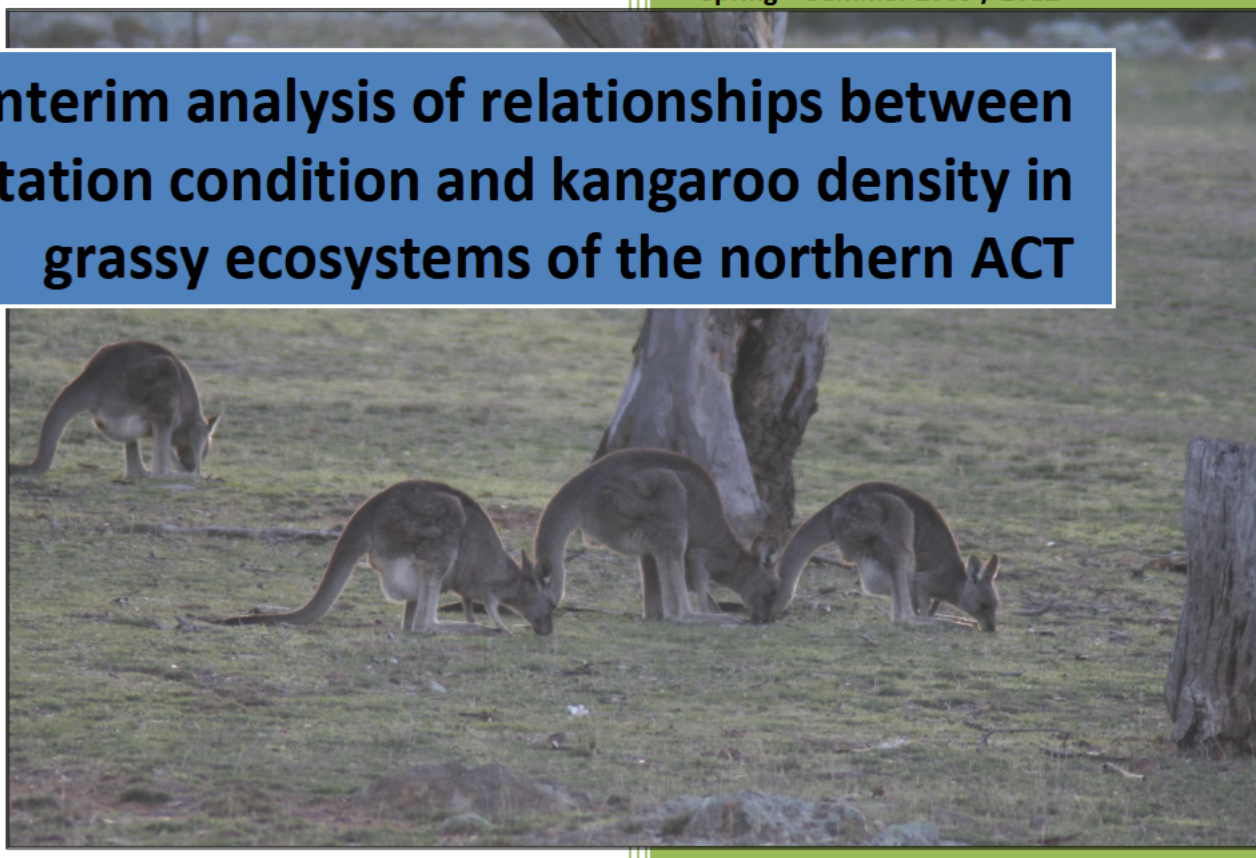
Analysis of data collected in
Spring – Summer 2009 / 2012

Interim analysis of relationships between vegetation condition and kangaroo density in grassy ecosystems of the northern ACT



Rob Armstrong

Environment & Sustainable Development

Directorate (ACT Government)

ACT Government
Environment and Sustainable Development

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Front cover:

Eastern Grey Kangaroos (*Macropus giganteus*) grazing in open woodland at Callum Brae NR, Symonston, ACT. July 2009. Photographer: ACT Conservation Research Group.

This document should be cited as:

Armstrong, R.C. (2013) Interim analysis of relationships between vegetation condition and kangaroo density in grassy ecosystems of the northern ACT: Data collected in Spring – Summer 2009 / 2012. A report prepared for ACT government, Environment & Sustainable Development Directorate, Canberra. February 2013.

Executive Summary

Kangaroos are an integral part of native grassy ecosystems. However, within the ACT kangaroos often occur at high densities, resulting in a range of impacts and related animal and human welfare considerations (TaMS 2010). In the northern ACT, many reserves and other sites contain native grassy ecosystems, including large areas of Lowland Natural Temperate Grassland and Yellow Box – Blakely's Red Gum woodland protected under the ACT *Nature Conservation Act 1980* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. These sites require active management of kangaroo populations in order to maintain a range of values within these landscapes.

This report provides *interim* guidance as to the optimal kangaroo densities for site management to protect *floristic values* of Lowland Natural Temperate Grassland and Yellow Box – Blakely's Red Gum woodland. An optimal kangaroo density of approximately 1.48 – 1.57 kangaroos per hectare is suggested for Lowland Natural Temperate Grassland, and 1.18 kangaroos per hectare is suggested for Yellow Box – Blakely's Red Gum woodland. Recommendations may evolve as more data is gathered across sites, and at this stage are only relevant for moderate rainfall conditions experienced in 2009 and 2012. Drought conditions are likely to require significantly lower kangaroo densities to maintain floristic values.

Observations from herpetologists suggest that lower kangaroo densities may be required to maintain optimal biomass and habitat structure for threatened reptile species and optimal reptile diversity in grassy ecosystems in the ACT. There is little data on needs to other fauna groups within the ACT. In grassy ecosystems, or parts thereof, grazing densities may need to be managed with greater spatial and temporal consideration to create habitat mosaics necessary to conserve multiple fauna species.

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Introduction

In order to support kangaroo management programs within grassy ecosystems in the ACT, a project was set up in 2009 to determine if there is a measurable relationship between kangaroo densities and vegetation attributes such as floristic condition, species richness, dominant grasses, indicator forbs, surface cover, sward height and tussock density.

In 2009, the Conservation Planning and Research Unit commenced a project aiming to:

1. provide advice based on quantitative empirical assessments to guide the management of grazing pressure, particularly from kangaroos, in lowland grassland and woodland areas of conservation value. As recommended by Morellet *et al*. (2007) for monitoring vegetation-herbivore systems, the measurements included abundance of large herbivores, indicators of herbivore performance, indicators of grazing pressure, and indicators of grazing impact such as change in plant species diversity;
2. improve the knowledge base for management of local grazing systems by estimating a kangaroo numerical response empirically from long term annual records of green herbage mass and kangaroo population growth rates; and
3. monitor the condition of high quality native grassland and woodland sites in the ACT.

To achieve these aims, the project collected field data on four main parameters;

1. Eastern grey kangaroo density;
2. Herbage mass;
3. Kangaroo off-take; and
4. Indicators of vegetation floristics and structure.

This report presents interim analysis of the relationships between eastern grey kangaroo density and vegetation floristic condition parameters, and, for each plot and site, changes in condition between 2009 and 2012.

Site Locations

The study area was comprised of a total of 17 sites (16 in 2009, 16 in 2012) in grassy ecosystems across the northern ACT and Googong Foreshores. Maps and basic site character for each site is outlined in *Results > Comparison of variables > Site level vegetation condition trends*. Figure 1 shows the general location of sites.

