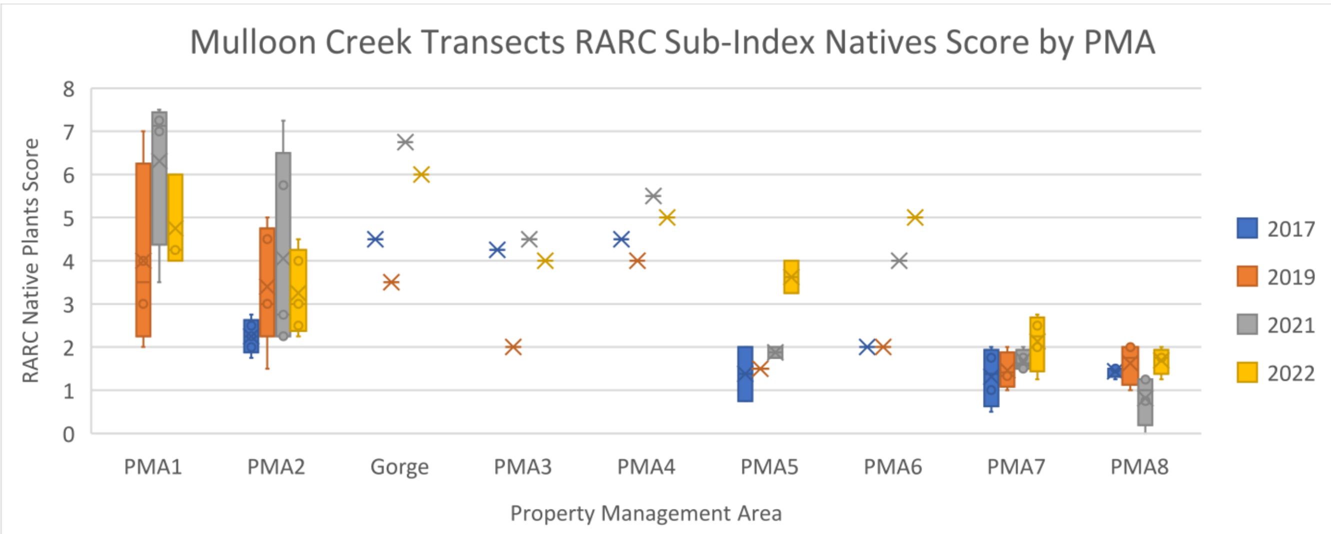

Figure 8: Box and Whisker plot RARC sub-index Natives score for each survey period by Property Management Area (PMA)

Nearly all PMA's (eight out of nine) recorded an increase in Natives score for the survey period of 2017-2021 (Figure 8), however in 2022 the opposite is seen: five of the nine PMA's show a decline in Native Index Scores in 2022, while four show an increase for the same period.

In 2022 PMA1, PMA2, Gorge, PMA 3 and PMA4 show a decline in both the canopy and understory in 2022, whilst the lower four PMAs show an increase in the understory.

Though the median score for Natives in PMA has declined in 2022 as compared to previous years, the minimum value has remained higher than previous years, indicating that there has not been an outright regression in this PMA.

Pilot project (PMA2) showed good increases in Natives scores during the drought (2019) and afterward (Figure 8). Note the significant increase in the 25th percentile and maximum scores in the 2021 survey, coupled with a moderate increase in the minimum score. This indicates most transects in PMA2 have significantly improved Native levels. The highest score has dropped in 2022, but the lowest score has remained relatively equal, suggesting a level of stability in this transect.

During the drought period, PMA5 and PMA6 experienced small increases in Natives scores while in 2021 and 2022, significant improvements are seen. This improvement in 2022 is in the understory and canopy levels, for both PMAs

PMA7 and PMA8 also show the results of recovery in 2022, with improved levels of groundcover accounting for the improvement, consistent with the La Nina of 2022. PMA8, experienced an initial minor increase during the drought (2019) followed by a decline in Natives score following flood events (2021). It is important to note that PMA8 is commencing from a low base and only half the transects have had rehydration works implemented days before the flood event of 2020.

Debris

The RARC sub-index Debris measures standing dead trees and associated hollow logs, fallen logs, and leaf litter, with a maximum potential score of 10.

