Plot JW01: *Austrostipa – Rytidosperma* grassland – grazing exclusion

2009

Floristic value score: **33**
Native species richness: **33**
Exotic species richness: **13**
Indicator spp. level 1: **3**
Indicator spp. level 2: **12**

2012

Floristic value score: **22**
Native species richness: **27**
Exotic species richness: **8**
Indicator spp. level 1: **3**
Indicator spp. level 2: **7**

Changes between 2009 – 2012

Floristic value score: **-11 (-33%)**
Native species richness: **-6**
Exotic species richness: **-5**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **-5**

25 – 50% *decline* in condition

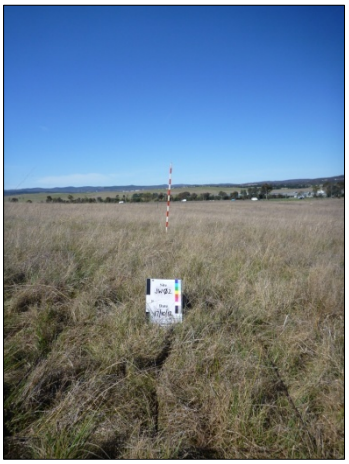
Note: This site has had kangaroo grazing exclusion since October 2009.

Plot JW02: *Austrostipa – Rytidosperma* grassland – grazing exclusion

2009

Floristic value score: **36**
Native species richness: **29**
Exotic species richness: **7**
Indicator spp. level 1: **2**
Indicator spp. level 2: **12**

2012



Floristic value score: **24**
Native species richness: **30**
Exotic species richness: **10**
Indicator spp. level 1: **4**
Indicator spp. level 2: **9**

Changes between 2009 – 2012

Floristic value score: **-12 (-33%)**
Native species richness: **+1**
Exotic species richness: **+3**
Indicator spp. level 1: **+2**
Indicator spp. level 2: **-3**

25 – 50% *decline* in condition

Note: This site has had kangaroo grazing exclusion since October 2009.

Plot JW03: Box woodland

2009

Floristic value score: **23**
Native species richness: **23**
Exotic species richness: **8**
Indicator spp. level 1: **2**
Indicator spp. level 2: **8**

2012

Floristic value score: **24**
Native species richness: **29**
Exotic species richness: **11**
Indicator spp. level 1: **2**
Indicator spp. level 2: **8**

Changes between 2009 – 2012

Floristic value score: **+1 (+4%)**
Native species richness: **+6**
Exotic species richness: **+3**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **stable**

25% *increase* to 25% decline (*stable*) in condition

Plot JW04: Box woodland

2009

Floristic value score: **27**
Native species richness: **26**
Exotic species richness: **14**
Indicator spp. level 1: **2**
Indicator spp. level 2: **9**

2012

Floristic value score: **28**
Native species richness: **33**
Exotic species richness: **17**
Indicator spp. level 1: **2**
Indicator spp. level 2: **10**

Changes between 2009 – 2012

Floristic value score: **+1 (+4%)**
Native species richness: **+7**
Exotic species richness: **+3**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **+1**

25% *increase* to 25% decline (*stable*) in condition

Plot JW06: *Austrostipa – Rytidosperma* grassland		
2009  *Floristic value score*: **7** *Native species richness*: **20** *Exotic species richness*: **11** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **3**	2012  *Floristic value score*: **17** *Native species richness*: **21** *Exotic species richness*: **15** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **5**	**Changes between 2009 – 2012** *Floristic value score*: **+10 (+143%)** *Native species richness*: **+1** *Exotic species richness*: **+4** *Indicator spp. level 1*: **stable** *Indicator spp. level 2*: **+2**  **≥100% *increase*** in condition

Kama NR

Kama NR is dominated by Box-Gum woodland in the north, and Natural Temperate Grassland in the south along with patches of secondary grassland and patches of *Eucalyptus rossii*. The overall site condition is considered relatively stable, although 'Floristic value scores' have dropped by 23% since 2009. This is most likely due to a higher density of perennial native grasses providing increased competition for indicator forb species. Kangaroo densities have decreased to 0.61 kangaroos per ha., down from 1.50 in 2009.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **-8 (-23%)**
Native species richness: **+2.5**
Exotic species richness: **-1.7**
Indicator spp. level 1: **+0.2**
Indicator spp. level 2: **-2.2**

25% increase to 25% *decline* (*stable*) in condition

Changes in key floristic indicators are shown in Table 18, with all indicators suggesting a relatively stable system. However, a loss of key indicator species (as indicated by the decreased 'Floristic value score') is primarily due to a lack of disturbance in grassland areas restricting plant establishment.

Table 18: Mean condition of Kama NR from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	1.50	**34.3**	23.5	15.5	1.8	12
2012	0.61	**26.3**	26	13.8	2	9.8