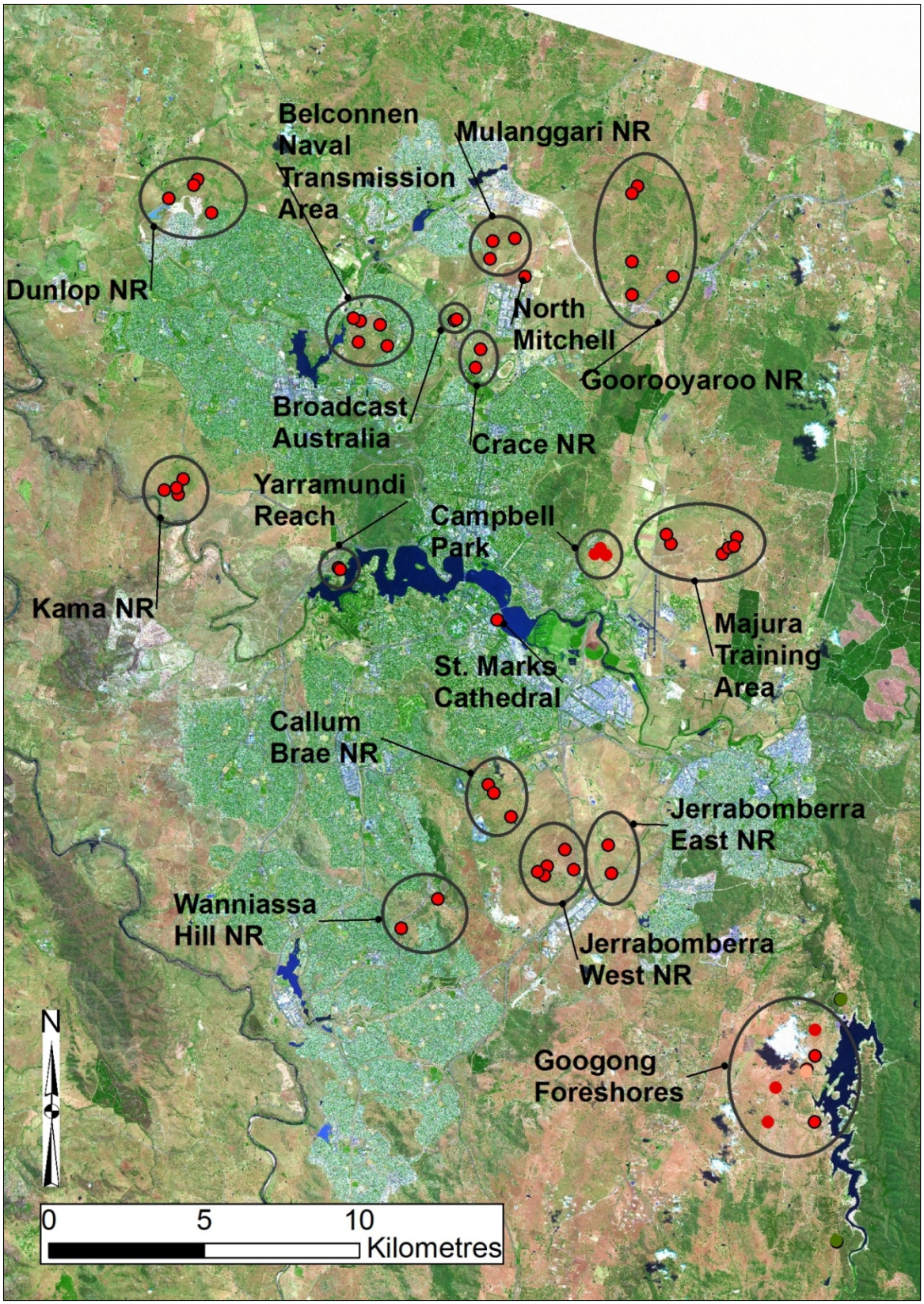


Figure 1: Site locations.

Methods

Vegetation Survey

Site and plot selection

A total of 17 sites were selected in grassy ecosystems within nine reserves and eight other conservation managed sites across the northern ACT and the adjacent Googong foreshores in NSW (managed by ACT Territory & Municipal Services). Sites ranged from basic in floristic and community structure (e.g. *Themeda* grassland at St. Mark Cathedral, Barton) to more complex sites containing more than one vegetation type and management regime (e.g. Jerrabomberra West Nature Reserve containing Yellow Box – Red Gum woodland and Lowland Natural Temperate grassland dominated by *Austrostipa bigeniculata*, with part of the grassland managed as a kangaroo exclusion zone).

In 2009, a total of 52 field survey plots were selected across 16 sites for collection of detailed vegetation condition and structure metrics. Plot counts within each site ranged from one (North Mitchell, St. Mark's Cathedral) to six (Majura Training Area). As access to Majura Training Area was not feasible during the October – December 2012 survey season, this site was removed from the study, and replaced with three plots at Campbell Park. In 2012, a total of 49 plots across 16 sites were surveyed. Plot selection within sites was undertaken based on a subjective assessment of floristic condition by experienced grassy ecosystem ecologists, and permanently marked with a star picket and three small yellow survey pegs. Generally plots were located in vegetation of high condition, relative to the rest of the site.

Floristic survey

20 x 20 metre plot survey

Between October and December 2012, full-floristic information was collected at 49 permanent 20 x 20 m plot locations. This followed on from surveys collecting the same information across 52 plots in 2009. Of the plots surveyed in 2009, 46 of these were revisited in 2012, with three new plots added at Campbell Park and six removed from Majura Training Area. Within each plot, all extant plant species were recorded and categorised into a seven scale cover/abundance rating (Braun-blaunquet 1932. Where necessary, individual plants were sampled for further identification, with the exception of *Rytidosperma* spp. and *Dichelachne* spp.

Full-floristic and cover/abundance data for each plot were entered into the 'Grassy Site Quality Assessment Tool' spreadsheet developed by Rehwinkel (2007) to provide a 'Floristic Value Score' (FVS). Using this metric, each species was assigned a value ranging from 1-5 based on their relative rarity determined by regional grassland assessment data. Species were categorised as follows:

- Common or increaser species, which do not add much to the value of a site;
- 'Indicator species, level 1', which indicates that a site has value; and
- 'Indicator species, level 2', which are the highly significant species; these are the rarest of the grassy ecosystems species and have the highest significance scores.

The sum of values for each species within a plot provides a plot floristic value. This is more valuable than conventional species richness scores as it provides each plot with a relative value score based on the presence and abundance of rare or regionally significant species that are often not present in sites of lesser quality. Additionally, it does not reward common or increaser species which often thrive in highly disturbed sites.

Rare species were assigned a higher score (up to five), although a number of rare species known to be disturbance tolerant, disturbance responding or increaser species were scored at a lower value as they were rare in the regional grassland dataset based on sampling artefacts. There is a limited subset of disturbance responders that retain their high scores, because, while responding to particular disturbance regimes (e.g. soil disturbance), they may not persist under others (e.g. grazing). Examples in this subset include *Rutidosis*

leptorrhynchoides, *Leucochrysum albicans* and *Lepidium hyssopifolium*, all of which are listed as endangered under Commonwealth, ACT or NSW legislation. For further information refer to Rehwinkel (2007).

Indicator species belt transect

Total counts of indicator species (i.e. selected species considered to indicate grassy ecosystem health) were undertaken on belt transects of 1m width on two sides (T1, T3) of the 20 x 20m survey plot (Figure 2). Tallies were recorded for a series of indicator species identified at the start of this project, being *Ajuga australis*, *Arthropodium* spp., *Dichopogon* spp., *Austrostipa densiflora*, *Brachyscome heterodonta*, *Bulbine bulbosa*, *Burchardia umbellata*, *Calocephalus citreus*, *Craspedia variabilis*, *Dichelachne* spp., *Eryngium rostratum* (syn. *E. ovinum*), *Geranium* spp., *Goodenia pinnitifida*, *Leucochrysum albicans*, *Microseris lanceolata*, *Microtis* spp., *Pimelea curviflora*, *Ranunculus* spp., *Scleranthus biflorus*, *Sorghum leiocladum*, *Stackhousia monogyna*, *Stylidium graminifolium sens. lat*., *Swainsona* spp., *Thysanotus tuberosus* and *Wurmbea dioica.* If the count was ≥ 100 for a species, a sum figure of 100+ was given.

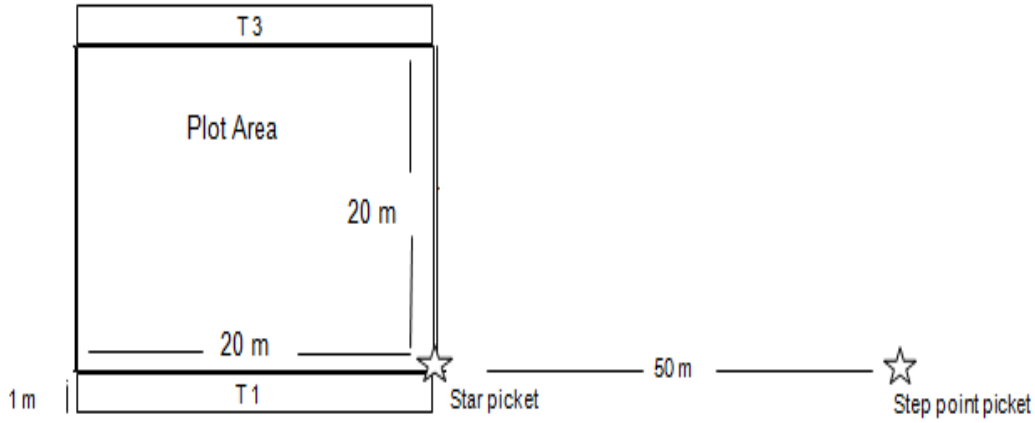


Figure 2: Location of indicator species belt transect relative to the plot and step-point transect.

Grassland Structure

Step-point (line-intersect) transect

An estimate of the relative composition of each life form, bare ground, litter etc. in an area adjacent to the plot was determined through recording data along a 50m step-point transect. This method involves recording the life form at intercept points along the linear transect such as the toe of a boot (when striding along a transect) or each metre mark. For this study, the toe-of-boot method was used to record composition at intercept points between the permanent star-picket marker of the survey plot and the permanent star-picket transect marker 50 m from the plot. To allow for over 100 samples in a transect, this is repeated for a further five steps (or metres) left or right of the transect marker, and returning back to the survey plot (Figure 3). A record of the relative composition of perennial native grass, other native, cryptogam (moss/lichen), bare earth, rocks, litter/dead vegetation, annual exotic grass, perennial exotic grass or exotic broadleaf is recorded at each intercept point, and tallied to surmise a percentage value of the site.