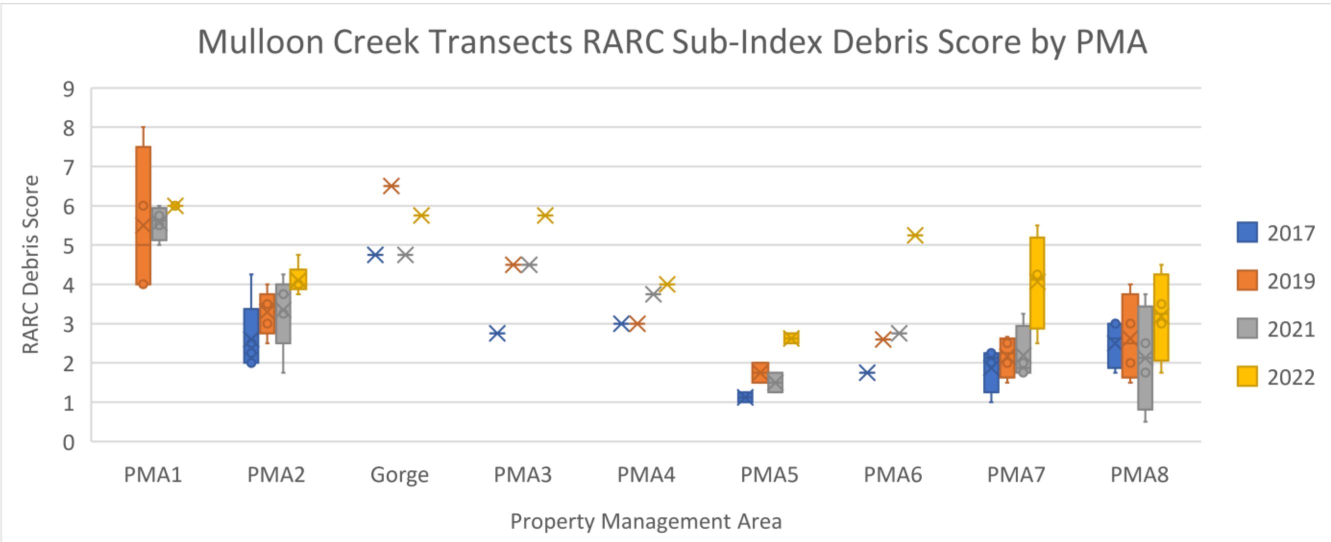

Figure 9: Box whisker plot RARC sub-index Debris score for each survey period by Property Management Area (PMA)

The Debris scores for the PMA's show a positive trend for all PMAs over the four survey periods, with the exception of the Gorge transect (Figure 9). Distinct improvements in 2022 across the catchment are seen.

All of the PMA's increased Debris scores from 2021 to 2022 (Figure 9) ranging from minor or small increases (PMA's 1, 2, 4), to moderate increases (Gorge, PMA3, 5 and 8) and large increases (PMA6 and 7).

PMA1 had quite a range of Debris scores in 2019 (maximum and minimum values) with the flood events redistributing material, including large amounts that came with the floods from upstream areas badly affected by the 2019-20 fires. This resulted in a reduction in the range of maximum and minimum values, culminating in only a small increase in Debris median scores in 2021. This increase in median continued in 2022, and the range became smaller again.

PMA2 has been improving in the Debris sub-index with each survey period. The increase from year to year has consistently been the increase of standing dead and hollow bearing trees.

The Gorge had a significant increase in Debris at the height of the drought (2019), however the force of floods squeezing through the bottom end of the gorge caused the loss of material and decline in Debris score in 2021. The smaller increase seen in 2022 is attributed to logs that have continued to be deposited in the Gorge transect during the 2022 La Nina.

At PMA3 the increase is actually due to native leaf litter, while other components remain steady.

A key element that underpins scoring in the Debris index is the presence of old trees that have hollow-bearing branches and trunks or standing dead trees. These components account for the substantial jump in Debris score for PMA5 6, 7 and 8.

Features

The RARC sub-index Features measures recruitment of juvenile native trees and shrub species, large native tussock grasses, and native emergent aquatic plants (e.g. reeds, sedges), with a maximum potential score of 8.

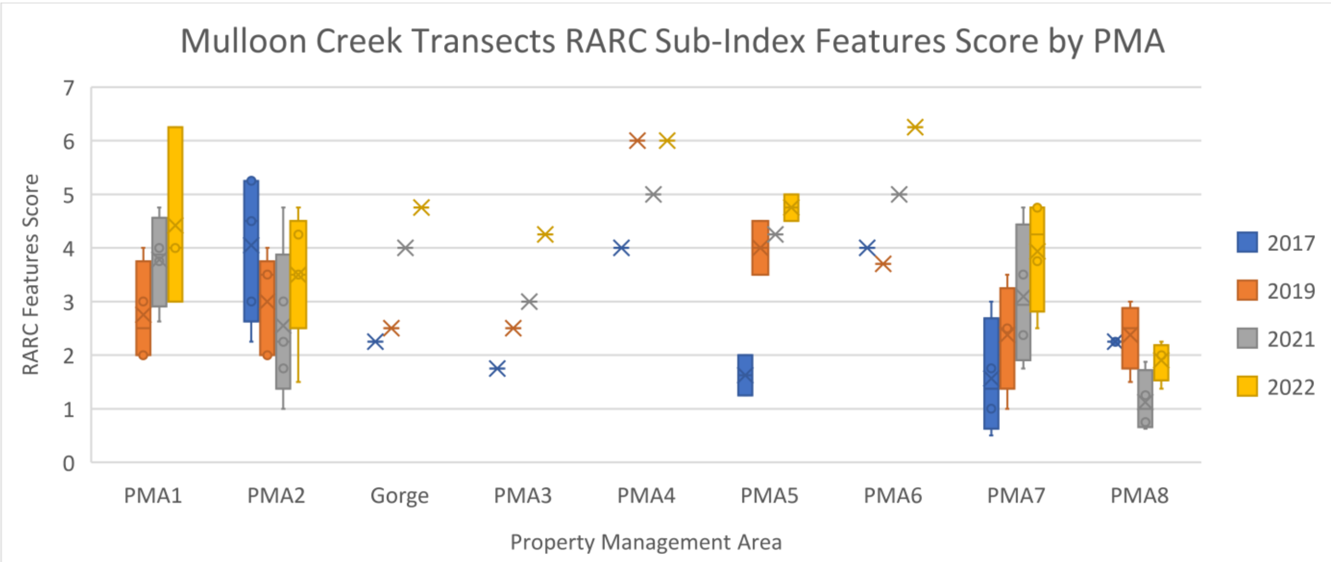

Figure 10: Box and Whisker plot RARC sub-index Features score for each survey period by Property Management Area (PMA)

Figure 10 shows all PMAs increased Features median scores from 2017 to 2022, with some slight drops in PMA2, 4 and 8 in 2019-2021. The 2022 survey also shows every PMA has improved since 2021, with the improvement due to an increase in presence of large native tussock grasses and reeds. PMA's 1, Gorge, 3, 5, and 7 consistently increased Features scores for each survey period (Figure 10).

PMA1 had good recruitment of trees and shrubs from 2019 to 2021, and an increased variability across the PMA as shown by the large range of score.

