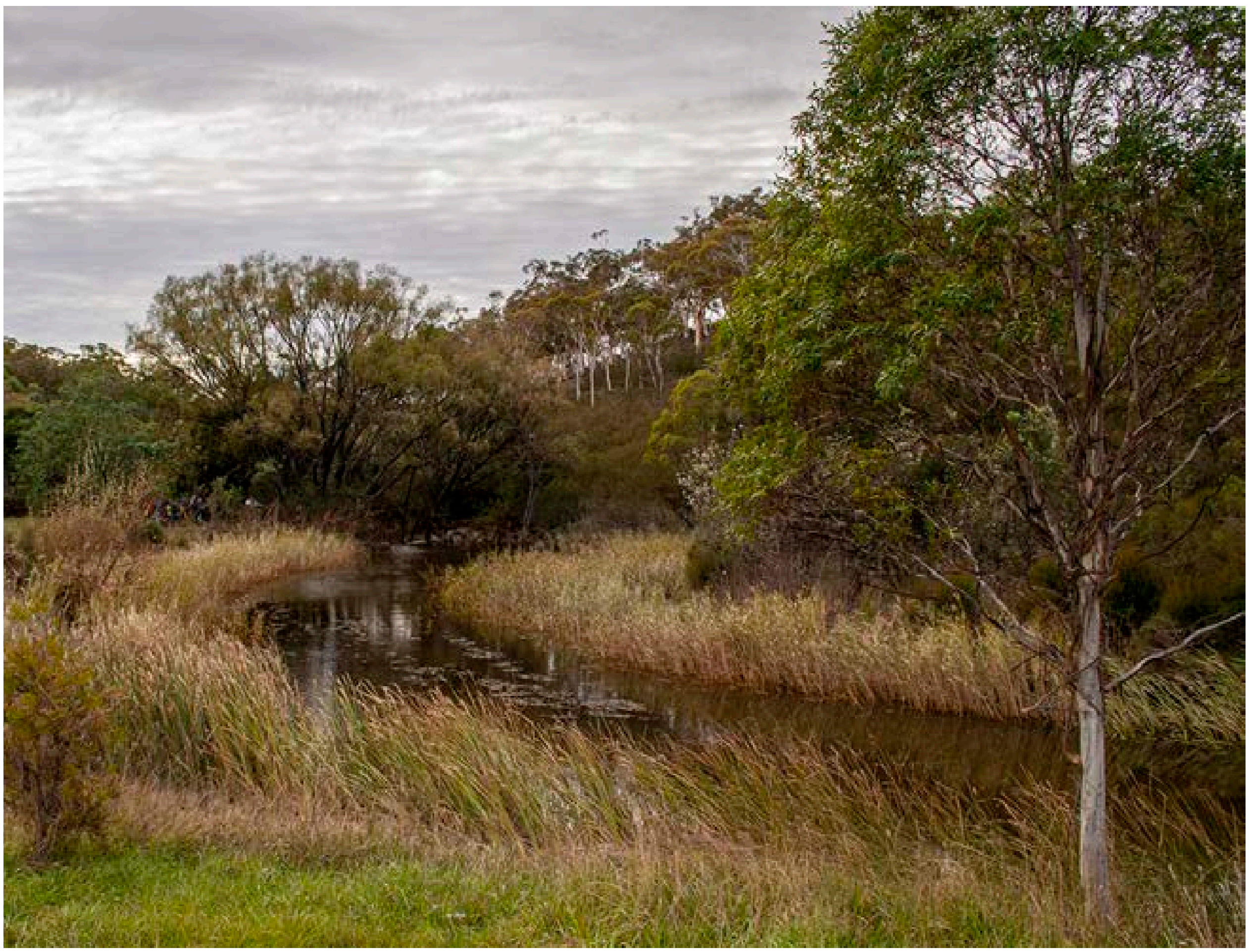
Baseline Rapid Appraisal of Riparian Condition Report

Ira Dudley-Bestow, Luke Peel

September 13, 2021



1 Acknowledgements

The Mulloon Institute (TMI) would like to acknowledge the Yuin people, the traditional owners of the land on which the surveys were done. The authors would like to acknowledge Campbell Wilson, Penny Cooper and James Diack who spent many hours in the field collecting data. Thanks also to Bill McAlister, Dr David Freudenberger (ANU), Kelly Thorburn, and Nolani McColl for reviewing the paper. The Mulloon Institute wish to thank and acknowledge SE Local Land Services for providing the initial seed funding for baseline surveys. The Mulloon Rehydration Initiative is jointly funded through The Mulloon Institute and the Australian Government's National Landcare Program.

2 Baseline RARC Surveys

2.1 Executive Summary

The Mulloon Insitute'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. In 2019, Rapid Appraisal of Riparian Condition (RARC) surveys were conducted along the length of Mulloon Creek and associated main tributaries with the aim of classifying the condition of riparian vegetation within the catchment. The RARC process involves quantifying different parameters such as width of riparian vegetation, canopy and ground cover, and leaf litter and other debris to reflect functional aspects of the physical, plant community and landscape features of the riparian zone. There was considerable variation of RARC scores varying from excellent (>30) to very poor (<15). RARC scores in the upper Mulloon were average (20-25) to excellent whereas RARC in the lower Mulloon floodplain ranged from very poor to average. Nineteen of the RARC sites were surveyed in 2017, providing an initial insight into the change of riparian vegetation condition over the intervening two years. An analysis of surveys before and after the installation of leaky weirs suggests a correlation between installation of leaky weirs and a RARC score increase. There also seems to be evidence to suggest that management practices can have an effect on RARC scores. A more rigorous monitoring protocol is recommended so as to provide statistical evidence towards the vegetation regeneration merits of leaky weirs.