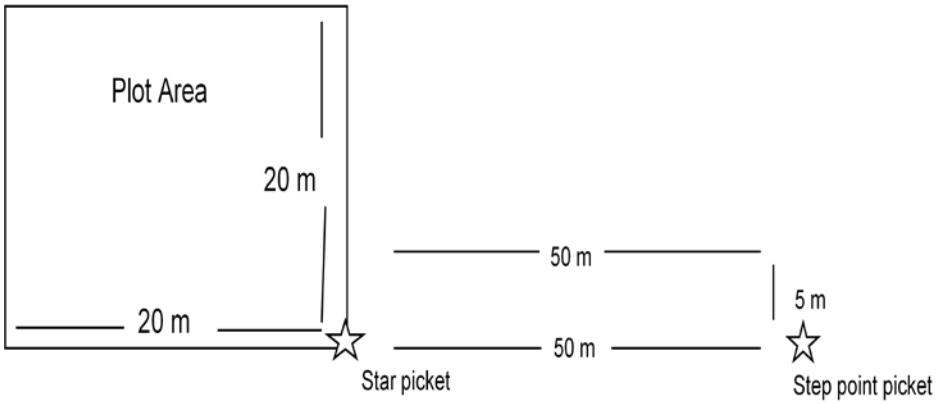


Figure 3: Step-point (line-intersect) transect method.

This method is derived from *Field estimation of foliage cover in the ground layer* in Walker & Hopkins (1990), however the toe-of-boot method allows for a rapid appraisal across a larger area.

Point-centred quarter (landscape function analysis)

In 2009 and the start of the 2012 surveys, data on grassland structure was collected using the 'Point-centred quarter method' developed by Tongway & Hindley (2004). This method is designed to measure the spatial distribution of vegetation at a given site through collecting a series of measurements (distance of tussock from point, tussock base breadth/width/height) in each quarter from a centred point at each metre along a 20m transect (n=80 measurements). Based on these measurements, calculations provided information on the number of tussocks per ha. and volume per ha. While this was considered useful information it has not been used in a temperate grassy ecosystem prior to this study, was time consuming and likely to provide misleading results unless multiple replicates were collected across each grassy ecosystem type and structure within each site.

Analysis of 2009 data indicated no correlation between outputs of the point-centred quarter method and metric outputs of the floristic survey and kangaroo counts, and it was decided to remove this from 2012 and subsequent survey. A new, simpler method (the Line-intersect structure method) was developed as part of this project to quantify vegetation structure and composition within the 20x20m quadrat and allow for comparisons once multiple years of data have been gathered.

Line-intersect structure method (LiSM)

The LiSM was designed to allow for rapid data collection of grassland structure within the 20x20m floristic survey plot to allow for direct comparison between vegetation structure, composition and floristic variables. Data was collected at intervals (or points of change ≥ 2cm in length) along a 5m measuring tape across a floristically and structurally representative transect within the survey plot. Variations of greater than 2cm in width were recorded, allowing for 250 samples within each 5m transect.

Information was recorded at points along the measuring tape when there was a change in height category, and/or growth form (native grass, forb, sedge, rush, fern, shrub, bare earth, rock, cryptogam, leaf litter, woody debris, other). This detail was summarised to provide information on mean grassland height, mean width of height category per growth form, portion of native versus exotic cover and number and size of inter-tussock spaces (and whether they are bare or covered with cryptogams or litter). A basic visualisation of this is shown in Figure 4. Information was also collected on mean tussock shape for each height category for native grasses, information which may be useful for projects where tussock structure is of interest (e.g. Grassland Earless Dragon *Tympanocryptis pinguicolla* habitat studies). The outputs were not used in this analysis, but will allow for comparison in subsequent years. For detail on the LiSM refer to Appendix 1.

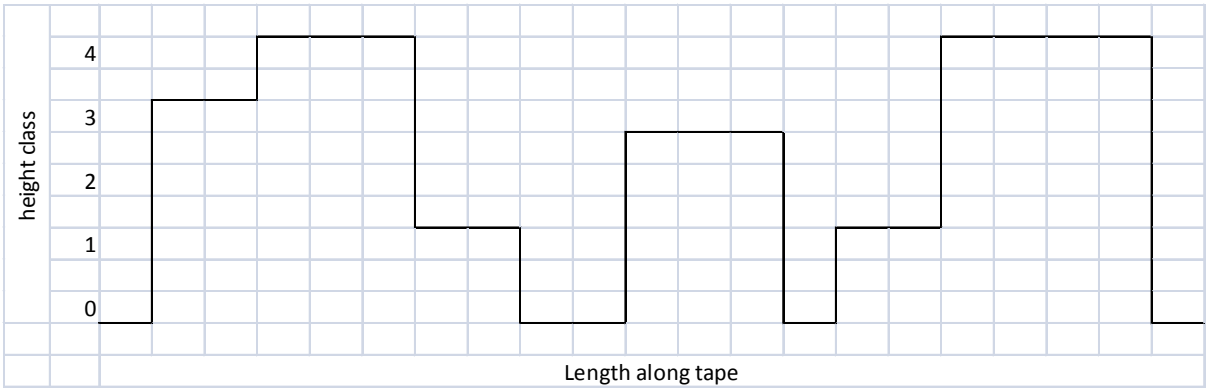


Figure 2: A two-dimensional representation of simple grassland structure using the LiSM.

Kangaroo density counts

Kangaroo density counts were undertaken for each site in 2009 and 2012, using methods outlined in Appendix 1 of the ACT kangaroo management plan (TaMS 2010). Table 1 outlines the methods used at each site.

Table 1: Methods used to estimate kangaroo densities at each site.

Site	2009	2012
Belconnen Naval Transmittion Station	Sweep count	Direct count
Broadcast Australia	Direct count	Direct count
Callum Brae NR	Pellet count	Line transect count
Campbell Park	not counted	Pellet count
Crace NR	Direct count	Direct count
Dunlop NR	Direct count	Direct count
Googong Foreshore	Pellet count	2011 pellet count + adjustment for pop. growth
Goorooyaroo NR	Pellet count	Line transect count
Jerrabomberra East NR	Direct count	Pellet count (excl. kangaroo exclosure)
Jerrabomberra West NR	Pellet count	Line transect count (excl. kangaroo exclosure)
Kama NR	Sweep count	Line transect count
Majura Training Area	Pellet count	not counted
Mulanggari NR	Direct count	Direct count
North Mitchell	not counted	not counted
St. Mark's Cathedral	not counted	not counted
Wanniassa Hills NR	Pellet count	Line transect count
Yarramundi Reach	not counted	not counted

Data analysis

Clustering floristic groups

To compare subsets of the broader dataset at the plant community level, it was important to classify meaningful floristic groups within the dataset. During the field survey, grassland plots and vegetation in the immediate surrounds were classified by observation into vegetation groups of '*Wet Themeda*', '*Dry Themeda*', '*Austrodanthonia*' (syn. *Rytidosperma*) or '*Austrostipa*' grassland as per the ACT lowland native grassland conservation strategy (ACT Government 2005). Woodland and secondary grassland plots were manually classified primarily as Yellow Box – Red Gum woodland and secondary grassland derived from this type. Post field survey, it was decided to test whether field assignment of vegetation types to the above groups were meaningful, particularly for similar 'Wet *Themeda*' and 'Dry *Themeda*', as well as *Austrostipa*' and '*Austrodanthonia*' (syn. *Rytidosperma*) grassland types.

Plot data collected from the 2012 surveys were extracted from each the 'Grassy Site Quality Assessment Tool' spreadsheets and combined into one spreadsheet. Only 2012 data were used to reduce seasonal effects in the dataset. A taxonomic cleanse was applied to remove any anomalies in the dataset which may provide false clustering. For example, as *Rytidosperma* spp. was generally not classified to species level, any records to this level were broadened to genus level to minimise false clustering. Species records were scaled based on Braun-blaunquet (1932).

Survey plot data were analysed to search for groups of consistently co-occurring species using the PATN version 3 multi-variate analysis software (Belbin 2004). PATN was used to generate estimates of association (resemblance, affinity, distance) between plots containing a suite of objects (species). Infrequent species ($n \leq 2$) in the 2012 survey dataset were automatically made extrinsic to the analysis with the exception of species from the *Eucalyptus* genus, which were considered important for exploring relationships between woodland and secondary grassland plots. Open woodland and secondary grassland plots were examined closely, and where there was an adjacent eucalypt that generally characterised the immediate surrounds of the plot this was also linked with the plot at a low abundance. A dendrogram (tree diagram to illustrate arrangement of clusters produced by hierarchical clustering) was produced using the Bray and Curtis association measure and applying the flexible UPGMA formula with the default Beta value of -0.1. Plots within each floristic grouping were examined relative to manually assigned vegetation groups and kangaroo densities. Six additional plots collected in 2009 from Majura Training Area were manually assigned a grouping based on the field classification at the time of survey.