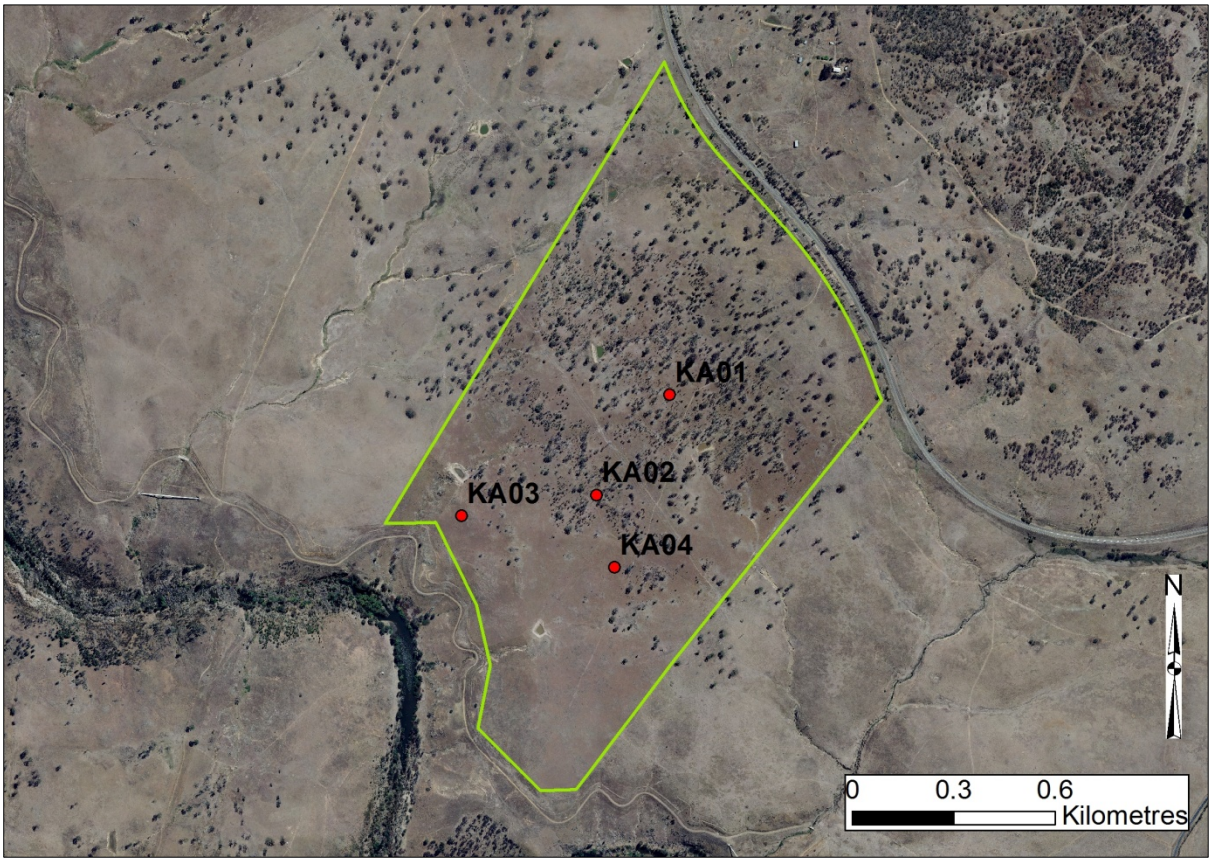


Figure 21: Map and plot locations: Kama NR.

Plot KA01: Box-Gum woodland		
2009  *Floristic value score*: **24** *Native species richness*: **18** *Exotic species richness*: **22** *Indicator spp. level 1*: **1** *Indicator spp. level 2*: **9**	2012  *Floristic value score*: **16** *Native species richness*: **20** *Exotic species richness*: **23** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **7**	**Changes between 2009 – 2012** *Floristic value score*: **-8 (-33%)** *Native species richness*: **+2** *Exotic species richness*: **+1** *Indicator spp. level 1*: **+1** *Indicator spp. level 2*: **-2**  **25 – 50% *decline*** in condition
Plot KA02: Box-Gum woodland		
2009  *Floristic value score*: **50** *Native species richness*: **30** *Exotic species richness*: **6** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **17**	2012  *Floristic value score*: **48** *Native species richness*: **42** *Exotic species richness*: **14** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **18**	**Changes between 2009 – 2012** *Floristic value score*: **-2 (-4%)** *Native species richness*: **+12** *Exotic species richness*: **+8** *Indicator spp. level 1*: **-1** *Indicator spp. level 2*: **+1**  **25% increase to 25% *decline* (*stable*)** in condition

Plot KA03: *Themeda* grassland

2009

Floristic value score: **38**
Native species richness: **24**
Exotic species richness: **15**
Indicator spp. level 1: **1**
Indicator spp. level 2: **13**

2012

Floristic value score: **24**
Native species richness: **25**
Exotic species richness: **11**
Indicator spp. level 1: **2**
Indicator spp. level 2: **8**

Changes between 2009 – 2012

Floristic value score: **-14 (-37%)**
Native species richness: **+1**
Exotic species richness: **-4**
Indicator spp. level 1: **+1**
Indicator spp. level 2: **-5**

25 – 50% *decline* in condition

Plot KA04: *Themeda* grassland

2009

Floristic value score: **25**
Native species richness: **22**
Exotic species richness: **19**
Indicator spp. level 1: **2**
Indicator spp. level 2: **9**

2012

Floristic value score: **17**
Native species richness: **17**
Exotic species richness: **7**
Indicator spp. level 1: **2**
Indicator spp. level 2: **6**

Changes between 2009 – 2012

Floristic value score: **-8 (-32%)**
Native species richness: **-5**
Exotic species richness: **-12**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **-3**

25 – 50% *decline* in condition

Majura Training Area

Majura Training Area is characterised by areas of lowland Natural Temperate Grassland, and Yellow Box – Blakely's Red Gum woodland above the cold air drainage lines. Data was collected at this site in 2009 only, so vegetation condition trends are not able to be predicted.

Key floristic indicators for 2012 are shown in Table 19.