Pilot project (PMA2) had the highest initial Features score of all PMA's in 2019 (Figure 10). PMA2 recorded a moderate decline in Features from 2017 to 2019 due mostly to decreased large tussock grasses, potentially due to large native herbivores. During the drought a survey of kangaroos was conducted at PMA2 that found the resident population (2,500) had at least doubled due to lack of fodder in the region and the presence of water in the creek. The decline in Features continued into 2021 due to decreased tussock grasses, and some loss of aquatic vegetation due to flood impact, however this was somewhat offset by good recruitment of trees and shrubs. However, an increase in reeds and native tussock grasses consistent with the wet period of 2021-2022, has boosted the score in 2022, while tree and shrub recruitment remained stable.

The Gorge site had a minor increase in 2019 due to tree recruitment, and significant increase in 2021 due to reeds and tussock grasses. This increase in reeds continued in 2022.

PMA3 had a moderate increase in 2019 due to recruitment of shrubs plus tussock grasses, a small increase in 2021 due to recruitment of trees and shrubs, and a large increase in 2022 due to reeds and tussock grasses, with a slight decline in recruitment.

We see that PMA4, though increasing significantly in 2019 throughout the drought attaining the highest score of all PMA's due to tree and shrub recruitment, a drop in 2021 was followed by a increase in reed and tussock grasses in 2022.

PMA5 had a significant increase in 2019 due to recruitment of trees and shrubs (tube stock plantings) and tussock grasses (fencing effect), followed by a small increase in 2021 due to an increase in reeds. This increase continued in the wet 2022 survey, promoting reeds and tussock grasses, as it did in PMA 6, 7 and 8.

PMA8 experienced a small increase during the drought due to shrub recruitment and reeds.

Discussion

The RARC results indicate transects that historically retained high percentages of native species experienced significant increases in RARC Index scores (e.g. PMA1), especially compared to transects historically cleared and accessed by stock (e.g. PMA5, 7) (see Figures 2, 3 and 4). This is partly due to RARC methods favouring native species, and that recovery of many other components measured take time to achieve i.e., mature canopy (trees), width of riparian vegetation species (fencing and land use), connectivity with nearby remnant vegetation patch, and dead standing trees and associated hollows.

On the reverse side however, we see that RARC has captured the quick components, that are responsive to rainfall – native tussock grass and reeds captured in the Features Index. These components were significantly higher in 2022 (Figure 10), due to the prolonged water availability of the 2020-2022 La Nina.

Compounding factors that can influence RARC Index scores (Figures 2, 3 and 4) are the implementation and timing of land management actions such as in-stream works, restricting stock access to riparian zone, and active planting of native vegetation. Climatic events are another factor such as the extreme drought (Jan 2017-Jan 2020), followed by two one-in-50-year floods events (Aug 2020 and Mar 2021). These extreme climatic events contribute to explaining why some transects that are still repairing and regenerating, potentially lose some of the gains attained in the RARC Index scores and reflected in respective sub-indexes. However, without the rehydration works and efforts by landholders to manage the riparian zone, RARC Index scores could have declined due to these significant climatic events.

The results have shown that in-stream structures are fundamental to maintaining water in the system to support diverse riparian and aquatic plant growth during dry or drought times. The emergent riparian and aquatic vegetation, coupled with the in-stream structures, has also provided a critical level of streambed and bank protection against the very high flows that have occurred since the drought broke in 2020. The improved water availability could also be having a positive effect on downstream transects such as T20 – T28 in PMA's 6, 7, and 8. Some of these transects still do not have in-stream structures installed (Figures 2, 3 and 4). Thick stands of reeds and sedges have also colonised many of the sites where in-stream structures have been built (Figure 11). This is helping to reduce flow rates, filter sediments, and provide necessary habitat for many native species.

Figure 11. The establishment of reeds and rushes at PMA5, in December 2020, 2 years after weir construction.

The bushfires of 2019-20, which burnt 8,000ha in the upper Mulloon catchment, very likely increased the severity of the August 2020 and March 2021 floods that impacted downstream properties. The intensity and extent of the fires, and loss of resources (plant cover and litter), triggered significant runoff and erosion in the upper catchment. This sediment was carried down Mulloon Creek, potentially slowing the rate of vegetation recovery (particularly ground cover). .

On the positive side, TMI staff observed that the floods deposited substantial silt, organic matter, and debris onto the lower Mulloon floodplains, particularly adjacent to in-stream works. TMI staff also observed that there was very little bank or bed erosion of lower Mulloon Creek. Mulloon landholders recalled that the previous flood of a similar scale, in 1974, caused significant erosion and changed the course of Mulloon Creek.

These observations suggest that the in-stream rehydration actions reduced stream power and, therefore flood impact, which also encouraged silt deposition. These observations support the modelled results of the report into Current and Predicted Hydraulics of Lower Mulloon Creek – Stages 1 & 2 (TMI, 2017; TMI, 2019), which predicted a significant reduction in bank-full stream power resulting from the installation of instream structures throughout lower Mulloon Creek.

Reducing flood intensity reduces erosion, which reduces turbidity and sediment transport. Any sediment that is mobilised is also more likely to be caught within the pond zones created by the instream structures. This improves water quality for downstream users. This sediment would otherwise continue downstream to a dam (in this instance Tallowa Dam) or through to the coast, affecting aquatic fauna and flora, infrastructure, and people's livelihoods along the entire waterway.

The RARC survey results are demonstrating that riparian vegetation is being maintained, and in most cases improving, during dry times. Based on the results, we can infer that the increased water availability in the waterway, due to in-stream works, and better management of the riparian zone due to fencing, is the reason for this.