Comparison of variables

Comparisons within the dataset was made in two ways:

1. Treating each plot sample across each year as an independent sample in order to determine relationships between vegetation condition and kangaroo densities; and
2. Examining changes in vegetation condition at a particular site or plot over time.

Outputs of the LiSM were not compared as data needs to be collected over multiple years.

Relationships between vegetation condition and kangaroo densities

With the exception of plots at Majura Training Area (2009) and Campbell Park (2012), floristic and kangaroo density data were collected on two occasions (in 2009 and 2012). Changes in vegetation condition metrics and kangaroo densities allowed individual plot records from each year to be treated as individual replicates. Data from both years was collated into a single spreadsheet to undertake exploratory analysis to compare kangaroo densities at each site with vegetation condition metrics (variables) including:

- Floristic value scores
- Floristic value scores (log10)
- Native species richness
- Exotic species richness
- Indicator level 2
- Indicator level 1+2
- Indicator level $1 + 2^2$

- Indicator level 1 + 2^2 (log10)
- Indicator spp./belt
- Count Indicator spp./belt
- Indicator spp./belt x Count Indicator spp./belt
- Indicator spp./belt x Count Indicator spp./belt (log10)

Using a simple scatter plot in MS Excel, data for each variable (y-axis) was plotted against kangaroo densities (x-axis) to explore linear relationships. Linear and polynomial (order 2) trendiness were fitted to each scatter plot to visually examine any trends in the data, with significance explored through analysing regression statistics produced using the *Data analysis* add-in in MS Excel. The vertex of polynomial trend lines were calculated by solving the polynomial equation, with the x-axis vertex indicating the optimal kangaroo density per hectare to maintain or improve a particular variable. The process was applied to subsets of the data by grouping sites into floristic groups as determined by the process outlined in 'Clustering floristic groups' above.

Site level vegetation condition trends

Data for all vegetation condition metrics and kangaroo densities between 2009 and 2012 were considered based on direct comparison of vegetation condition metrics between years. Each plot and site was compared to determine the level of change in floristic value scores, native species richness, exotic species richness and indicator species (from within the 20x20 m plot) between 2009 and 2012. Statistical relationships between these variables and changes in kangaroo densities were not reported

In future years and with additional data, changes may be graphically displayed and potentially statistically explored, however as changes are only compared over two observational periods this does not occur in this report.

Results

Kangaroo density counts

Kangaroo densities were counted across 16 sites in 2009 and 2012; Campbell Park was not counted in 2009, and Majura Training Area was not counted in 2012. Jerrabomberra East NR, Jerrabomberra West NR and Majura Training Area have separate kangaroo density counts to account for varied grazing pressures within grazing inclusion and exclusion zones. Kangaroo densities per ha. for each site are shown in Table 2.

Table 2: Kangaroo densities per ha. in 2009 and 2012 for selected sites across the northern ACT.

	Kangaroo density per ha.		
Site	**2009**	**2012**	**Net change**
Belconnen Naval Transmission Station	1.12	2.74	+ 1.62
Broadcast Australia	1.44	1.73	+ 0.29
Callum Brae NR	2.05	1.00	- 1.05
Campbell Park	n/a	1.53	n/a
Crace NR	1.40	0.70	- 0.70
Dunlop NR	0.60	0.58	- 0.02
Googong Foreshore	2.15	3.40	+ 1.25
Goorooyaroo NR	2.17	1.03	- 1.14
Jerrabomberra East NR (exclusion zone)	n/a	0.00	n/a
Jerrabomberra East NR (inclusion zone)	3.04	2.69	- 0.35
Jerrabomberra West NR (exclusion zone)	n/a	0.00	n/a
Jerrabomberra West NR (inclusion zone)	1.19	0.10	- 1.09
Kama NR	1.50	0.61	- 0.89
Majura Training Area (exclusion zone)	0.00	n/a	n/a
Majura Training Area (inclusion zone)	1.37	n/a	n/a
Mulanggari NR	1.05	1.24	+ 0.19
North Mitchell	0.00	0.00	0.00
St. Mark's Cathedral, Barton	0.00	0.00	0.00
Wanniassa Hill NR	1.27	0.82	- 0.45
Yarramundi Reach	0.00	0.00	0.00

An active kangaroo population density management program has maintained or reduced kangaroo populations on seven out of nine reserves actively managed by the ACT Territory and Municipal Services. Mulanggari NR has increased by 0.19 kangaroos per ha. to a density of 1.24 kangaroos per ha, with Googong Foreshores in NSW is estimated to have increased by 1.25 kangaroos per ha. to a density of 3.40 kangaroos per ha. Additionally, Belconnen Naval Transmission Station has increased by 1.62 kangaroos per ha. to a density of 2.74 kangaroos per ha and Broadcast Australia has increased by 0.29 kangaroos per ha. to a density of 1.73 kangaroos per ha. These sites are not actively managed by ACT Territory and Municipal Services, although they do provide advice and assistance at these sites as required.

Clustering floristic groups

Based on analysis of plot data collected in 2012, the PATN analysis indicated three groups of 'Box woodland', '*Themeda* grassland' and '*Austrostipa – Rytidosperma* grassland' in the dataset. While this is a higher grouping than that indicated by the manual assignment of vegetation type in the field, it supports field observations that 'Dry *Themeda*' and 'Wet *Themeda*' were closely related, as well as '*Austrostipa*' and '*Austrodanthonia*' (syn. *Rytidosperma*) grassland types. Grouping these similar grassland types increased the number of replicates in each vegetation grouping to increase analysis power for comparison of variables.

When examining the dendrogram (Figure 5), grazing disturbance was a significant factor in clustering of '*Themeda* grassland' plots. Highly grazed '*Themeda* grassland' plots more closely aligned with 'Box woodland' types, however these were retained in the '*Themeda* grassland' grouping to maintain comparisons between grazing levels in this group. Three plots (CP01, DU03a, NM01) manually assigned to the original '*Austrodanthonia*' (syn. *Rytidosperma*) group were strongly associated with the original '*Austrostipa*' group and ultimately combined into an '*Austrostipa – Rytidosperma*' group. The original 'Box woodlands' and 'Secondary grasslands' showed a floristic relationship irrespective of grazing levels, however Secondary grasslands were ultimately kept separate as, probably due to their disturbance history, they provided noise when combined with the 'Box-Gum woodland' data group in later analysis of variables.

Final groupings are shown in Table 3, with hierarchical associations between plots shown in Figure 5.

Table 3: Plots assigned to final floristic groups based on analysis of 2012 floristic data and manual assignment of Majura Training Area plots collected in 2009.

Final Group	Manual (original / field) group	Plots (2009)	Plots (2012)	Plots (total)
***Themeda* grassland**	Dry *Themeda*, Wet *Themeda*	10	10	**20**
***Austrostipa – Rytidosperma* grassland**	*Austrostipa*, *Austrodanthonia* (syn. *Rytidosperma*)	14	14	**28**
Secondary grassland	Secondary grassland	12	12	**24**
Box-Gum woodland	Yellow Box – Red Gum	16	13	**29**