2.2 Background

TMI aims to establish a baseline data set of the condition of riparian habitat across the length of Mulloon Creek to be used in establishing the effects of rehydration interventions colloquially known as leaky weirs (C. Wilson, 2019). TMI is a not-for-profit organisation based just east of the Great-Dividing Range near Bungendore (C. Wilson, 2019). Post settlement, the alluvial floodplains and the surrounding hills in the area have been used as pasture, running both sheep and cattle (C. Wilson, 2019). This grazing has severely degraded the landscape in both productivity and ecosystem function. TMI owns Mulloon Creek Natural Farms (MCNF) consisting of two properties along Mulloon Creek and uses regenerative farming practices aiming to improve the landscape and ecosystem function of the land it operates on (C. Wilson, 2019).

The RARC approach to assessing the condition of watercourses was developed for south-eastern Australia by Dr Amy Jansen and measures the departure of riparian condition from a semi-natural state (Jansen, Robertson, Thompson, & Wilson, 2005). The approach generates an index score based on field surveys (Jansen et al., 2005). The score 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 estimates such as the degree of understorey or proportion of canopy coverage (Jansen et al., 2005). See Table 1 for a complete listing of sub-index category breakdown.

Riparian zones are especially sensitive to traditional farming and suffer from land clearing and unfenced rivers (A. Wilson, 1990). These practices have compounding effects on the rate of erosion resulting in deep creek excision and large amounts of surface erosion (A. Wilson, 1990). TMI has implemented a number of management strategies to reverse the effects of past grazing on the area.

Leaky weirs are intervention structures made from rocks and logs used to slow down the flow of water and raise the base water level by creating a chain of ponds. While the volume of water moving through the system remains constant, the rate of movement slows due to the greater cross-sectional area. Consequently, the increased water level reduces the scouring effect of fast moving water and enables a more reliable source of water for flora and fauna during dry periods. This increases vegetation thereby armouring the banks and further reducing the rate of erosion. Other management strategies such as fencing riparian zones from stock and native plantings are combined with leaky weirs to maximise the rate of recovery. Figure 2 depicts an elevation profile of the proposed changes to creek bed as well as relative bank height along the property of Palerang.

To determine whether the leaky weirs are repairing the landscape, RARC surveys were conducted across the catchment prior to the installation of leaky weirs as part of a baseline survey for the entire catchment. Historic bird and frog survey sites were used for the RARC transect locations at MCNF and the lower Mulloon floodplain. The additional sites in the remaining catchment areas were selected using satellite and aerial imagery, site accessibility and local knowledge to be representative of the landholder's property.

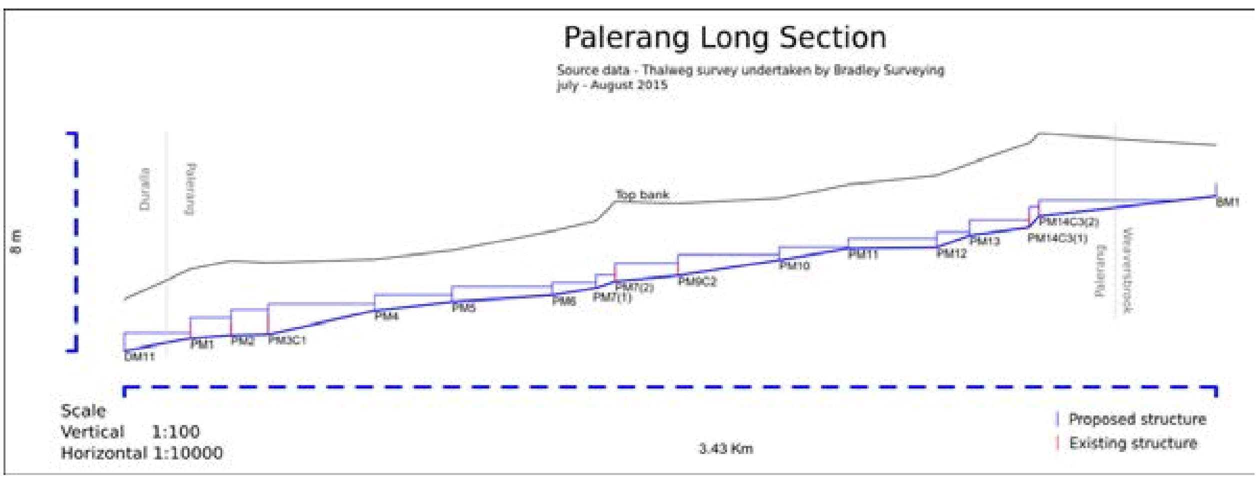


Figure 2: Elevation profile of leaky weirs along the Palerang section of Mulloon Creek. Weirs were installed during 2018-2019. An example of the rehabilitated creek section on a property where RARC surveys were conducted.