Table 19: Mean condition of Majura Training Area from 2009.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2012	1.37	**20.7**	23.7	15	3	9.7

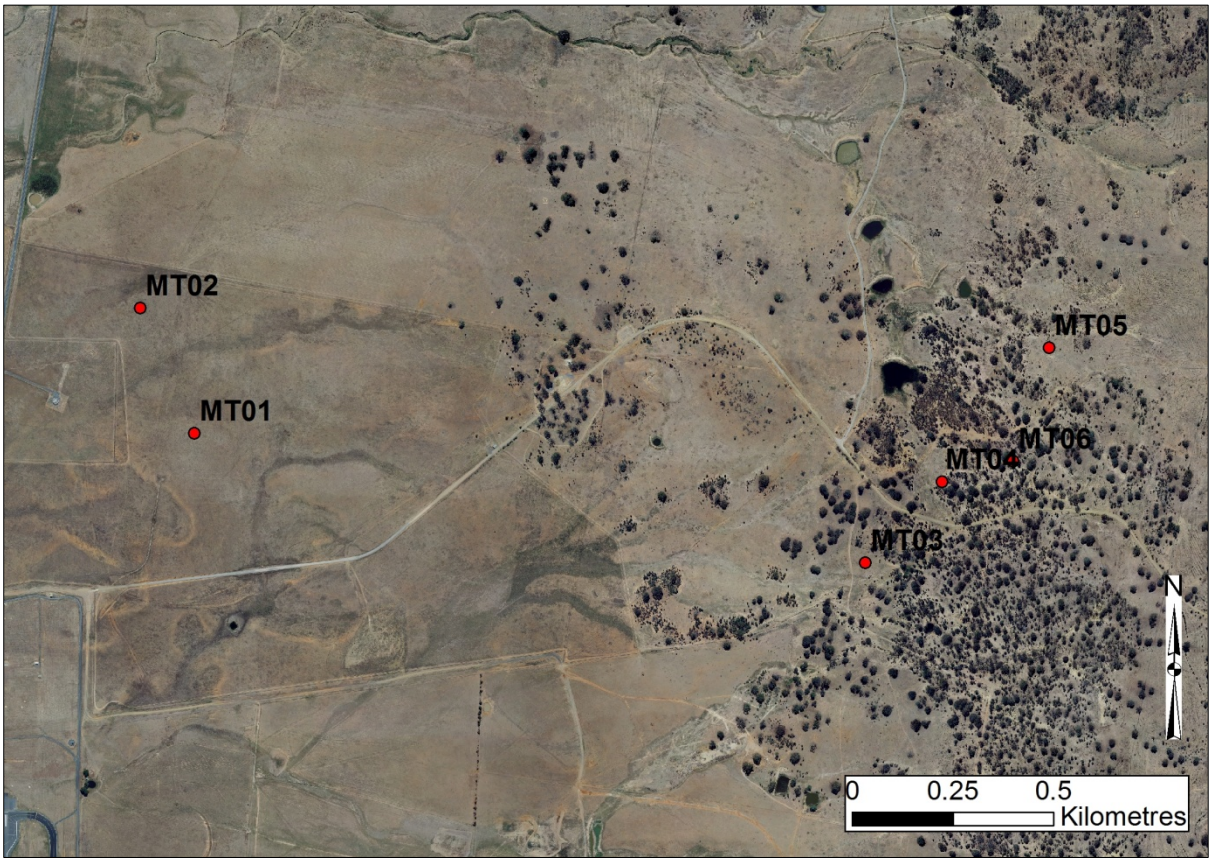


Figure 22: Map and plot locations: Majura Training Area.

Plot MT01: *Austrostipa – Rytidosperma* grassland	Plot MT02: *Austrostipa – Rytidosperma* grassland	Plot MT03: Box-Gum woodland
2009  *Floristic value score*: **18** *Native species richness*: **19** *Exotic species richness*: **8** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **6**	2009  *Floristic value score*: **21** *Native species richness*: **22** *Exotic species richness*: **6** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **7**	2009  *Floristic value score*: **28** *Native species richness*: **27** *Exotic species richness*: **17** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **10**
Plot MT03: Box-Gum woodland	**Plot MT03: Box-Gum woodland**	**Plot MT03: Box-Gum woodland**
2009  *Floristic value score*: **30** *Native species richness*: **26** *Exotic species richness*: **16** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **10**	2009  *Floristic value score*: **55** *Native species richness*: **39** *Exotic species richness*: **13** *Indicator spp. level 1*: **4** *Indicator spp. level 2*: **19**	2009  *Floristic value score*: **16** *Native species richness*: **17** *Exotic species richness*: **4** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **6**

Mulanggari NR

Mulanggari NR contains a mosaic of open woodland, secondary grassland and Lowland Natural Temperate Grassland. Open woodland areas are dominated by *Eucalyptus blakelyi*, with surveyed areas of Lowland Natural Temperate Grassland dominated by *Themeda triandra*.

As there is one plot in *Themeda* grassland and two in secondary grassland (one burnt), it is difficult to broadly assess trends across each vegetation community. For plot-specific information, refer to plot comparisons below. When combining all plots, the overall site condition is considered stable, with a slight decrease in the mean floristic value since 2009. This incorporates one burnt site (MU01) that has declined significantly based on a lack of regeneration of some indicator forbs, with unburnt areas generally showing an increase in vegetation condition. Kangaroo densities have increased to 1.24 kangaroos per ha., up from 1.05 in 2009.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **-0.3 (-1%)**
Native species richness: **+5**
Exotic species richness: **+4**
Indicator spp. level 1: **+0.7**
Indicator spp. level 2: **-0.7**

25% increase to 25% *decline* (*stable*) in condition

Changes in key floristic indicators are shown in Table 20, with all indicators indicating a relatively stable system.