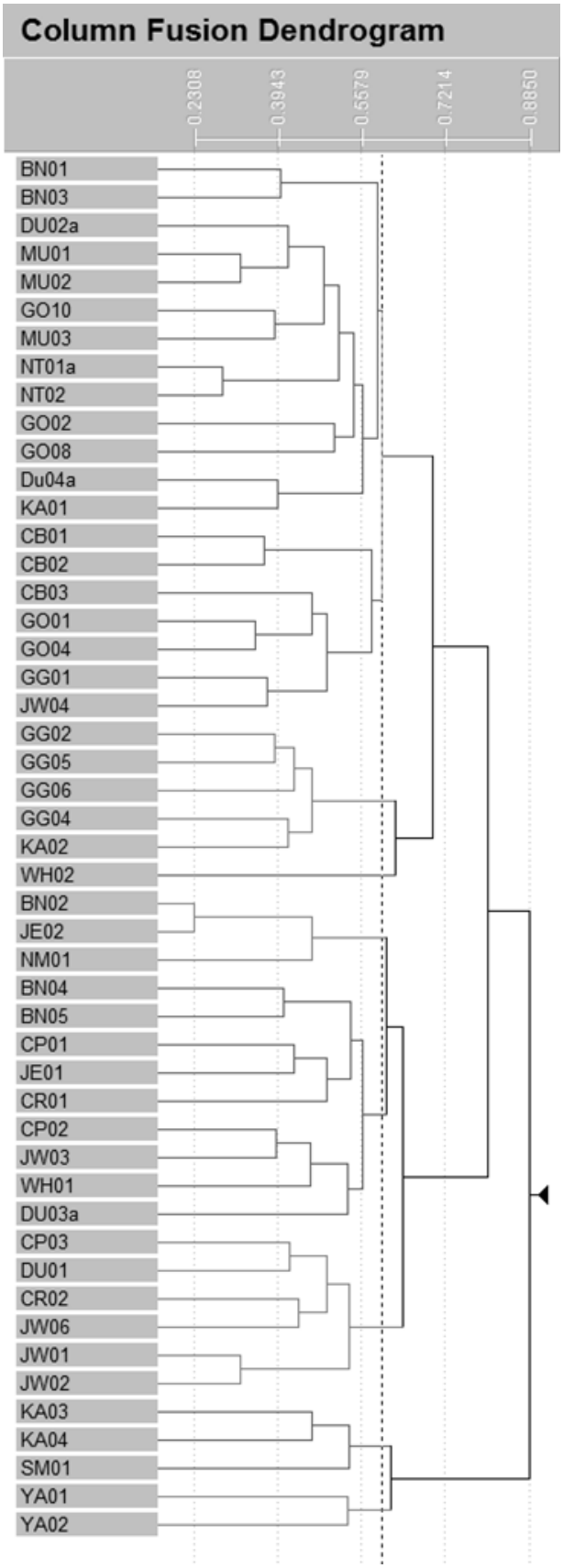


Figure 3: Dendrogram showing hierarchical relationships between plots collected as part of the 2012 surveys.

Comparison of variables

Relationships between vegetation condition and kangaroo densities

Exploratory analysis comparing kangaroo density data with variables outlined in Methods > Data analysis > comparison of variables > *Relationships between vegetation condition and kangaroo densities* was undertaken to determine relationship between variables. Table 4 shows r^2 correlations between key indicator variables for the entire dataset (with logarithmic standards removed as these provided similar results). Generally, correlations of ±≥0.9 are considered strong, ±0.9 to ±0.6 weak, and less than ±0.6 little or none (Townend 2002). Where two variables were strongly correlated (such as A and C in Table 4), they were not considered independent and were likely to give a similar analysis result, hence many of these variables were removed. Not surprisingly, relationships were either very strong as they are closely related (e.g. 'Floristic value score' and 'Indicator Species 1 + 2'), or insignificant as they were, essentially, mutually exclusive. Given the intent of the 'Floristic value scores' in indicating site condition, this is likely to be the most effective variable for indicating overall vegetation condition. 'Native species richness' is weakly correlated with 'Floristic value scores' and is worth examining as a separate variable. However, variables displaying zero or minimal correlation with 'Floristic value scores' were not worth exploring due to limitations identified in the sampling method, and no correlation when exploring these values independently.

Table 4: Linear correlation (r^2) values between vegetation condition metrics.

	A	B	C	D	E	F
A	*n/a*	0.585	0.945	0.897	0.001	0.017
B	0.585	*n/a*	0.659	0.542	0.005	0.001
C	0.945	0.659	*n/a*	0.914	0.000	0.008
D	0.897	0.542	0.914	*n/a*	0.001	0.013
E	0.001	0.005	0.000	0.001	*n/a*	0.868
F	0.017	0.001	0.008	0.013	0.868	*n/a*

A. Floristic value scores; **B.** Native species richness; **C.** Indicator level 1+2; **D**. Indicator level 1 + 2^2; **E.** Count Indicator spp./belt; **F**. Indicator spp./belt x Count Indicator spp./belt.

For the entire dataset across 2009 and 2012, and each of the floristic groups identified in Table 3, kangaroo densities were analysed against the following vegetation metrics (variables):

Floristic value scores (FVS): The FVS of a plot with respect to the presence of rare or high condition indicator species within a 20 x 20m plot, as determined by Rehwinkel (2007). Refer to Methods > Vegetation survey > Floristic survey > *20 x 20m plot survey*.

Native species richness: The *count* of native species within each 20 x 20m plot.

For each variable within each floristic group, regression statistics were examined, and polynomial (order 2) trendlines were fitted with the vertex calculated to indicate the optimal kangaroo density per hectare. Note that for each variable, r^2 (correlation, coefficient of determination) were *not significant* for both linear and polynomial trendlines, however the vertex of the polynomial line still provides as useful indication of the optimal kangaroo density per hectare for each floristic group. The optimal kangaroo density to maintain a high 'Floristic value score' is recommended, however 'Native species richness' is also presented for comparison.

Themeda grasslands

A total of 20 plots (10 from 2009, 10 from 2012) within the '*Themeda* grasslands' floristic group were analysed, comparing a range of vegetation metrics with kangaroo densities/ha. At sites containing this grassland type, grazing densities ranged from zero kangaroos per ha. (nil grazing observed; n=6) at St. Mark's Cathedral and Yarramundi Reach in 2009 and 2012 to 2.74 kangaroos per ha. (n=2) at Belconnen Naval Transmission Station in 2009.

Relationships between kangaroo density per ha. and 'Floristic value score' and 'Native species richness' were explored, with the vertex of the polynomial (order 2) trendline calculated for each to indicate the optimal kangaroo density per ha to best manage for maintenance of each value (Table 5). The mean recommended kangaroo density per ha. to maintain floristic values was 1.48.

Table 5: Interim optimal kangaroo density per ha. for *Themeda* grasslands.

Vegetation Metric	Interim optimal kangaroo density / ha.
Floristic Value Score	**1.48**
Native Species Richness	1.88
Interim recommendation	**1.48 kangaroos / ha.**

Graphical displays showing the relationship between each vegetation metric and kangaroo density per ha. are shown in Figures 6 and 7. The polynomial r^2 (correlation, coefficient of determination) is insignificant when comparing each vegetation metric with kangaroo densities, most likely as a result of a number of factors including site management history, moisture/fertility gradients, and a lack of sites with between 1.5 and 2.74 as well as greater than three kangaroos per ha.

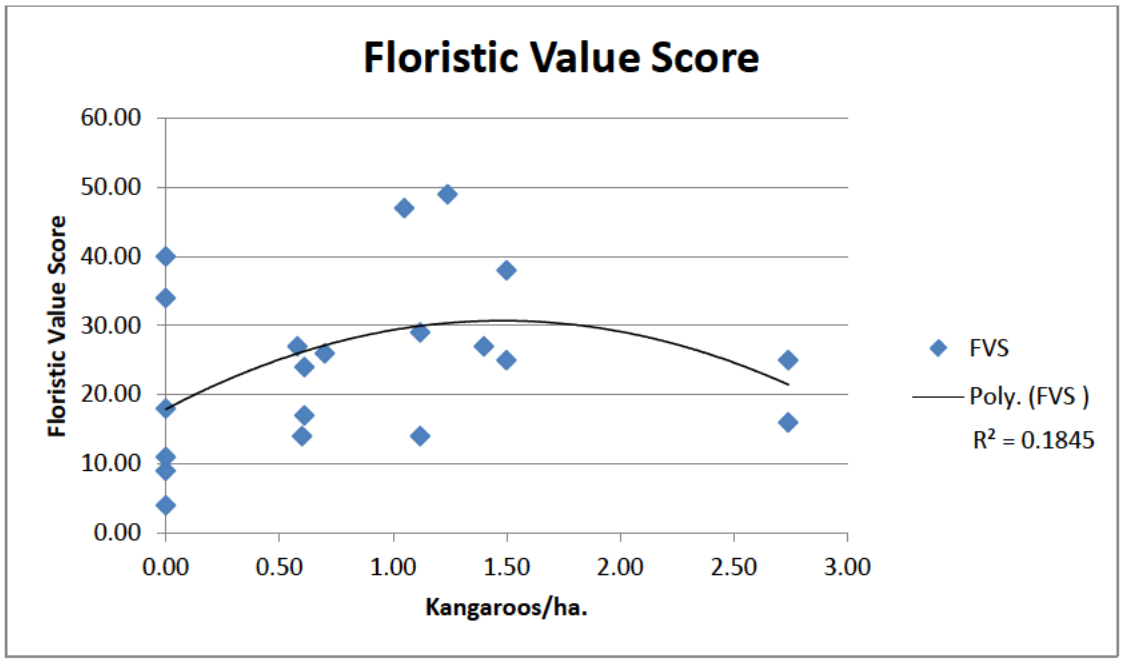


Figure 4: 'Floristic Value Score' relative to relative to kangaroo densities per ha. in *Themeda* grasslands.