2.3 Methods

RARC survey methods were carried out at each of the transects along the Mulloon, Shiel and Sandhills Creeks using the methodology developed by Jansen et al. (2005). RARC surveys were conducted at 17 transects between 28th June and 20th July 2017. Two more transects were surveyed in April 2018 to include another property that joined the MRI. These transects were subsequently relabelled 11-29 to follow a naming convention and allow for transects completed upstream of the MRI demonstration site. In September to December 2019, the project resurveyed the initial 19 transects (11-29) and expanded its monitoring sites to another 25 transects (44 in total) so as to include the upper Mulloon, Sandhills and Shiel Creeks with leaky weirs planned in the future (Figure 3). Data consistency was ensured by having the same person present at each survey over all years.

Transects that had a score of 1 in total canopy cover dominated by non-natives with a low proportion of native canopy cover, were counted as zero. This would alleviate potential bias associated with attributing 100% of the canopy to native vegetation when this wasn't the case. Leaky weirs were installed at the MRI demonstration site in 2006, lower Mulloon floodplain area commencing with stage one south of Kings Hwy (three properties) 2018-19, and stage two North of Kings Hwy (three properties) 2019-20.

Table 1: RARC survey breakdown by sub-index.

Habitat	**Vegetation Cover**	**Natives**	**Debris**	**Features**
Vegetation continuity	Canopy	Native canopy	Leaf litter	Native canopy regen.
Vegetation width	Understorey	Native understorey	Native understorey regen.	Large native grasses
Habitat proximity	Ground cover	Native ground cover	Native leaf litter	Stand dead trees
	Number of layers		Hollow Logs	Reeds
			Fallen logs	

2.4 Catchment Scale Results

There was considerable variation in the RARC scores across the catchment. Notably, in Figure 4 sites in the lower Mulloon catchment present considerably lower RARC scores than the ones further up the stream. Upper Mulloon Creek contained the only area that had transects in excellent condition (>30 RARC score) and all scores were average or above (see Figure 5). This compares to the lower Mulloon floodplain with 85% of the transects scoring poor (<20 RARC score). Sites in the Sandhills and Shiel Creeks also scored poor or very poor in the majority of transects (Figure 9).

There was also a large degree of variation between each sub-index for the five different catchment areas as shown in Figure 11. This demonstrates where the variation in scores from Figure 4 comes from in terms of the RARC sub-scores. It is clear that habitat, cover, natives, and debris each contribute heavily to the overall scores whereas the feature category displays very little variation across the sites (Table 1 for sub-index categories). Vegetation cover has the highest score across the sub-indices whereas the lowest RARC score category average varies based off management area.