Among other benefits, increased water availability, resulting in greener vegetation, can greatly reduce the impact and severity of fire. Current studies at Mulloon are being undertaken to determine the effects of the instream works on the greenness of the valley floor. Assuming that the increased water availability in the waterway is also increasing the greenness of valley floor, this become a powerful ally in slowing fire progress and helping to reduce build-up of fire intensity as it moves through the country. Greater water availability in the creek also provides resources to fight fires and the riparian zone can be a refuge for fauna during fires, as well as habitat and food resources post-fire.

The use of landscape rehydration techniques as part of a broader wildfire control strategy warrants further investigation. In particular, a better understanding of the role of intact valley floors in providing hydrated refugia for flora and fauna during wildfire and in mitigating erosion from intense rainfall post wildfire events would be of value. Consideration of current and historical fire intensity spatial mapping along with the known locations of intact or rehydrated valley floors would contribute to a better understanding of landscape rehydration as a fire mitigation strategy in the Shoalhaven River catchment (Figure 12).

Figure 12: Firetruck rewatering from intact valley system at Baarlijan, fire burnt around area

As discussed earlier in this paper, in-stream structures seem to also reduce the rate and intensity of which flood waters cumulatively create powerful destructive forces. The results presented here could be extended and stretched to apply in a management strategy that lessens risk to people’s lives and infrastructure. The slower release of water allows for extended water availability and improved quality for environmental, farming and broader community outcomes.

TMI and MRI landholders are expectantly hopeful the next RARC survey will see continued recovery of vegetation due to the current wet period that has occurred in the catchment and broader region. It is hoped that the combined positive effect of in-stream structures and land management actions will generate further improvements to riparian vegetation growth conditions. The positive vegetation response will greatly aid riparian and waterway function that will help improve and maintain water quantity and quality for local and downstream users.

Recommendations

Additional monitoring components should be considered to provide further measurable and statistical evidence that captures the full merits of rehydration works and of riparian zone vegetation regeneration. Keeping in mind that additional monitoring needs to be practical, informative, and relatively simple (e.g. not identifying at species scientific level) to accommodate time and resources.

According to Webb and Erskine (2003) *vegetation zonation refers to the lateral, vertical and longitudinal distribution of vegetation within the riparian corridor. Such zonation of species is due to their relative tolerance of the varying frequency, magnitude, and duration of, and sediment deposited by floods experienced at different elevations above or away from the streambed or at various locations on the floodplain. A replication of such zonation in planting programs is likely to result in higher survival rates. Appropriate species should be identified and planted on all landforms from the streambed to the high floodplain.*

Such components to consider are:

- A scoring system that gives value to presence or establishment of vegetation, regardless of being native or introduced. This minimises the bias given in RARC to riparian areas which are composed more of natives (e.g. PMA1).

Dufour and Rodríguez-González (2019) conclude with, *we consider riparian vegetation in fluvial systems as a co-constructed complex of vegetation units along the river network, regardless of physiognomy or origin, that is functionally related to the other components of the fluvial system and surrounding area. It belongs to the riparian zone, which is a hybrid and open landscape: hybrid because it results from co-construction driven by human and natural processes, and open because the land alongside fluvial systems influences, and is influenced by, the river and associated processes. Thus, the structure and ecological functioning of the biotic communities in this area vary along the four dimensions of the fluvial hydrosystem (including time). This variability is driven mainly by bioclimatic, geomorphological, and land-use conditions, which change over time under the influence of natural and human drivers. This variability clearly influences how riparian vegetation is studied. Moreover, the fact that this variability is related to a particular context imposes some notable contingencies, creating difficulties for generalization and knowledge transfer.*

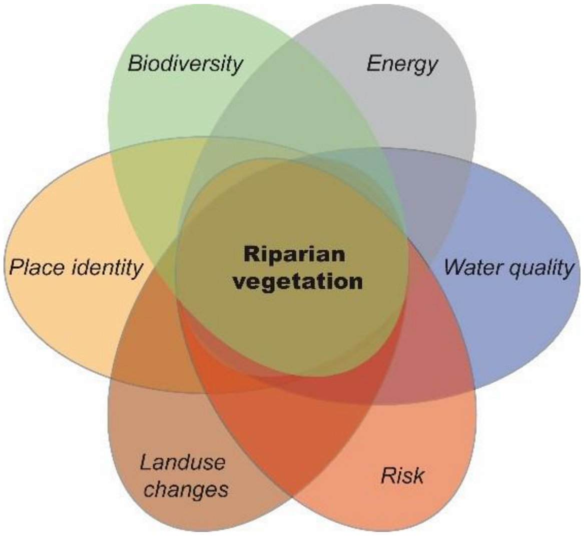

Figure 62: Schematic from Dufour and Rodríguez-González (2019)

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TMI 2017 Current and Predicted Stream Hydraulics for Stage 1 of the Mulloon Community Landscape Rehydration Project. Report available on website.

TMI 2019 Current and Predicted Stream Hydraulics for Stage 2 of the Mulloon Community Landscape Rehydration Project.

Appendix A

Table 1: Sub-indices and indicators of the Rapid Appraisal of Riparian Condition, the range within which each is scored, the method of scoring for each indicator, and the maximum possible total for each sub-index (Jansen et al 2005). dbh = diameter at breast height, < less than, ≤ less than or equal to, > greater than, ≥ greater than or equal to.