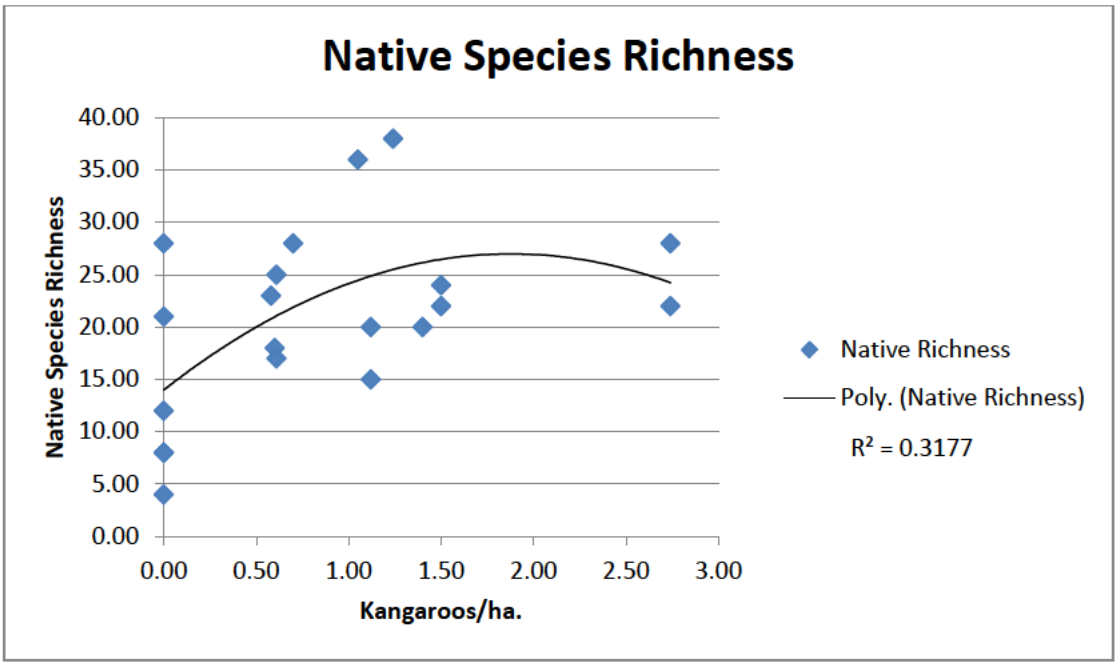


Figure 5: 'Native species richness' relative to relative to kangaroo densities per ha. in *Themeda* grasslands.

Austrostipa – Rytidosperma grasslands

A total of 28 plots (14 from 2009, 14 from 2012) within the '*Austrostipa* - *Rytidosperma* grasslands' floristic group were analysed, comparing a range of vegetation metrics with kangaroo densities/ha. At sites containing this grassland type, grazing densities ranged from zero (nil grazing observed, grazing exclusion; n=7) kangaroos per ha. at North Mitchell, Majura Training Area (2009 only), Jerrabomberra East (2012 only) and Jerrabomberra West (2012 only) to 3.04 (n=2) kangaroos per ha. at Jerrabomberra East in 2009.

Relationships between kangaroo density per ha. and 'Floristic value score' and 'Native species richness' were explored, with the vertex of the polynomial (order 2) trendline calculated for each to indicate the optimal kangaroo density per ha to best manage for maintenance of each value (Table 6). The mean recommended kangaroo density per ha. to maintain floristic values was 1.57.

Table 6: Interim optimal kangaroo density per ha. for *Austrostipa - Rytidosperma* grasslands.

Vegetation Metric	Interim optimal kangaroo density / ha.
Floristic Value Score	**1.57**
Native Species Richness	1.59
Interim recommendation	**1.57 kangaroos / ha.**

Graphical displays showing the relationship between each vegetation metric and kangaroo density per ha. are shown in Figures 8 and 9. The polynomial r^2 (correlation, coefficient of determination) is insignificant when comparing each vegetation metric with kangaroo densities, most likely as a result of a number of factors including site management history, moisture/fertility gradients, and a lack of sites with between 1.53 and 2.69 as well as greater than three kangaroos per ha.

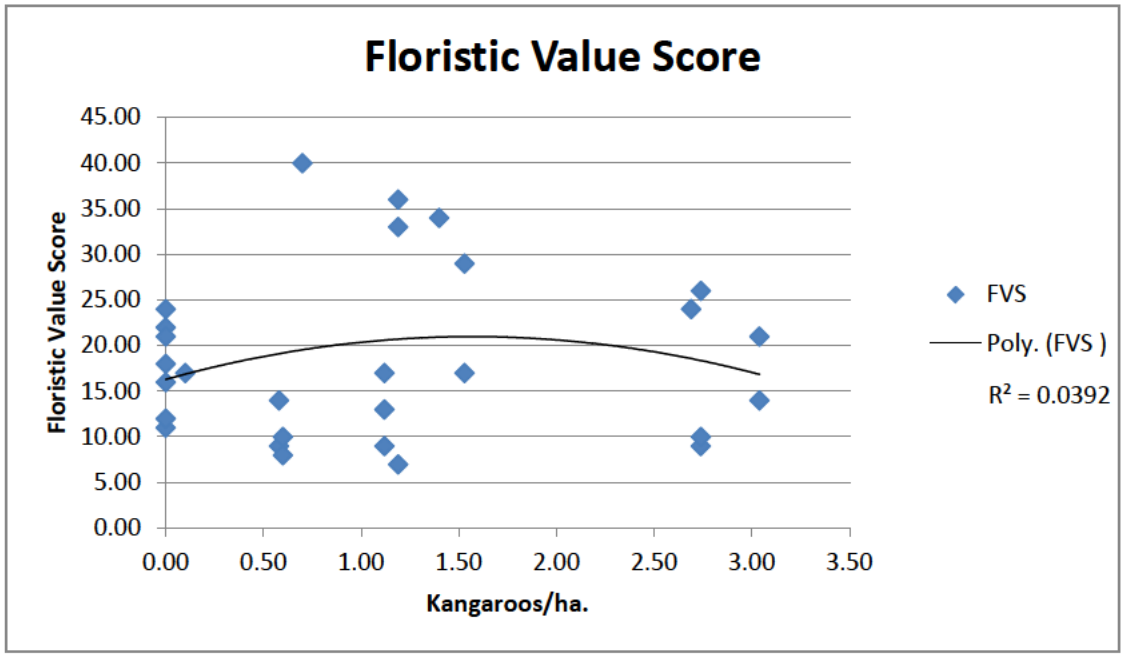


Figure 6: 'Floristic value score' relative to relative to kangaroo densities per ha. in *Austrostipa - Rytidosperma* grasslands.

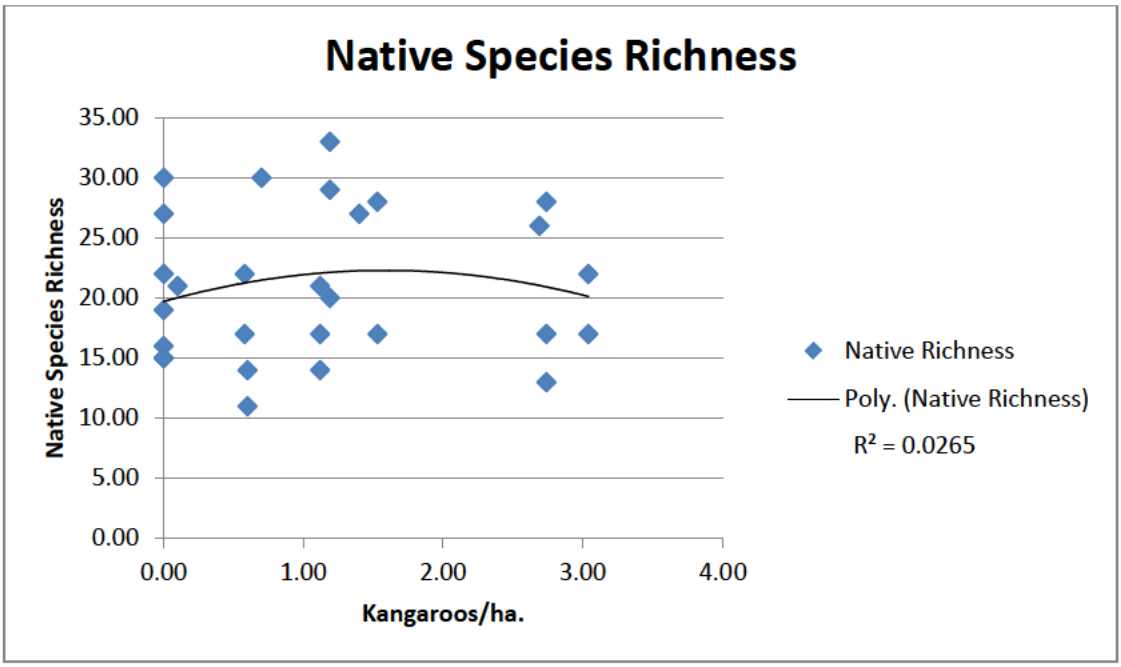


Figure 7: 'Native species richness' relative to relative to kangaroo densities per ha. in *Austrostipa - Rytidosperma* grasslands.