Table 20: Mean condition of Mulanggari NR from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	1.05	**29.3**	25.7	9.7	2.3	9.7
2012	1.24	**29**	30.7	13.7	3	9

Figure 23: Map and plot locations: Mulanggari NR.

Plot MU01: Secondary grassland - burnt		
2009 No site photo *Floristic value score*: **27** *Native species richness*: **22** *Exotic species richness*: **13** *Indicator spp. level 1*: **1** *Indicator spp. level 2*: **10**	2012  *Floristic value score*: **17** *Native species richness*: **27** *Exotic species richness*: **12** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **5**	**Changes between 2009 – 2012** *Floristic value score*: **-10 (-37%)** *Native species richness*: **+5** *Exotic species richness*: **-1** *Indicator spp. level 1*: **+2** *Indicator spp. level 2*: **-5**  **25 – 50% *decline*** in condition Note: This plot was burnt in August 2012, making direct comparison difficult.
Plot MU02: Secondary grassland		
2009  *Floristic value score*: **14** *Native species richness*: **19** *Exotic species richness*: **9** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **4**	2012  *Floristic value score*: **21** *Native species richness*: **27** *Exotic species richness*: **17** *Indicator spp. level 1*: **2** *Indicator spp. level 2*: **7**	**Changes between 2009 – 2012** *Floristic value score*: **+7 (+50%)** *Native species richness*: **+8** *Exotic species richness*: **+8** *Indicator spp. level 1*: **stable** *Indicator spp. level 2*: **+3**  **50 – 100% *increase*** in condition

Plot MU03: *Themeda* grassland		
2009  *Floristic value score*: **47** *Native species richness*: **36** *Exotic species richness*: **7** *Indicator spp. level 1*: **4** *Indicator spp. level 2*: **15**	2012  *Floristic value score*: **49** *Native species richness*: **38** *Exotic species richness*: **12** *Indicator spp. level 1*: **4** *Indicator spp. level 2*: **15**	**Changes between 2009 – 2012** *Floristic value score*: **+2 (+4%)** *Native species richness*: **+2** *Exotic species richness*: **+5** *Indicator spp. level 1*: **stable** *Indicator spp. level 2*: **stable**  **25% *increase* to 25% decline (*stable*)** in condition

North Mitchell

In its current state, North Mitchell is a disturbed example of Lowland Natural Temperate Grassland, forming a mosaic of grassland in moderate condition with patches dominated by perennial exotic grasses. The condition information below is based on one plot in an area of high condition relative to the remainder of the site. The overall site condition is considered stable, with a slight increase in the 'Floristic value score' and 'Indicator level 2' species since 2009. Kangaroo densities were not recorded on this site as it is a small parcel located in a suburban environment, and no evidence of kangaroo activity has been observed here.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **+1 (+9%)**
Native species richness: **-1**
Exotic species richness: **+4**
Indicator spp. level 1: **-1**
Indicator spp. level 2: **+1**

25% *increase* to 25% decline (*stable*) in condition

Changes in key floristic indicators are shown in Table 21, with all indicators suggesting a relatively stable system.

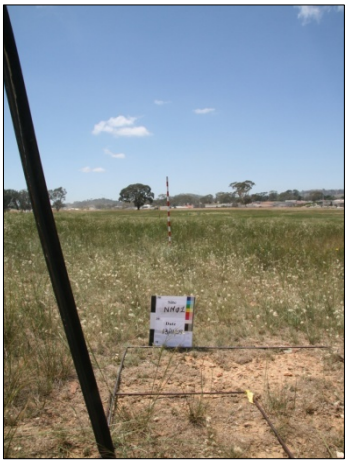
Table 21: Mean condition of North Mitchell from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	0	**11**	16	10	3	3
2012	0	**12**	15	14	2	4

Figure 24: Map and plot locations: North Mitchell.

Plot NM01: *Austrostipa – Rytidosperma* grassland

2009



Floristic value score: **11**
Native species richness: **16**
Exotic species richness: **10**
Indicator spp. level 1: **3**
Indicator spp. level 2: **3**

2012

Floristic value score: **12**
Native species richness: **15**
Exotic species richness: **14**
Indicator spp. level 1: **2**
Indicator spp. level 2: **4**

Changes between 2009 – 2012

Floristic value score: **+1 (+9%)**
Native species richness: **-1**
Exotic species richness: **+4**
Indicator spp. level 1: **-1**
Indicator spp. level 2: **+1**

25% *increase* to 25% decline (*stable*) in condition

St. Mark's Cathedral

St. Mark's Cathedral is renowned as an excellent example of a floristic diverse *Themeda triandra* dominated Lowland Natural Temperate Grassland. The overall site condition is considered stable, with a slight decrease in all vegetation condition metrics, and a decrease in exotic species. This decrease is likely to be due to the increased dominance of *Themeda triandra*, which has increased from 25-50% cover in 2009 to >75% cover in 2012. Kangaroo densities were not recorded on this site as it is a small unfenced parcel located in a suburban environment, and no evidence of kangaroo activity has been observed here.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **-6 (-15%)**
Native species richness: **-7**
Exotic species richness: **-3**
Indicator spp. level 1: **-1**
Indicator spp. level 2: **-4**

25% increase to 25% *decline* (*stable*) in condition

Changes in key floristic indicators are shown in Table 22, with all indicators suggesting a relatively stable system.