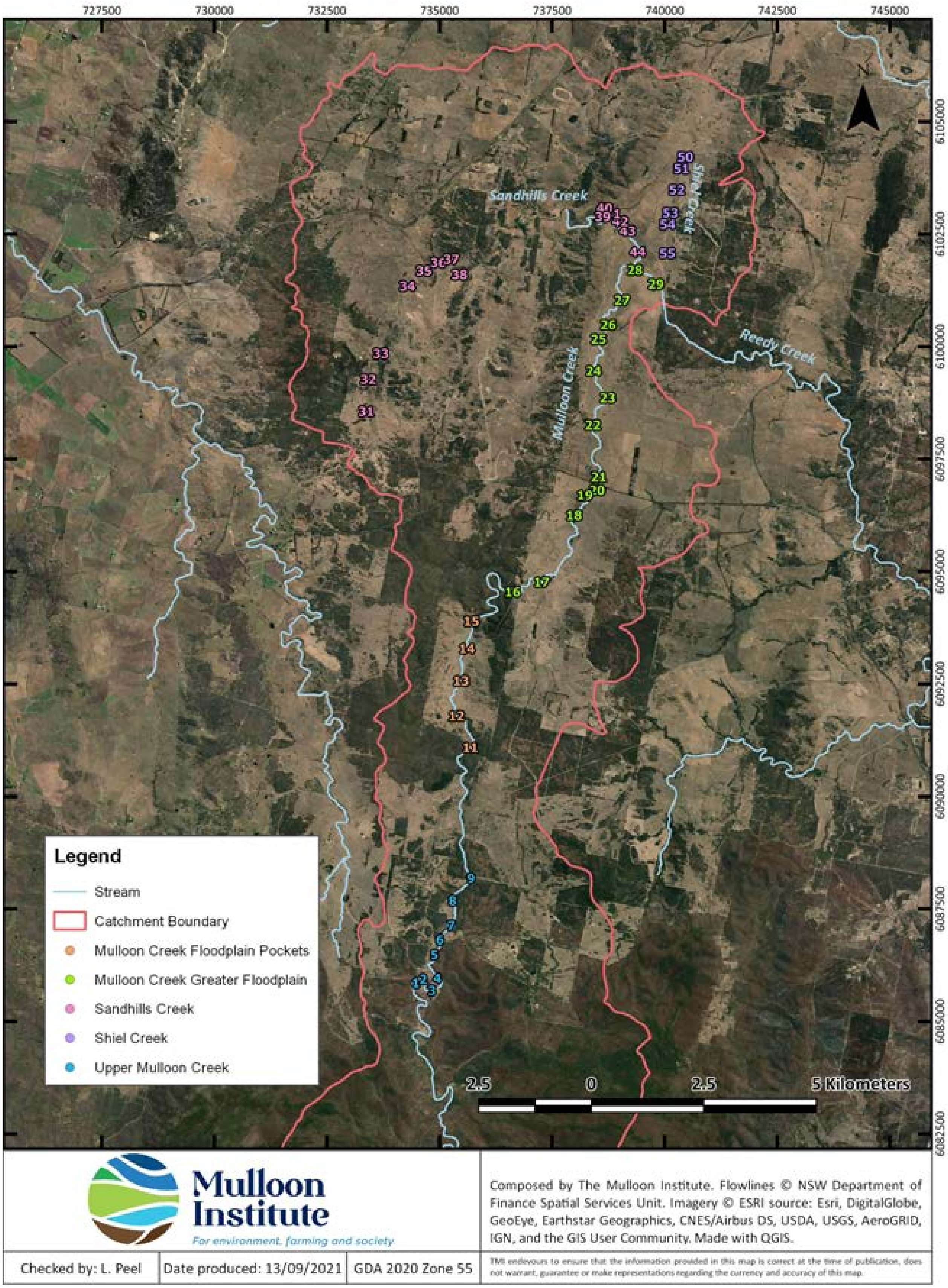


Figure 3: Locations of RARC transects across the study area.

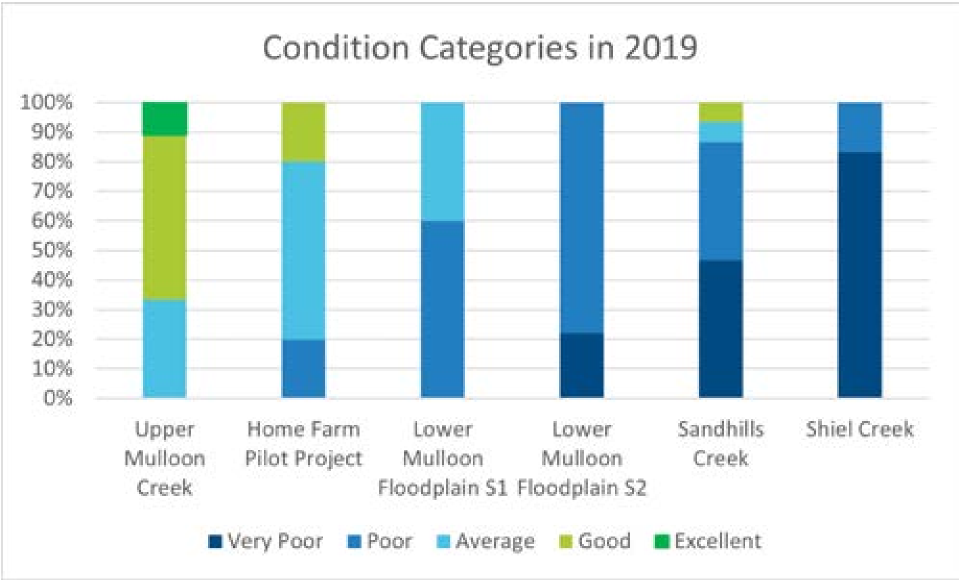


Figure 4: The percentage of sites scoring in each category (<15 very poor, 15-20 poor, 20-25 average, 25-30 good, >30 excellent) of the RARC index for sections of the study area. Values were generated using RARC surveying technique. See Table 4 in Appendix for raw data.

Figure 5: Transect 7 in the upper Mulloon part of the catchment. This site received a RARC score of 26 out of a maximum of 30 in 2019. It received this high score due to it being old regrowth vegetation with a high proportion of natives.

Figure 6: Transect 15 in the MRI demonstration site catchment area. In 2019 this site received a RARC score of 23.5 out of 30.

Figure 7: Transect 19 in stage one of the lower Mulloon floodplain. In 2019 this site received a RARC score of 17.5 out of 30.

Figure 8: Transect 22 in stage two of the lower Mulloon floodplain at Duralla. In 2019 this site received a RARC score of 16.0 out of 30.

Figure 9: Transect 35 in the Sandhills Creek part of the catchment. This site received a RARC score of 17 out of a maximum of 30 in 2019. This lowish score is largely due to the absence of larger trees to provide suitable habitat.

Figure 10: Transect 54 in the Shiel Creek catchment area. In 2019 this site received a RARC score of 10 out of 30.