Box-Gum woodlands

A total of 29 plots (16 from 2009, 13 from 2012) within the 'Box-gum woodlands' floristic group were analysed, comparing a range of vegetation metrics with kangaroo densities/ha. At sites containing this woodland type, grazing densities ranged from 0.1 (n=2) kangaroos per ha. at Jerrabomberra West in 2012 to 2.17 (n=4) kangaroos per ha. at Goorooyaroo NR in 2009.

Relationships between kangaroo density per ha. and 'Floristic value score' and 'Native species richness' were explored, with the vertex of the polynomial (order 2) trendline calculated for each to indicate the optimal kangaroo density per ha to best manage for maintenance of each value (Table 7). The mean recommended kangaroo density per ha. to maintain floristic values was 1.18.

Table 7: Interim optimal kangaroo density per ha. for Box-Gum woodlands.

Vegetation Metric	Interim optimal kangaroo density / ha.
Floristic Value Score	1.18
Native Species Richness	0.58 (outlier amongst other variables)
Mean	**1.18 kangaroos / ha.**

Graphical displays showing the relationship between each vegetation metric and kangaroo density per ha. are shown in Figures 10 and 11. The polynomial r^2 (correlation, coefficient of determination) is insignificant when comparing each vegetation metric with kangaroo densities, most likely as a result of a number of factors including site management history and moisture/fertility gradients.

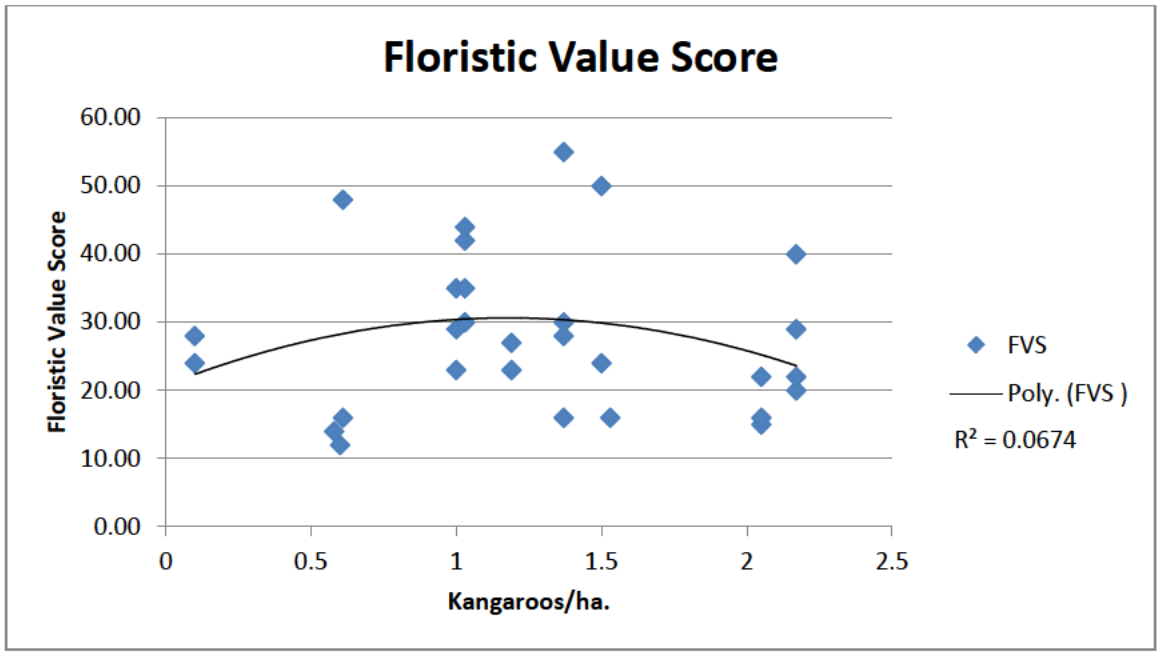


Figure 8: 'Floristic value score' relative to relative to kangaroo densities per ha. in Box-gum woodlands.

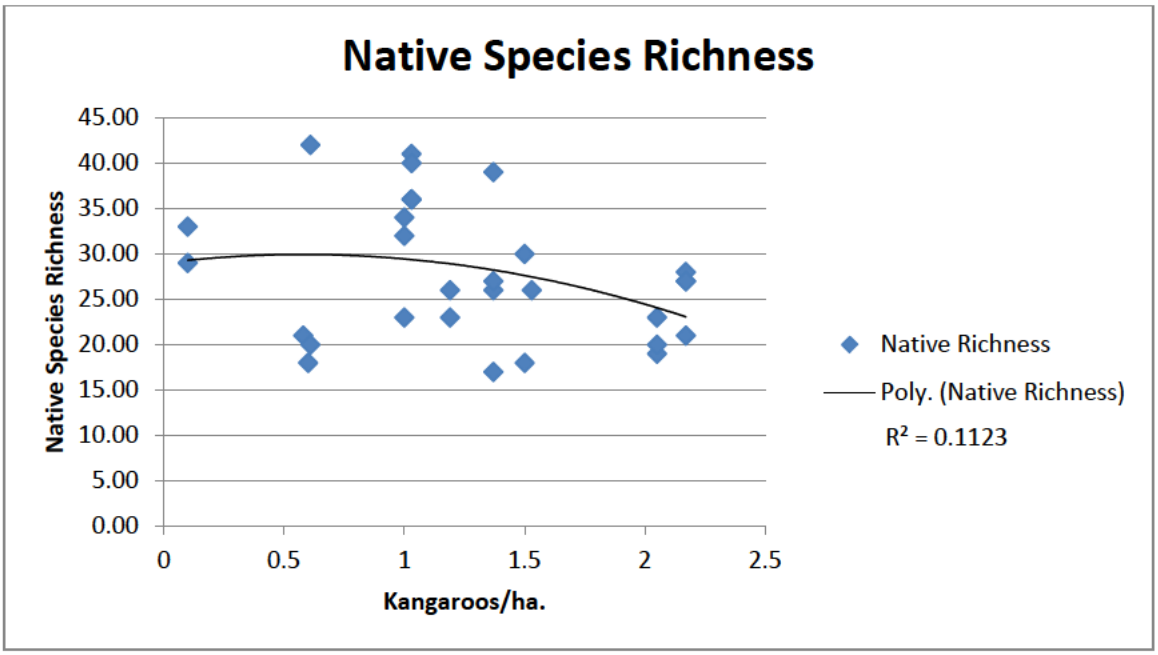


Figure 9: 'Native species richness' relative to relative to kangaroo densities per ha. in Box-gum woodlands.

Secondary grasslands

Exploratory analysis of a number of vegetation metrics in comparison to kangaroo densities per ha. revealed insignificant (almost nil) correlation, and this data is not presented here. Correlations may improve with a larger dataset, but at this time it is recommended to manage secondary grasslands in line with their floristically nearest neighbours. That is, secondary grassland sites dominated by *Austrostipa* and *Rytidosperma* spp. should be managed as per natural *Austrostipa* – *Rytidosperma* spp. grassland until such time that data indicates otherwise. If the management goal is to restore such areas to their primary woodland structure, such sites should be regularly monitored to ensure that management is sympathetic to recruitment of key woody species.

Site level vegetation condition trends

As there are only two years of data for comparison, each site is compared in tabular format with a visual aid to indicate change an increase or decline in condition. Note that apart from kangaroo grazing pressures, changes may be due to a number of causative factors including seasonality, observer bias and natural species turnover.

Floristic value scores are used as the primary indicator of vegetation condition. Changes in grassland condition metrics are indicated by the 'kangaroo jack' condition rating system:

≥100% *increase* in condition

25 – 50% *decline* in condition

50 – 100% *increase* in condition

50 – 100 % *decline* in condition

25 – 50% *increase* in condition

≥100% *decline* in condition

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

Figure 10: The 'kangaroo jack' condition rating system.

Belconnen Naval Transmission Station

Belconnen Naval Transmission Station is dominated by Lowland Natural Temperate Grassland, containing a mosaic of *Austrostipa – Rytidosperma* grassland and *Themeda* grassland. The overall site condition is considered stable, with an increase in the mean floristic value, native species richness, and indicator species since 2009. Kangaroo densities have increased to 2.74 kangaroos per ha., up from 1.12 in 2009.

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

Mean floristic value score: **+0.8 (+5%)**
Native species richness: **+4.2**
Exotic species richness: **+3.6**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **+0.8**

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

Changes in key floristic indicators are shown in Table 8, with all indicators suggesting a stable system. Exotic species richness has increased, however this may be insignificant considering recent favourable conditions for exotic species. The increase in kangaroo densities at this site may be, to some extent, alleviated by conditions favourable to enhancing grassland condition metrics in recent years.

Table 8: Mean condition of Belconnen Naval Transmission Station from 2009 and 2012.