Table 22: Mean condition of St. Mark's Cathedral from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	0	**40**	28	11	3	15
2012	0	**34**	21	8	2	11

Figure 25: Map and plot locations: St. Mark's Cathedral.

Plot SM01: *Themeda* grassland

2009

Floristic value score: **40**
Native species richness: **28**
Exotic species richness: **11**
Indicator spp. level 1: **3**
Indicator spp. level 2: **15**

2012

Floristic value score: **34**
Native species richness: **21**
Exotic species richness: **8**
Indicator spp. level 1: **2**
Indicator spp. level 2: **11**

Changes between 2009 – 2012

Floristic value score: **-6 (-15%)**
Native species richness: **-7**
Exotic species richness: **-3**
Indicator spp. level 1: **-1**
Indicator spp. level 2: **-4**

25% increase to 25% *decline* (*stable*) in condition

Wanniassa Hill NR

Wanniassa Hill NR is dominated by Dry Shrubby Box woodland, mainly with *Eucalyptus nortonii* and *E. rossii,* and patches of *E. melliodora, E. polyanthemos* and *E. blakelyi,* with patches of secondary grassland. The secondary grassland at this site is of lower fertility than others in this study, particularly for plot WH02 which is derived from Dry Shrubby Box woodland. Both plots within the reserve are located in secondary grassland, as this is where the grazing pressure is higher. Within the secondary grassland, the mean site condition has improved, with an increase in the mean floristic value, native species richness, and indicator species since 2009. Kangaroo densities have decreased to 0.82 kangaroos per ha., down from 1.27 in 2009.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **+9 (+42%)**
Native species richness: **+4**
Exotic species richness: **+5.5**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **+2**

25 – 50% *increase* in condition

Changes in key floristic indicators are shown in Table 23, with all indicators suggesting an increase in site condition for secondary grasslands. Exotic species richness has also increased, however this is expected due to successive moderate seasons.

Table 23: Mean condition of Wanniassa Hill NR from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	1.27	**21.5**	24	12	3	7.5
2012	0.82	**30.5**	28	17.5	3	9.5

Figure 26: Map and plot locations: Wanniassa Hill NR.

Plot WH01: Secondary grassland		
2009  *Floristic value score*: **20** *Native species richness*: **27** *Exotic species richness*: **12** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **7**	2012  *Floristic value score*: **31** *Native species richness*: **31** *Exotic species richness*: **18** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **10**	**Changes between 2009 – 2012** *Floristic value score*: **+11 (+55%)** *Native species richness*: **+4** *Exotic species richness*: **+6** *Indicator spp. level 1*: **stable** *Indicator spp. level 2*: **+3**  ***50 – 100% increase*** *in condition*
Plot WH02: Secondary grassland		
2009  *Floristic value score*: **23** *Native species richness*: **21** *Exotic species richness*: **12** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **8**	2012  *Floristic value score*: **30** *Native species richness*: **25** *Exotic species richness*: **17** *Indicator spp. level 1*: **3** *Indicator spp. level 2*: **9**	**Changes between 2009 – 2012** *Floristic value score*: **+7 (+30%)** *Native species richness*: **+4** *Exotic species richness*: **+5** *Indicator spp. level 1*: **stable** *Indicator spp. level 2*: **+1**  **25 – 50% *increase*** in condition

Yarramundi Reach

Yarramundi reach is characterised by Natural Temperate Grassland dominated by *Themeda*, with patches of high biomass and recently burnt areas, each of these zones containing one plot. The mean site condition has declined significantly, with both plots recording a significant decrease in 'Floristic value scores' despite an increase in 'Native species richness'. In the unburnt area, this is likely due to increased *Themeda triandra* biomass, which appears to have restricted plant diversity through increased site domination. In the burnt area, indicator species are yet to recover. Kangaroo densities for this site were not recorded as there are no sedentary mobs on site, and grazing pressure is considered negligible.

Trends in overall site condition between 2009 and 2012 are as follows:

Mean floristic value score: **-6 (-44%)**
Native species richness: **+4**
Exotic species richness: **+2**
Indicator spp. level 1: **+1**
Indicator spp. level 2: **-2**

25 – 50% *decline* in condition

Changes in floristic indicators are shown in Table 24.

Table 24: Mean condition of Yarramundi Reach from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	0	**13.5**	6	11	0	4.5
2012	0	**7.5**	10	13	1	2.5

Figure 27: Map and plot locations: Yarramundi Reach.

Plot YA01: *Themeda* grassland - burnt

2009

Floristic value score: **9**
Native species richness: **4**
Exotic species richness: **12**
Indicator spp. level 1: **0**
Indicator spp. level 2: **3**

2012

Floristic value score: **4**
Native species richness: **8**
Exotic species richness: **17**
Indicator spp. level 1: **1**
Indicator spp. level 2: **1**

Changes between 2009 – 2012

Floristic value score: **-5 (-56%)**
Native species richness: **+4**
Exotic species richness: **+5**
Indicator spp. level 1: **+1**
Indicator spp. level 2: **-2**

50 – 100 % *decline* in condition

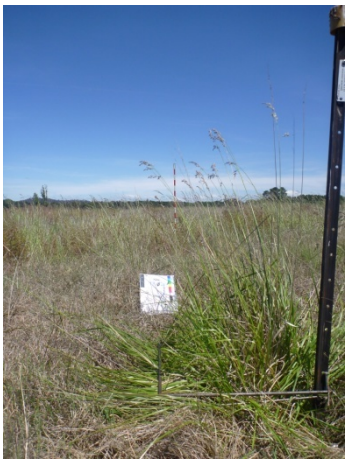
Note: This plot was burnt in April 2012, making direct comparison difficult.