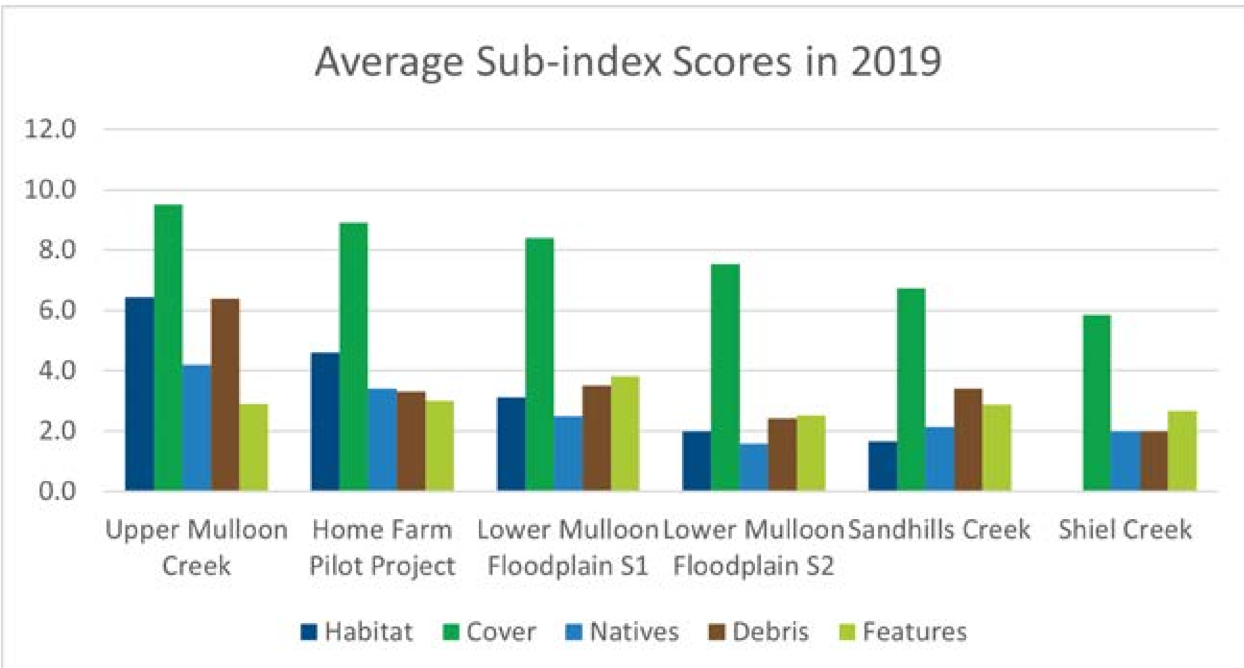


Figure 11: Average sub-index scores for sections of the study area in 2019. Values were generated using RARC surveying technique. Higher scores indicate that the sub-index is in better condition. See Figure 1 for description of sub-index components.

2.5 Site Descriptions

Transects 1-9 in the upper Mulloon catchment are generally in good condition where the riparian zone is rarely grazed and close to large stretches of remnant forest. While the area hasn't had leaky weirs installed, the property has a very high proportion of native vegetation and considerable amounts of large debris. Figure 5 is a representative example of transects in the upper Mulloon catchment.

Transects 11-15 are on the MRI demonstration site which have had leaky weirs installed since 2006 and follow regenerative farming practices. The riparian zone is completely fenced from stock and a large amount of plantings were installed, with a dominant canopy of Weeping Willows (*Salix babylonica*). Transect 11 is in a heavily vegetated site that is rarely grazed and above the leaky weirs. Transects 12-14 are in the alluvial channel. Transect 15 in this area is where the river goes through a gorge and is surrounded by native vegetation. Figure 6 is a representative example of transects in the MRI demonstration site.

Stage one transects (T16-T20) go over several properties with different management practices and have a riparian zone with a canopy dominated by Weeping Willows. Transect 17 is in a part of the riparian zone where stock have access to the riparian zone and conventional farming practices are followed. On Transect 18, regenerative farming practices are followed and the riparian zone is fenced from cattle. Transects 19-20 have had leaky weirs installed with considerable plantings in the immediate riparian zone, while the area was recently fenced from stock. Figure 7 is a representative example of transects in the stage one floodplain area.

Stage two transects (T21-T29) are all on a wide part of the alluvial channel with some vegetation and a canopy dominated by weeping willows. Transects 21-25 are on a cattle property with a fenced riparian zone following largely conventional management practices. Transects 26-29 are on a chicken property, that occasionally stocks cattle following regenerative farming practices. Figure 8 is a representative example of transects in the upper tributary of Mulloon Creek.

Transects along Sandhills Creek (T31-T44) are on a smaller creek with with comparatively little vegetation. There are small local stands of *Eucalyptus mannifera*, but otherwise the catchment has comparatively little riparian vegetation and largely runs through grazing enterprises with sections that have direct access to the riparian zone. Figure 9 is a representative example of transects in the upper Mulloon catchment.

Transects 52-55 are on Shiel Creek and have very little vegetation in the riparian zone. However what vegetation is there is often native. While very little grazing from stock occurs, it is usually heavily impacted by high densities of kangaroo and deer on the property. Figure 10 is a representative example of transects in the upper Mulloon catchment.

2.6 Site Scale Results

Out of the 19 transects, 16 had a higher RARC score in 2019 than 2017 as is depicted in Figure 12. Transect 11 and Transect 19 increased the most with an increase of 4.75. Whereas Transect 26 had the greatest decrease, with a decrease of 1.00. The average change across all transects was an increase of 1.72. The average change in RARC score on the MRI demonstration site (T11-T15) was 2.54, while the average change in the lower Mulloon floodplain (T16-T29) area was 1.50. Table 2 depicts the standard deviation and averages of the changes in each sub-index. Cover had the highest average change of 0.649 with a standard deviation of 1.04 whereas habitat had the lowest average change of -0.212 with a standard deviation of 1.21.