Sub-index	Indicator	Range	Method of scoring	Total
HABITAT				11
	Longitudinal continuity of riparian vegetation (≥ 5 m wide)	0–4	0 = < 50%, 1 = 50–64%, 2 = 65–79%, 3 = 80–94%, 4 = ≥ 95% vegetated bank; with 1/2 point subtracted for each significant discontinuity (≥ 50 m long)	
	Width of riparian vegetation (scored differently for channels < or ≥ 10 m wide)	0–4	*Channel ≤ 10 m wide:* 0 = VW < 5 m, 1 = VW 5–9 m , 2 = VW 10–29 m, 3 = VW 30–39 m, 4 = VW ≥ 40 m *Channel > 10 m wide:* 0 = VW/CW < 0.5, 1 = VW/CW 0.5–0.9, 2 = VW/CW 1–1.9, 3 = VW/CW 2–3.9, 4 = VW/CW ≥ 4, where CW = channel width and VW = vegetation width	
	Proximity to nearest patch of intact native vegetation > 10 ha	0–3	0 = > 1 km, 1 = 200 m–1 km, 2 = contiguous, 3 = contiguous with patch > 50 ha	
COVER				12
	Canopy (> 5 m tall)	0–3	0 = absent, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
	Understorey (1–5 m tall)	0–3	0 = absent, 1 = 1–5%, 2 = 6–30%, 3 = > 30% cover	
	Ground (< 1 m tall)	0–3	0 = absent, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
	Number of layers	0–3	0 = no vegetation layers to 3 = ground cover, understorey and canopy layers	
NATIVES				9
	Canopy (> 5 m tall)	0–3	0 = none, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
	Understorey (1–5 m tall)	0–3	0 = absent, 1 = 1–5%, 2 = 6–30%, 3 = > 30% cover	
	Ground (< 1 m tall)	0–3	0 = none, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
DEBRIS				10
	Leaf litter	0–3	0 = none, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
	Native leaf litter	0–3	0 = none, 1 = 1–30%, 2 = 31–60%, 3 = > 60% cover	
	Standing dead trees (> 20 cm dbh)	0–1	0 = absent, 1 = present	
	Hollow-bearing trees	0–1	0 = absent, 1 = present	
	Fallen logs (> 10 cm diameter)	0–2	0 = none, 1 = small quantities, 2 = abundant	

Sub-index	Indicator	Range	Method of scoring	Total
FEATURES				8
	Native canopy species regeneration (< 1 m tall)	0–2	0 = none, 1 = scattered, 2 = abundant; with 1/2 point subtracted for grazing damage	
	Native understorey regeneration	0–2	0 = none, 1 = scattered, 2 = abundant; with 1/2 point subtracted for grazing damage	
	Large native tussock grasses	0–2	0 = none, 1 = scattered, 2 = abundant	
	Reeds	0–2	0 = none, 1 = scattered, 2 = abundant	

Appendix B

Table 2. Ranking according to RARC methodology for transects in the Mulloon Catchment (not surveyed).*

Transect	Property Management Area	2017 Rank	2019 Rank	2021 Rank	2022 Rank
T2	PMA1		Good	Good	Good
T4	PMA1		Poor	Good	Average
T6	PMA1		Poor	Average	Average
T9	PMA1		Poor	Good	*
T10	PMA2	Poor	Average	Average	Poor
T11	PMA2	Very Poor	Poor	Poor	Poor
T12	PMA2	Very Poor	Poor	Poor	Poor
T13	PMA2	Very Poor	Poor	Poor	Poor
T14	PMA2	Poor	Poor	Average	Average
T15	Gorge	Poor	Poor	Good	Good
T16	PMA3	Very Poor	Very Poor	Poor	Poor
T17	PMA4	Poor	Poor	Poor	Average
T18	PMA5	Very Poor	Very Poor	Very Poor	Very Poor
T19	PMA5	Very Poor	Very Poor	Very Poor	Very Poor
T20	PMA6	Very Poor	Very Poor	Poor	Average
T21	PMA7	Very Poor	Very Poor	Very Poor	Very Poor
T22	PMA7	Very Poor	Very Poor	Very Poor	Very Poor
T23	PMA7	Very Poor	Very Poor	Very Poor	Very Poor
T24	PMA7	Very Poor	Very Poor	Very Poor	Very Poor
T25	PMA8	Very Poor	Very Poor	Very Poor	Very Poor
T26	PMA8	Very Poor	Very Poor	Very Poor	Very Poor
T27	PMA8	Very Poor	Very Poor	Very Poor	Very Poor
T28	PMA8	Very Poor	Very Poor	Very Poor	Very Poor

Appendix C

The following provides additional information for each of the PMA's with a selection of transect site photos to provide context for the changes in RARC Index scores for respective properties and transects.

PMA1

Much of the riparian zone on this property has not been extensively cleared and restricted stock access to the waterway for well over a decade has resulted in a high number and ratio of native plants compared to exotic species. PMA1 transects have benefitted from these combined historical actions and remnant plant resources generating relatively high total RARC Index scores during drought and good response to rainfall and protection during floods. Fire adversely affected T2 and to a lesser degree T4 in 2021, which is seen in Figure 13 – 15 and Figure 16 -18 respectively. The fire dramatically reduced the canopy cover, reflected in the lower Cover score (Figure 7), and lower Natives score (Figure 8) in 2022. However, three of the four RARC transects responded well to the drought-relieving rainfall. The fire affected areas did have high levels of germination and suckering of shrubs and tree species after the fire, as seen in Figures 16- 18. Woody debris accumulated in sections of PMA1 due to the flood events depositing material from fire-affected areas upstream (Figure 14, 15, 17, 18). In 2022, PMA1 continued to respond post-fire in the germination and re-generation of native trees, captured in the Features score (Figure 10), and seen in Figures 14, 15, 17 and 18. Stage 3 of the MRI is planned for PMA1 in 2023, which may (expectantly) further improve the riparian vegetation response in due course, particularly aquatic reeds and rushes.