Plot YA02: *Themeda* grassland

2009

Floristic value score: **18**
Native species richness: **8**
Exotic species richness: **10**
Indicator spp. level 1: **0**
Indicator spp. level 2: **6**

2012



Floristic value score: **11**
Native species richness: **12**
Exotic species richness: **9**
Indicator spp. level 1: **1**
Indicator spp. level 2: **4**

Changes between 2009 – 2012

Floristic value score: **-7 (-39%)**
Native species richness: **+4**
Exotic species richness: **-1**
Indicator spp. level 1: **+1**
Indicator spp. level 2: **-2**

25 – 50% *decline* in condition

Conclusions

Interim Findings

Table 25 shows interim kangaroo densities for promoting floristic diversity within grassy ecosystems of northern ACT and Googong Foreshores. Note that these kangaroo density recommendations are based on data collected in moderate seasons: the data used in this study is based on surveys undertaken in late 2009 and 2012 only, which for the July – December period recorded 81% and 76% of the mean rainfall for this period. While these are not considered wet Spring-Summer periods, they are far from drought conditions.

Table 25: Interim kangaroo densities to promote floristic diversity within grassy ecosystems of northern ACT and Googong Foreshores.

Ecosystem	Kangaroos per ha.
Themeda grassland	**1.48**
Austrostipa – Rytidosperma grassland	**1.57**
Box – Gum woodland	**1.18**
Secondary grassland	Non-conclusive

These interim findings support the 'intermediate disturbance hypothesis' (Cornell 1978 in Krebs 1994), which assumes that plant diversity is reduced in undisturbed conditions due to increased biomass of strong competitors, higher at moderate grazing levels, and again reduced under heavy grazing where palatable species may be removed (Lunt *et al*. 2007). In fertile ecosystems such as the grassy ecosystems of the northern ACT, increased floristic diversity in moderately grazed grasslands may be related to reduced biomass of dominant species, and enhanced recruitment and reduced mortality of less competitive (indicator) species.

Trends were not able to be established for secondary grasslands, potentially due to these sites having additional layers of disturbance making comparison within this group complex.

Other factors determining site condition

The study explored relationships between kangaroo densities and vegetation (floristic) condition. Apart from kangaroo densities, vegetation community and structure, there are a number of historical management, edaphic and other landscape factors which may affect vegetation condition at a site or plot level. These include variation in historical grazing patterns, grazing impacts of other herbivores and omnivores, nutrient application, localised climatic conditions, time since fire, time since drought, seasonal variation, micro-topography, soil moisture, natural soil nutrient levels, aspect, slope and topography. Seasonality was partially controlled in a temporal sense (i.e. plots surveyed in November 2009 were generally surveyed in November 2012), although the Spring-Summer of 2009 no doubt varied from that of 2012. Grazing impacts of other herbivores was also partly controlled as none of the plots have been grazed by domestic stock since well prior to the original surveys in 2009. Ideally, plots may be sampled during times of extreme drought with separate analysis undertaken, as kangaroo densities necessary to maintain vegetation condition are likely to be significantly less in such conditions. All other factors are likely to affect vegetation conditions in ways that are difficult to calibrate for in a study of this scale.

Sensitivity of vegetation metrics

'Floristic value scores' developed by Rehwinkel (2007) were the main metric used to relate vegetation condition with kangaroo densities. This is an appropriate metric as it provides a site value based on the presence of key indicator species, where other scores such as 'Native species richness' may provide value to species which thrive in over-disturbed environments. 'Floristic value scores', 'Native species richness' and any metric based on field observation, is sensitive to variation based on seasonality, observer bias and general fine-scale species turnover. This was particularly evident in plots where species were observed just inside/outside the plot in 2012, where in 2009 the opposite may have occurred.

Data analysis

The data analysis pathway was chosen based on the small size of the dataset and discussion with staff within the Conservation Research and Planning Unit. The low correlation between kangaroo densities and vegetation condition metrics is likely due to the variable nature of grassy ecosystem condition relative to a number of current and historical site factors not related to kangaroo densities, the small number of replicates in each floristic grouping, and the sensitivity of vegetation metrics to seasonality and species turnover. Increased replication in coming years may alleviate this to some extent.

Recommendations for future study

Site management

1. Liaise with land managers to ensure grazing exclusion (control) plots are not significantly compromised by management activities such as ecological / fuel reduction burning or crash grazing. If necessary, fence off 20 x 20m exclusion plots with a buffer of at least 10 m to protect control plots. Within the reserve system this applies to JE02 (Jerrabomberra East NR) and JW01, JW02 (Jerrabomberra West NR). Outside the reserve system this applies to NM01 (North Mitchell), SM01 (St Mark's Cathedral), YA01 and YA02 (Yarramundi Reach). Note: YA01 was burnt approximately 12 months prior to 2012 survey and had significantly altered structure and composition.

Data management

2. When undertaking kangaroo density counts, consider quantifying the relationship between kangaroo density and broad vegetation structure (i.e. variation within grazing patterns in woodland, open woodland, grassland/secondary grassland environments). Presently, kangaroo densities are determined across the entire site, which may contain a number of vegetation structures. Interim analysis by kangaroo researchers indicate that kangaroo density is higher in grassland and open woodland compared to woodland areas.

3. Consider methods for quantifying relationships between floristic values and climatic conditions. Note: this was not explored in this analysis due to a lack of site based accurate spatial and temporal data.