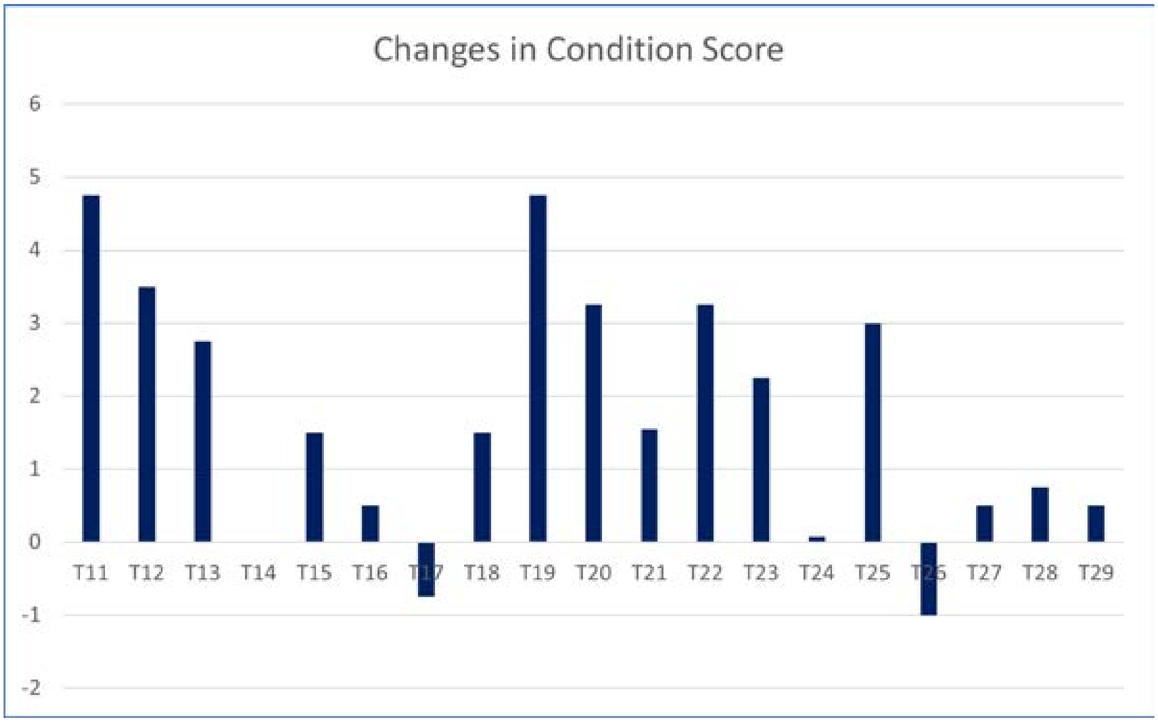


Figure 12: RARC score difference at each of the transects between initial 2017 survey and subsequent 2019 survey. Positive values indicate there was a better RARC score in 2019, whereas negative RARC scores indicate that riparian condition degenerated. Sites T11-T15 are part of the MRI demonstration site, sites T16-T29 are part on the lower Mulloon floodplain area. Raw values were generated using RARC surveying technique and can be found in Table 3 Appendix.

Table 2: Average and standard deviation for change in each of the RARC sub-indices between 2017 and 2019 surveys across the entire catchment. RARC scores are calculated using the sub-index categories from 1. Negative values indicate that the RARC score reduced over the survey interval.

	Habitat	Cover	Natives	Debris	Features	Total
Average	-0.21	0.64	0.18	0.56	0.31	1.71
Std. Deviation	1.20	1.03	1.02	0.90	1.40	1.68

The RARC transects that were surveyed in 2017 and 2019 (T11-T29) provide some initial trends related to land management and timing of implementation of leaky weirs. MRI demonstration site transects (T11-T15) had leaky weirs installed since 2006 and were also fenced off, with an average increase of 2.5 RARC score. Transects 16 and 17 is on a property that had leaky weirs installed in 2018, but have not finalised fencing off riparian area from stock access, with a decrease of 0.75 RARC score. Transects 18 and 19-20 are on properties that had leaky weirs installed in 2018 and 2019 and fenced off, with an increase of 1.5 and 4 (average) RARC score respectively. Transect 16 is a relatively stable native-dominated site at the end of a gorge system and has had no leaky weirs implemented and is fenced off from stock. These sites fall within stage one of the MRI implementation area.

Stage two of the MRI leaky weir implementation occurred in 2019 and 2020 thereby allowing survey results to capture the difference in RARC score for those transects that had no leaky weirs installed at time of survey. Transects T22-T25 were on a property that had leaky weirs installed and riparian zones fenced off from stock, with an average increase in RARC score pf 2.15. Transects 26-29 were on a property that had no leaky weirs and a riparian zone had not been completely fenced off from stock, with an increase in RARC score of 0.18. Transect 21, with an increase in

RARC score of 1.5, is on a property that does not directly benefit from leaky weirs installed but may benefit from weirs installed upstream. This riparian area is not fenced off, however it is rarely utilised for grazing.

2.7 Discussion

It is clear from the RARC results that the condition of riparian vegetation varies greatly in the Mulloon catchment. This is due to a number of variables such as degree of clearing, whether the riparian corridors are fenced, the degree of grazing, as well as what management values and priorities in the landscape (Osborne & Kovacic, 1993; Grudzinski, Fritz, & Dodds, 2020). Many grazing values have historically been inconsistent with traditional conservation values which largely explains the widespread ecological loss of function, reductions in biodiversity and soil degradation in fertile landscapes (Dorrough et al., 2004; Steinfeld et al., 2006; Greenwood & McKenzie, 2001). While modern farming techniques such as rotational grazing and regenerative farming are far more compatible with ecosystem functions, there are aspects of grazing which are inherently at odds with maintaining natural ecosystems in Australia (LaCanne & Lundgren, 2018; Greenwood & McKenzie, 2001). This explains the large variation between site sub-indices as well as explaining why even farms following best practice in agriculture and regenerative farming are not able to achieve high RARC scores.