Figure 13: PMA1 T2 2019 survey


Figure 14: PMA1 T2 2021 survey


Figure 15: PMA1 T2 2022 survey


Figure 16: PMA1 T4 2021 survey


Figure 17: PMA1 T4 2021 survey


Figure 18: PMA1 T4 2022 survey

PMA2

These transects reflect the historical land use and management (clearing, stock access to waterway), with the native riparian zone vegetation replaced with willow revetments established in the 1970's and 80's. Native vegetation was present at all sites but were at their highest levels at the gorges that top and tail this pocket floodplain that influence T10 and T14. The remainder of the transects would be comparable to transects further downstream and would potentially have achieved a RARC Index of less than 15 (Very Poor) prior to the pilot project rehydration actions in 2006-07. Management decision to implement rehydration actions and restrict stock access to the riparian zone coupled with native plantings have achieved good native vegetation response.

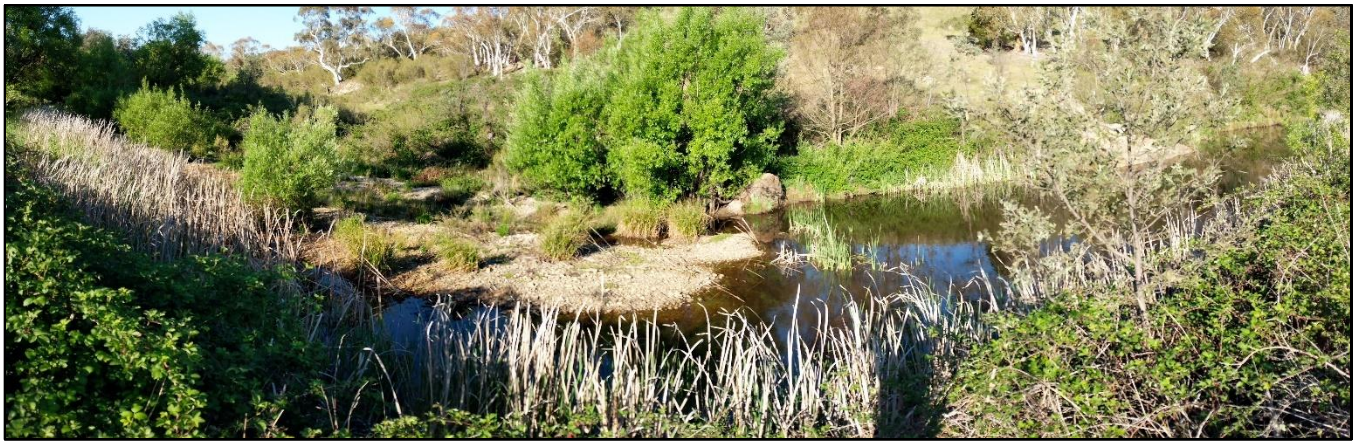

Figure 19: PMA2 T12c 2017 survey

Figure 20: PMA2 T12c 2019 survey

Figure 21: PMA2 T12c 2021 survey

Although some natives have been planted (e.g. the eucalyptus front and centre in Figures 22 - 25), many more upper, mid and ground-storey native plants have self-propagated and are thriving as can be seen in the results for RARC sub-index Natives score (Figure 8). Of particular note is the proliferation of aquatic reeds and sedges, captured in the Features index (Figure 10) and the site photos (Figures 22 - 25).

Four of the five the transects in this PMA (T10, 11, 12, and 14) have experienced significant increases in total RARC Index scores since initial monitoring began in 2017 (Figures 2). It is interesting to note the upper 3 transects (T10, 11, and 12) had higher increases in total RARC

Figure 22: PMA2 T14a 2017 survey

Figure 23: PMA2 T14a 2019 survey

Figure 24: PMA2 T14a 2021 survey

Index during the drought (Figure 3), and the lower 2 transects had higher increases in RARC Index following the flood events in 2020 and 2021 (T13 and 14) and again after the heavy rainfall in 2022. Note the emergent aquatic reeds provide a buffer to flood impact along the stream banks while also providing habitat and reducing the effects of evaporation by sun and wind (Figures 22-25). Another interesting trend is how the total RARC Index for T11 to T14 progressively increases, suggesting a cumulative positive effect on RARC observations downstream. The collective RARC Index for PMA2 (Figure 4) indicates consistent improvements from 2017 to 2021, particularly due to significant increases in Cover and Natives (Figures 7 and 8). However, in 2022 both Cover and Natives decline (Figure 7 and 8), whilst Debris and Features improve, resulting in the total median RARC score for 2022 remaining stable with 2021 (Figure 2).

Figure 25: PMA2 T14a 2022 survey

Three of the five transects at the pilot project (PMA2) have experienced significant increases in RARC Index scores since monitoring began (Figure 3). Transect T13 declined marginally in the extreme drought but recovered the loss following the rains and flood events in 2020. The data for T14 in 2022 indicates a loss in canopy and understory as compared to 2021, however, this may be a surveyor difference, as photos do not indicate a decline in canopy and understory from 2021 to 2022 (Figure 24 and 25). The three transects in the upper reaches of PMA2 (T10-12) performed well during the extreme drought, which suggests the increased available water in the creek due to in-stream structures had a positive effect on vegetation growth and subsequent RARC Index scores. All transects in PMA2 increased RARC Index scores in 2021, a great result considering this survey followed two significant flood events. This increased score is particularly evident in the three downstream transects (T12, T13, T14) where the cumulative effect of in-stream works has acted to slow the rate of flow, protecting and nurturing vegetation growth. Although floods will temporarily remove some of the aquatic vegetation, the in-stream leaky weirs help reduce the impact and subsequently increase rate of recovery. The cumulative effect of the pilot project has most likely had a positive effect on the Gorge transect downstream (T15), particularly to de-energise flood waters that could have caused damage to vegetation and banks in T15.