4. Consider managing sites to account for kangaroo densities missing from the dataset. In particular, the dataset would benefit from additional *Themeda* grassland sites between 1.5 – 2.74 kangaroos per ha., and *Austrostipa – Rytidosperma* grassland sites between 1.53 – 2.69 kangaroos per ha.

5. Consider removing 'Indicator species belt transect' from future survey. In 2012, it was not always possible to complete the exact same transect as in 2009 on areas of high biomass, where at times one or two plot corners were located based on measurement rather than permanent plot markers. As such, the method is not repeatable and may be highly sensitive to fine-scale species turnover. Analysis of species turnover with respect to 'Indicator level 1 and 2' species as determined by Rehwinkel (2007) is likely to be more meaningful due to the larger plot dimensions, although this does not incorporate species counts beyond coarse Braun-blanquet scaling.

6. Consider removing 'Step-point (line intersect) method' from future surveys, or refine to provide more replicates across the landscape for broader site compositional analysis. While the method is relatively sound in determining ground layer composition, the 50m step-point transect was estimated to have low (subjectively assessed) correlation with the plot at least 25% of the time. This is due to the often small extent of higher quality grassland areas, with 20x20m survey plots often located adjacent to disturbed areas. All key information can be derived and related directly to the plot from LiSM data outputs, which also provides additional structural information. The permanent transect star-pickets should remain to assist surveyors determining plot bearings.

7. Determine whether precise site photos using colour-metric cards are required. If not, this will save on significant field equipment carrying (tripod, 1x1m metal transect, metal height stick).

8. Consider removing secondary grassland plots from the analysis and further sampling, as these sites have additional layers of disturbance making comparison within this group complex. Plots maybe reallocated into climax vegetation communities to increase replication within these groups, with management actions for secondary grassland considered based on metrics depending on the goal of management (e.g. woody recruitment observations).
9. Review floristic groupings based on vegetation structural mapping, and consider whether plots considered Lowland Natural Temperate Grassland may be secondary woodland, or visa-versa.
10. Consider seeking advice from a biometrician prior to undertaking additional sampling to determine whether there are better data analysis pathways or ways to enhance replication

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Appendix 1: Detail on the Line-intersect Structure Method (LiSM)

2D Line-intersect structure measurements (LiSM)

a simple method for measuring structure in natural temperate grassland

Version 1.1, December 10, 2012

Method

1. Run a measuring tape 5m across a floristically and structurally representative transect within the full-floristic quadrat.

Note: (a) this does not have to be a permanent line-transect, as representative areas can be selected in following years in a different (adjacent) location if a line-transect is disturbed. (b) ideally, the line-transect should be within the 20*20m full-floristic quadrat, but may be adjacent. (c) do not cross a vegetation sub-type ecotone, and ensure that the vegetation sub-type is representative of the full-floristic quadrat.

The tape should be suspended above the ground vegetation to minimise disturbance to foliage. Avoid walking or disturbing the linear zone to be measured.

2. Separate the native perennial grass tussocks (and other graminoids) into foliage height categories [>30cm; 20-30cm; 10-20cm; 5-10cm; >0-5cm; 0 (broken down into bare earth/cryptogam/rock)]. Additional measures include other native, exotic broadleaf, perennial exotic grass, annual exotic grass, cryptograms, leaf litter, woody debris and other). As the area is only 5m, there is likely to only be a few height classes, and 2-3 additional variables). Codes include:

   Native / Exotic categories: N = native; **X** = exotic annual; **Y** = exotic perennial

   Life form categories: **G** = tussock grass; **F** = forb; **V** =sedge; **R** = rush; **E** = fern; **S** = shrub; **B** = bare earth; **Ro** = rock; **C** = cryptogams; **L** = leaf litter; **W** = woody debris; **O** = other

   Foliage height categories (HC): 1 = 0cm; 2 = >0 - 5 cm; 3 = 5 - 10cm; 4 = 10 - 20cm; 5 = 20 - 30cm; 6 = 30+ cm

   Note: Foliage height (HC) is defined as the height of the leaf tussock at which the canopy droops or ceases to contain significant biomass. Culms and other less-palatable biomass are not included.

   e.g. **NG3** = Native Tussock grass, 5 - 10cm; **C1** = cryptogam

3. Measure along the tape, recording changes in category (native/exotic, life form and foliage height categories as outlined in Step 2) to the nearest cm.

Category	Length	Category	Length	Category	Length
e.g. NG3	0.21	etc.	.		.
NG4	0.46		.		.
NX2	0.63.		.		.
C1	0.7				
NG(F)4	0.91				

   In instances where two life forms are co-dominant and effecting vegetation structure (e.g. the forb *Haloragis heterophylla* providing structural compliment to a sward of the tussock grass *Austrostipa bigeniculata*) record the assisting life form in brackets [e.g. NG(F)4].

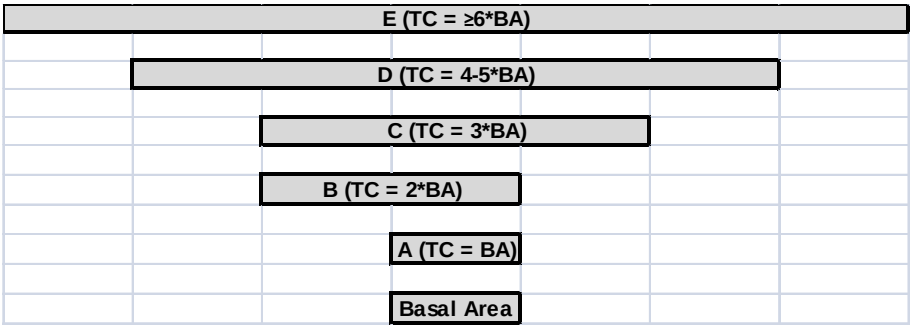
   Heights can be measured using a height stick divided into the relevant categories rather than a metric ruler.