The majority (16 out of 19) of sites were rated by the RARC system as average, poor or very poor condition to start out with indicating that the Mulloon catchment is a degraded landscape with the upper catchment being in better condition with a higher RARC score than the lower catchment. Transects in the MRI demonstration site that once existed in a heavily degraded state had the greatest increase over the survey period. This indicates that 14 years of leaky weirs in combination with fencing the riparian corridors can improve the condition of riparian areas and is unlikely to make it worse given the risk of using heavy machinery to put large constructions in the creek. Likewise with the stage one and two sites that had leaky weirs installed, RARC scores generally improved over the survey interval indicating that implementing leaky weirs didn't adversely effect the condition of the riparian vegetation. However, given that the RARC scores were considerably higher in the MRI demonstration site which had leaky weirs installed 14 years prior, it is likely that leaky weirs produce continual long-term improvements from maintaining a consistent and natural waterlevel. These long-term improvements would likely be in the form of banks repairing themselves and woody debris accumulating.

At the site scale there appears to be an overall increase in the RARC score across the Mulloon Creek catchment. One possible explanation for this is that there was an overall improvement in riparian vegetation over the intervening survey period. This may be due to the installation of leaky weirs or improved management practices such as fencing off riparian zones to exclude stock, or planting native trees and shrubs. The overall improvement in RARC scores on sites that were affected by leaky weirs does support this hypothesis. The comparatively small improvement in transects 26-29 which did not yet have weirs installed providers further evidence towards the benefits of leaky weirs. However there is currently insufficient data to make any conclusive statements. This can be remedied by continuing the surveys at each of the sites. Some proportion of the variance could be attributed to seasonal variation as the surveys were not conducted at a consistent time of year. Another possible explanation for the improvement is the periodic variation in climatic conditions such as drought, which produce considerable change in RARC scores. Alternatively this could be interpreted as an interaction effect where sites that have had leaky weirs for a long time create an ecosystem with vegetation that is better able to respond to improved seasonal conditions than sites that have had only had leaky weirs for a short period of time. This improved resilience would be a valuable addition to riparian zones in times of drought recovery. However to test this hypothesis it would be necessary to do a long term monitoring project to investigate the response of vegetation with leaky weirs to drought in comparison to the same vegetation without leaky weirs.

2.8 Recommendations

In order to capture the effect of leaky weirs on riparian vegetation, establishing and following a rigorous monitoring protocol for the Mulloon catchment will be necessary. Paramount to this protocol will be understanding available resources such as personnel, transport and funding and integrating said resources into surveying a predetermined number of transects over a predetermined survey period. Such a protocol would involve prioritising exactly which transects would be required to account for periodic changes in RARC scores such that the true effects of leaky weirs is understood. From this it would then be possible to understand the number of transects that could be surveyed each year while staying within the limits of resource availability.

As part of the monitoring protocol, TMI should consider initiating a series of control transects in catchment areas that have not yet had leaky weirs implemented such that one can observe how these transects differ to sites that have leaky weirs. This will need to be additional to the 55 transects that were surveyed each in 2019. In consideration of these extra transects TMI will likely need to consider removing less important transects such that resource limitations don't impact on the timing or quality of the surveys. Furthermore, the construction of stage three and four weirs should incorporate the monitoring protocol to inform decisions about when and where leaky weirs should be constructed.

In addition to adding control sites, TMI should have survey the transects annually instead of biannually improving the ability to account for any remedial or land management actions and climatic seasonal variations. This will also need to be considered in terms of resource limitations and accounted for in the number of location of transects surveyed each year, potentially by removing less important transects from the monitoring protocol.

3 Conclusion

The RARC surveys provided an insight into the condition of riparian vegetation along the entire Mulloon catchment. There are clearly areas such as upper Mulloon that are fairing far better than others such as the Sandhills and Shiel Creeks. This survey clearly marks areas which have been managed well in terms of their ecological value as well identifying others that may benefit from changed management or assisted regeneration. Any further rehydration projects will need to be done while balancing the needs of farming operations such that the ecology can be restored without detriment to productivity. There is potential for leaky weirs to be a means of restoring riparian zones but considerably more long term RARC monitoring will be required to test the expected benefits before any conclusions can be made about the efficacy of doing so. There is also a clear need to establish a more rigorous long-term monitoring protocol to better understand the long-term effects of leaky weirs on riparian vegetation.

4 Appendix

Table 3: 2017 and 2018 RARC data for the first 19 transects. They are labelled as such to match the changed naming convention that occurred when the additional transects were added in 2019.