Gorge

This transect is located at the bottom end of a gorge immediately downstream from the pilot project and potentially benefits from the improved water management actions in the pilot project area. As discussed in the previous section (PMA2) the benefits of rehydration actions potentially influence downstream areas, especially as there is only a gorge between PMA2 (T14) and this Gorge transect (T15). The transect has a relatively good amount of remnant native vegetation and structural composition with only minor clearing in the past, although there are some exotic species present (Figures 26 – 33). T15 RARC Index scores are consistently in the top five transects in the MRI (Figures 2 and 3) – and when compared at the PMA level the median RARC Index score moves from 2nd place in 2021 to first place in 2022 (Figure 4). The total RARC scores improved slightly during the drought period and responded well to rainfall due to possible benefits from rehydration works upstream. The transect is technically not on a property (hence no PMA) but is bordered by PMA2 and by the adjoining neighbour and MRI participants, Antony and Rhonda Mulhall who nurture the area by planting natives, managing weeds, and removing rubbish left by others. In 2022, as with most other PMAs, an increase in Debris and Features is seen in the Gorge, and a decline in Cover and Natives. However, as, mentioned before, this decline could be due to surveyor differences, as photo evidence does not show any particular differences in Cover and Natives from 2021 to 2022 (Figure 28 to 29, 32 to 33).

Figure 26: Gorge T15a 2017 survey

Figure 27: Gorge T15a 2019 survey

Figure 28: Gorge T15a 2021 survey

Figure 29: Gorge T15a 2022 survey

Figure 30: Gorge T15c 2017 survey

Figure 31: Gorge T15c 2019 survey

Figure 32: Gorge T15c 2021 survey

Figure 33: Gorge T15c 2022 survey

PMA3

The total RARC score for T16 declined from 2017 to 2019 due to a combination of severe drought and stock, with declines in sub-indexes Habitat (Figure 6), Cover (Figure 7), and Natives (Figure 8), although offset by an increase in Debris (Figure 9). Following the drought-breaking rain and floods the 2021 survey indicates good recovery and surpassed its baseline RARC Index score (Figures 2, 3 and 4). An increase in Natives sub-index (Figure 8) was the main contributor to PMA3 RARC Index scores (Figures 2, 3, and 4), with small increases in sub-indices Cover (Figure 7), and Features (Figure 10). As is becoming a feature of the catchment, in 2022 the Habitat, Cover and Natives declined, whilst the Debris and Features substantially improved, giving PMA3 an overall higher RARC total score than in 2021 (Figure 4).

The in-stream structures are potentially generating much of the recovery as the riparian zone is still to be fenced off, however the property manager has indicated they minimise stock access to the waterway. With no other significant changes to other drivers (stock access, planting additional native plants), this transect provides a strong indication of the level of benefit in-stream actions with leaky weirs can generate. The understorey and native shrub layers have had some improvement in 2021 as indicated in Figures 37, compared to 2019 in Figure 36. The improved precense of aquatic plants from 2019 to 2022 can be seen in Figure 36, 37 and 39, and a consistent level of understory in Figure 38 to 40.

Figure 34: PMA3 T16b 2017 survey (featuring Cam Wilson)

Figure 35: PMA3 T16c 2017 survey (featuring Cam Wilson)

Figure 36: PMA3 T16b (left background) & T16c (right foreground) 2019 survey

Figure 37: PMA3 T16b 2021 survey

Figure 38: PMA3 T16c 2021 survey

Figure 39: PMA3 T16b 2022 survey

Figure 40: PMA3 T16c 2022 survey

PMA4

This transect (T17) is relatively stable due to management fencing off the riparian zone for many years and has a good composition of native vegetation present with a moderate number of non-native species. The transect will benefit to have other elements such as larger native trees that in time provide hollow-bearing trunks and branches. There are thick patches of tea tree with other acacias, and patches of stony cobble and gravel are evident in 2019 (Figure 43). There is a good groundcover response and a general improvement in through time (Figures 41 - 47).

The transect has further benefitted from the rehydration actions implemented in 2018 that provided water to sustain existing vegetation during the extreme drought. Following the 2020 and 2021 flood events, the in-stream structures and vegetation generated a positive effect to reduce any flood impact and spread the water into the riparian zone to promote a good response in ground cover and aquatic plants (reeds and sedges). It is also worth noting that this transect has frog surveys conducted and now provides a great habitat for a variety of frog populations (2021 frog survey report).

Figure 41: PMA4 T17a 2017 survey

Figure 42: PMA4 T17b 2017 survey

Figure 43: PMA4 T17a (right foreground) and T17b (left background), 2019 survey

Figure 44: PMA4 T17a, 2021 survey

Figure 45: PMA4 T17b, 2021 survey

Figure 46: PMA4 T17a, 2022, survey

Figure 47: PMA4 T17b, 2022, survey

PMA5

The two transects (T18 & T19) on PMA5 have been historically impacted by past clearing and stock access, with willow revetments on T18 implemented late 1970's and small patch of native shrubs/trees on T19, with a mix of groundcover dominated by non-native species. These transects are recovering from a low baseline, but recovery is underway since implementing the in-stream actions (Figure 48 and 49), assisted by the planting of native trees and shrubs (e.g as seen on the far bank in Figure 52) and restriction of stock access. Despite very low average RARC Index scores (Figures 2, 3 and 4), there is a large improvement in total RARC Index for PMA5 from 2017-2022 (Figure 3) due to its positive response to in-stream works in late 2018, which resulted in increased aquatic vegetation (Figures 52, 53) and planting of native trees and shrubs in 2019.