Year	Kangaroo (ha)	FVS	Native Richness	Exotic Richness (genus)	Indicator Level 1	Indicator Level 2
2009	1.12	**16.4**	17.4	11	1.8	5.4
2012	2.74	**17.2**	21.6	14.6	1.8	6.2

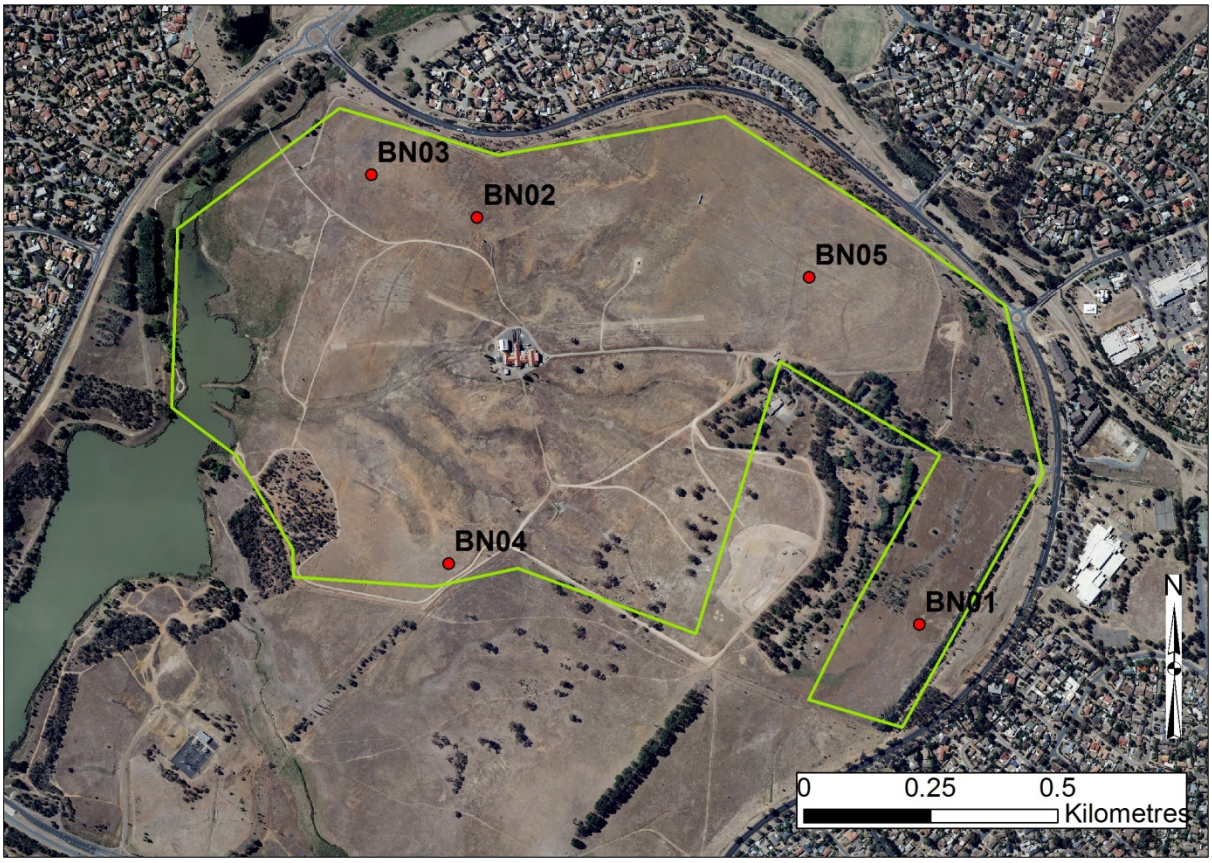
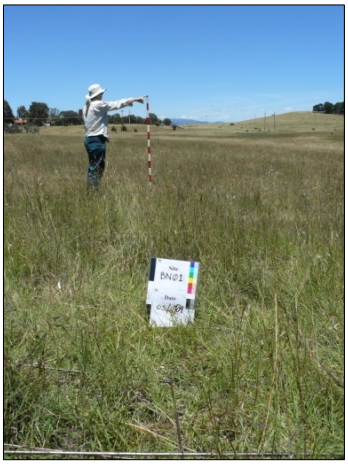


Figure 11: Map and plot locations: Belconnen Naval Transmission Station.

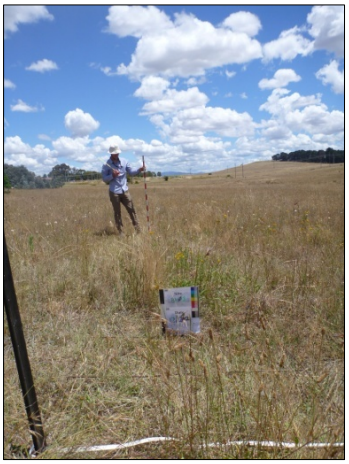
Plot BN01: *Themeda* grassland

2009



Floristic value score: **29**
Native species richness: **20**
Exotic species richness: **13**
Indicator spp. level 1: **2**
Indicator spp. level 2: **9**

2012



Floristic value score: **16**
Native species richness: **22**
Exotic species richness: **17**
Indicator spp. level 1: **2**
Indicator spp. level 2: **6**

Changes between 2009 – 2012

Floristic value score: **-13 (-45%)**
Native species richness: **+2**
Exotic species richness: **+4**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **-3**

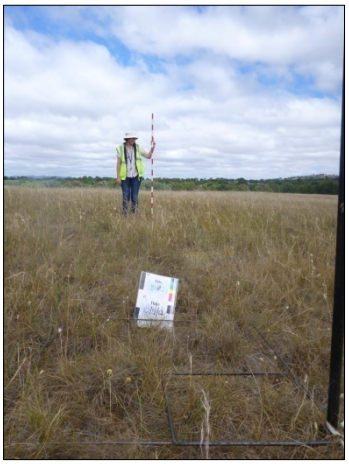
25 – 50% *decline* in condition

Plot BN02: *Austrostipa* – *Rytidosperma* grassland

2009

Floristic value score: **13**
Native species richness: **17**
Exotic species richness: **11**
Indicator spp. level 1: **2**
Indicator spp. level 2: **5**

2012



Floristic value score: **9**
Native species richness: **13**
Exotic species richness: **14**
Indicator spp. level 1: **2**
Indicator spp. level 2: **3**

Changes between 2009 – 2012

Floristic value score: **-4 (-31%)**
Native species richness: **-4**
Exotic species richness: **+3**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **-2**

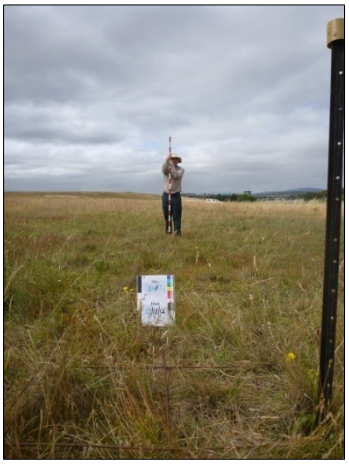
25 – 50% *decline* in condition

Plot BN03: *Themeda* grassland

2009

Floristic value score: **14**
Native species richness: **15**
Exotic species richness: **17**
Indicator spp. level 1: **2**
Indicator spp. level 2: **4**

2012



Floristic value score: **25**
Native species richness: **28**
Exotic species richness: **18**
Indicator spp. level 1: **2**
Indicator spp. level 2: **9**

Changes between 2009 – 2012

Floristic value score: **+11 (+78%)**
Native species richness: **+13**
Exotic species richness: **+1**
Indicator spp. level 1: **stable**
Indicator spp. level 2: **+5**

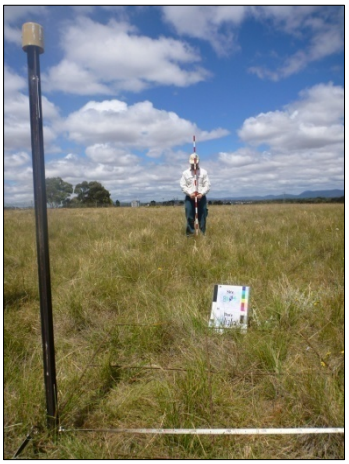
50 – 100% *increase* in condition

Plot BN04: *Austrostipa – Rytidosperma* grassland

2009

Floristic value score: **9**
Native species richness: **14**
Exotic species richness: **5**
Indicator spp. level 1: **1**
Indicator spp. level 2: **4**

2012



Floristic value score: **26**
Native species richness: **28**
Exotic species richness: **10**
Indicator spp. level 1: **2**
Indicator spp. level 2: **10**

Changes between 2009 – 2012

Floristic value score: **+17 (+189%)**
Native species richness: **+13**
Exotic species richness: **+5**
Indicator spp. level 1: **+1**
Indicator spp. level 2: **+6**

≥100% *increase* in condition