Site	Habitat A+B+C	Cover D+E+F+G	Natives H+I+J	Debris K+L+M+N+O	Features P+q+r+s	Total
(out of)	11	12	9	10	8	50
T11	10.75	6.75	2.5	2.5	3	25.5
T12	4.75	6.25	2	2	2.25	17.25
T13	3.75	7	2.25	2	4.5	19.5
T14	7.25	8.25	1.75	2.25	5.25	24.75
T15	7.5	7.75	2.75	4.25	5.25	27.5
T16	7.75	9	4.5	4.75	2.25	28.25
T17	5.75	8.5	4.25	2.75	1.75	23
T18	6.75	9.5	4.5	3	4	27.75
T19	4	8	0.75	1.25	1.25	15.25
T20	1.5	6.75	2	1	2	13.25
T21	3.75	7	2	1.75	4	18.5
T22	2.5	5.75	2	1	3	14.25
T23	4	7	0.5	2.25	0.5	14.25
T24	4.25	7.75	1.75	2	1.75	17.5
T25	4.5	6.75	1	2.25	1	15.5
T26	1.75	8.25	1.5	3	2.25	16.75
T27	1.25	6	1.5	1.75	2.25	12.75
T28	1.75	8	1.5	3	2.25	16.5
T29	3.75	7.75	1.25	2.25	2.25	17.25

Table 4: Values acquired for all sites across the 2019 RARC surveys.

Site	Habitat A+B+C	Cover D+E+F+G	Natives H+I+J	Debris K+L+M+N+O	Features P+q+r+s	Total
(out of)	11	12	9	10	8	50
T1	9	9	4	7	3	32
T2	10	10	7	8	4	39
T3	9	9	3	7	2	30
T4	9	9	3	6	2	29
T5	8	9	4	5	2	28
T6	8	9	2	4	2	25
T7	8	10	3	7	1	29
T8	8	10	3	6	2	29
T9	5	8	4	4	3	24
T11	10.75	9	5	3.5	2	30.25

Site	Habitat A+B+C	Cover D+E+F+G	Natives H+I+J	Debris K+L+M+N+O	Features P+q+r+s	Total
(out of)	11	12	9	10	8	50
T12	6	8	1.5	3	3.5	22
T13	5	9.5	3	4	2	23.5
T14	4	8.5	3	2.5	3.5	21.5
T15	6.5	9.5	4.5	3.5	4	28
T16	7	8.5	3.5	6.5	2.5	28
T17	4	7.5	2	4.5	2.5	20.5
T18	6	9.5	4	3	6	28.5
T19	3	8	1.5	2	4.5	19
T20	3	8.5	1.5	1.5	3.5	18
T21	4.3	8	2	2.6	3.7	20.6
T22	3	7.5	2	2	3.5	18
T23	4	7	1.5	1.5	2.5	16.5
T24	3.66	8.33	1.33	2.66	1	16.98
T25	3	8	1	2.5	2.5	17
T26	1.5	7.5	2	1.5	3	15.5
T27	1.5	6	1.5	2	2.5	13.5
T28	3.5	8	2	3	2.5	19
T29	3.5	7.5	1	4	1.5	17.5
T30	1	4	1	1	1	8
T31	2	6	1	3	2	14
T32	4	8	4	4	3	23
T33	1	4	1	1	2	9
T34	1	4	1	6	3	15
T35	1	8	3	5	3	20
T36	1	7	3	6	6	23
T37	1	5	2	3	3	14
T38	1	7	3	5	4	20
T39	5	8	2	2	4	21
T40	6	9	3	4	4	26
T41	2	8	2	2	2	16
T42	2	8	2	3	3	18
T43	1	8	2	4	2	17
T44	1	7	2	2	1	13
T50	3	7	1	2	2	15
T51	3	6	3	2	4	18
T52	1	7	3	3	3	17
T53	1	3	1	2	3	10
T54	1	5	2	2	2	12

Site	Habitat A+B+C	Cover D+E+F+G	Natives H+I+J	Debris K+L+M+N+O	Features P+q+r+s	Total
(out of)	11	12	9	10	8	50
T55	1	7	2	1	2	13

References

Dorrough, J., Yen, A., Turner, V., Clark, S., Crosthwaite, J., & Hirth, J. (2004). Livestock grazing management and biodiversity conservation in australian temperate grassy landscapes. *Australian Journal of Agricultural Research*, *55*(3), 279–295.

Greenwood, K., & McKenzie, B. (2001). Grazing effects on soil physical properties and the consequences for pastures: a review. *Australian Journal of Experimental Agriculture*, *41*(8), 1231–1250.

Grudzinski, B., Fritz, K., & Dodds, W. (2020). Does riparian fencing protect stream water quality in cattle-grazed lands? *Environmental management*, *66*(1), 121–135.

Jansen, A., Robertson, A., Thompson, L., & Wilson, A. (2005). Rapid appraisal of riparian condition, version 2. *River Management Technical Guideline*(4A).

LaCanne, C. E., & Lundgren, J. G. (2018). Regenerative agriculture: merging farming and natural resource conservation profitably. *PeerJ (San Francisco, CA)*, *6*, e4428-e4428.

Osborne, L. L., & Kovacic, D. A. (1993). Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology*, *29*(2), 243-258. doi: https://doi.org/10.1111/j.1365-2427.1993.tb00761.x

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., Rosales, M., & de Haan, C. (2006). *Livestock's long shadow: environmental issues and options*. Food & Agriculture Org.

Wilson, A. (1990). The effect of grazing on australian ecosystems.

Wilson, C. (2019). Dehydration and rehydration of the australian landscape. *Geography Bulletin*(51(1), 31–34).