Figure 48: Implementing in-stream structure late 2018

Figure 49: Vegetation response at in-stream structure Feb 2020

There was some loss of aquatic vegetation due to the flood events which causes the minor decline in RARC Index scores for T18 in 2019, but T19 continuously improved its vegetation response. This positive response continued for T18 and T19 in 2022 in response to the long period of rainfall in 2021-2022. Note in Figures 52 and 58 the planted tube stock trees and shrubs have responded on the opposite riparian bank. There was a minor loss of cover and debris in 2021, partly due to flood inundation of exotic pasture species and these are expected to be replaced by native sedges and reeds as the transect transitions.


Figure 50: PMA5 T18a 2018


Figure 51: PMA5 T18a 2019 survey


Figure 52: PMA5 T18a 2021 survey


Figure 53: PMA5 T18a 2022 survey

Figure 56: PMA5 T18c 2017 survey

Figure 57: PMA5 T18c 2019 survey

Figure 58: PMA5 T18c 2021 survey

Figure 59: PMA5 T18c 2022 survey

PMA6

This transect (T20) has been historically impacted by clearing and stock access, and historical planting of willows, but has been fenced off for over 10 years and planting of native trees and shrubs has occurred. The transect is located immediately downstream of a major highway and impacted by the force of water channelled under the bridge and stormwater runoff from the highway. The increase in total RARC Index during the drought (Figures 2, 3 and 4) and substantial increase following the flood events (2021 survey) could be attributed to rehydration activities upstream (PMA 3, 4 and 5) that maintained some water during the drought and reduced the impact of the floods. The first half of the transect has high amounts of native shrubs and trees, willow revetment (opposite bank, as seen in Figure 64 - 67), and exotic species. Groundcover reduced during the drought (Figure 61) with the flood events triggering a burst of vegetation growth in 2021 and 2022 (Figures 62 and 63).

Figure 60: PMA6 T20a 2017 survey

Figure 61: PMA6 T20a 2019 survey

Figure 62: PMA6 T20a 2021 survey

Figure 63: PMA6 T20a 2022 survey

The second half of the transect is less vegetated open channel consisting of cobbles and gravel, willow revetment and other exotic plants, but less native plants (Figures 64 - 67). This section of T20 had had quite a transformation following the flood events in 2021 (Figure 66), with a significant increase in native plants, particularly aquatic native species, shrubs, and other groundcover. This transformation continued in 2022, with PMA6 receiving improved scores in all sub-indices except habitat, and evidenced by Figures 64 – 67.

Figure 64: PMA6 T20c 2017 survey

Figure 65: PMA6 T20c 2019 survey

Figure 66: PMA6 T20c 2021 survey

Figure 67: PMA6 T20c 2022 survey

PMA7

All transects on PMA7 have been impacted by historical clearing and stock access, and upper storey vegetation is dominated by willow revetments on outer banks and introduced pasture species. Most transects increased total RARC Index scores (Figures 2, 3, and 4) during the drought, that could be attributed to the implementation of in-stream structures in 2018-19, that supported the growth of aquatic plants. Following the 2019 survey, the remaining riparian zone has been fenced, and supported by TMI and volunteers, many native shrubs and tree seedlings were planted. The two flood events had some impact as vegetation recovery was still in its infancy, particularly aquatic plants, but by 2022 these have shown they have recovered (Figure 68 - 71). Transects T21 and T22 total RARC Index scores decreased in the 2021 survey this can be partly attributed to the loss of a few of the remaining native trees that didn't survive the drought, reduction in ground cover due to inundation and loss of existing debris that was moved on by the flood. There are no in-stream structures for 1.6km upstream and this could have exacerbated the effect of the floods on the first two transects, with the first of any in-stream structures immediately below T21. In 2022, PMA7 is the only PMA where an improvement was seen in all of the sub-indices from 2021 scores.

Figure 68: PMA7 T21b 2017 survey

Figure 69: PMA7 T21b 2019 survey

Figure 70: PMA7 T21b 2021 survey

Figure 71: PMA7 T21b 2022 survey

The two transects further downstream (T23 and T24) were potentially protected by a series of in-stream works on PMA7 that generated an increase in RARC Index scores (Figures 72 - 75). The landholders and TMI are hopefully expectant of a continued increase particularly in aquatic vegetation, tube stock plantings, and that native plants self-propagating will respond positively to the increased water availability in the riparian zone.

Figure 72: PMA7 T24a 2017 survey

Figure 73: PMA7 T24a 2019 survey

Figure 74: PMA7 T24a 2021 survey

Figure 75: PMA7 T24b 2022 survey

PMA8

All transects on PMA8 have been historically impacted by clearing and stock access, and vegetation is dominated by mostly willow revetments on outer banks and introduced species. Much of the riparian zone was fenced off over a decade ago and stock access minimised, however the underlying issue of historical clearing and maintaining water levels in the creek has curtailed the establishment and growth of native plants.

There were small improvements in total RARC scores from 2017 to 2019 for most of the transects (Figure 2), however T25 indicated a small decrease as could be expected during the extreme drought (Figures 76 and 77). In-stream interventions were implemented mid-2020 and had minimal time for regeneration before the floods yet three of the four transects had minor increases in 2021 total RARC score (Figure 3) after the flood. The exception of T26 total RARC scores decreased in 2021 due to significant loss of non-native terrestrial plants, plus loss of aquatic species and inundation of groundcover during the flood events (Figures 80 - 82). Its subsequent recovery in 2022 is seen in positive change in all sub-indices with the exception of Habitat (Figures 5 – 10), and in Figure 83.

Figure 76: PMA8 25a 2017 survey

Figure 77: PMA8 25a 2019 survey

Figure 78: PMA8 T25a 2021 survey

Figure 79: PMA8 T25b 2022 survey

Figure 80: PMA8 T27a 2017 survey

Figure 81: PMA8 T27a 2019 survey

Figure 82: PMA8 T27a 2021 survey

Figure 83: PMA8 T27b 2022 survey