4. Once Step 3 is completed, *estimate* the mean tussock canopy to basal area (TC:BA) ratio, mean tussock shape and tussock canopies / linear metre for each height class.

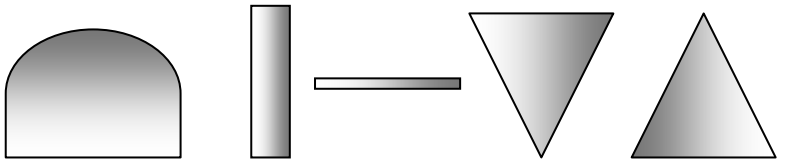
HC	Mean TC:BA ratio	Mean tussock shape	Est. Tussock width
2	e.g. B	c	15 - 20
3			
4			
5			
6			

Each measure (and category within) is outlined below.

Mean TC:BA ratio is intended as an estimate (as metric measurements may be subjective also). The below diagram can guide assessment.



Mean tussock shape is intended to assess the general structure of tussock grasses (*tussock foliage only*, not culms etc) within each height class. Tussock shapes are as follows:



drooping *(d)* *erect (e)* *prostrate (p)* *conical (c)* *inverse conical (i)*

While species can change shape based on grazing or other disturbance, in an undisturbed low to medium grazing regime the following is *generally* expected of common tussock grass species:

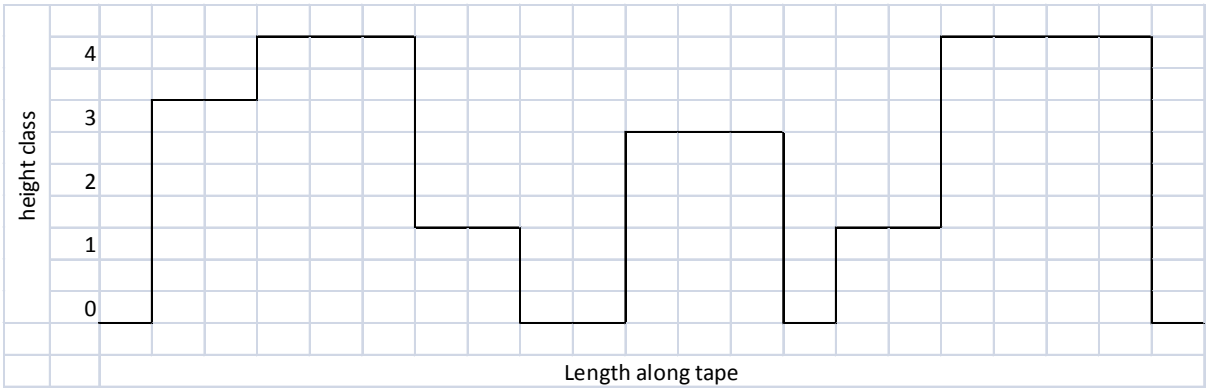
Drooping	Erect	Prostrate	Conical
Austrostipa bigeniculata *Themeda australis* *Rytidosperma* spp. (large) *Poa sieberiana*	*Elymus scaber*	*Bothriochloa macra* (partially grazed) *Microlaeana stipoides* (partially grazed) *Rytidosperma* spp. (heavily grazed)	*Aristida ramosa* *Austrostipa scabra* *Rytidosperma* spp. (small)

Inverse conical tussocks are generally found in robust tussocks grasses subject to high grazing intensity.

Estimated tussock width is grouped into <5. 5 – 1-, 10 – 15, 15 – 20, 20 – 30, 30 – 40, > 40cm classes.

Outputs

- A 2-D representation of grassland structure within the 5m linear transect. For example:



The above can be coded based on tussock shape, growth form etc.

- *Estimates* on the mean tussock canopy : basal area (TC:BA) ratio, mean tussock shape and tussock canopy width for each height class

Replicates

A total of two replicates may be collected per vegetation survey plot (e.g. n = 100 across 50 plots). It is suggested that each replicate selected based on a *floristically* and *structurally* representative 5m transect within a full-floristic plot so the data can be related. Depending on the project, it may not be necessary to identify these with a permanent marker.

As each 5m replicate will represent a vegetation sub-type (refer to point 1), this data can be grouped with other replicates of the same vegetation sub-type from other reserves for analysis.

Estimated Time

Approximately 5 - 15 minutes per transect in the field depending on structural complexity

Data Outputs

- Mean height;
- Proportion in each foliage height category (grouped by height, growth form and native/perennial exotic/annual exotic);
- Mean (estimated) tussock structure and tussock canopy:basal area ratio for each height category;
- Estimated tussock width (size as tussocks are generally circular) in each foliage height class; and
- Estimates (subjective) on the mean tussock size and tussock canopy:base ratio for each foliage height class.

Advantages

- Provides useful information on tussock and inter-tussock structure;
- The 5m linear sample can be aligned to not cross a vegetation sub-type ecotone;
- Allows replicates of common vegetation sub-types to be compared with others across reserves;
- Provides a 2D conceptual model of tussock canopy spacing, as well as the relationship between tussock basal area and tussock canopy area;
- Indicates spatial arrangement of height classes and inter-tussock (inter-canopy) space; and
- Rapid.