VEGWATCH MONITORING PROGRAM: PRACTICE AND FINDINGS 2011 TO 2018

SARAH SHARP

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REPORT TO THE MOLONGLO CONSERVATION GROUP

Capital Region Landkeepers
Molonglo Conservation Group
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For more information on the Vegwatch program or to obtain copies of this report go to: Molonglo Conservation Group, https://molonglo.org.au or contact communications@molonglo.org.au

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About the author

Sarah Sharp is one of the developers of the Vegwatch program, and has taken the lead role in training, field and other assistance to volunteers, collation of data, testing of the database during development and data entry since its inception. She is a plant ecologist, and she has undertaken survey and assessment of condition of grassland ecosystems through work with ACT Government and as a consultant and volunteer for the past 30 years. Her particular area of interest and expertise is in ecological management of grassy ecosystems.

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TERMINOLOGY AND DEFINITIONS USED IN THE REPORT

Annual species	A species that completes its full life cycle within one vegetative period (within one year or less).
Baseline condition	The condition at a particular time, against which change in an indicator is compared.
Benchmark condition	The 'best' condition state of each vegetation association in an area (e.g. ACT) is identified from sites that are relatively unmodified, based on ten parameters (metrics) (Gibbons et al. 2008). Other sites condition can be compared to the benchmark (reference) values.
Box-Gum Woodland (BGW)	Native woodland that is dominated by box eucalypts and gum eucalypts; it may refer to any grassy woodland but is generally used within the ACT and nearby region to refer to the grassy woodlands dominated by Yellow Box (*Eucalyptus melliodora*) and Blakely's Red Gum (*E. blakelyi*). It includes those sites that meet the criteria as the critically endangered White Box – Yellow Box – Blakely's Red Gum grassy woodlands and derived native grasslands ecological community (EPBC Act 1999).
Conservation effectiveness monitoring program	Established by the ACT Government for monitoring changes in threatened species and community condition.
Condition	In an ecological context, condition refers to the health or status of ecological attributes that are measured against an identifiable target condition of a vegetation association and may refer to diversity of native or introduced species, habitat, function etc. Condition may change as a result of disturbance or management.
Condition indicator	An attribute that is measured to provide an indication of condition. Different indicators measure different types of condition (e.g., native species richness, introduced species richness, habitat diversity). Indicator scores may combine and weight different metrics to get one value, for example, benchmark condition.
Control plot	A plot measured at the same time and place as one measured in which specific management actions are applied, in order to compare differences as a result of management.
Derived grassland	A native grassland from which native trees and/or shrubs have been cleared.
Diversity	A measure of the variety of elements within a defined space, such as the variety of plants in a 0.04 ha area.
Ecosystem drivers	The fundamental variables that impact/drive any ecosystem, including natural variables such as climate, geology, soils, hydrology, topography and seasonal condition variation, and imposed variables such as past land uses and management.
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth).
Floristic Value Score	A score developed that establishes a score for a standard sized plot based on a native species list (NVS) and a separate calculation for introduced species (IFS).
Groundcover	The percentage cover of the attributes that occur in the groundlayer. Includes live vegetation, litter, rocks and bare earth. Groundcover may be over 100% when taking into account the attributes that are measured may overlap.
Introduced species	A species whose presence is directly related to human actions. Such species include species from outside Australia or indigenous species not local to a region. Also known as alien plants, non-indigenous or exotic plants. This group includes any species that is deliberately introduced or one that establishes and reproduces unaided by deliberate cultivation. Introduced species of concern are those that are **invasive**, and may **transform** the ecosystem (Hui C. & Richardson D.M. (2017) Invasion Dynamics. Oxford University Press).
Introduced Floristic Value Score	A similar calculation method as used for native species, in which transformer species are allocated the highest score. In this report, the scores for introduced species has been modified from Rehwinkel (2015). The higher the score the higher the composition and importance of the introduced species component.
Management - incremental	Management has a slower or reduced influence on biomass, such as spot spraying or hand weeding than interventionist management..
Management - interventionist	Management that results in a significant and immediate alteration to biomass (burning, slashing, crash grazing) and/or an immediate change in species composition (revegetation).
Metrics	The data sources measured to identify indicator condition; more than one metric may be used to contribute to an indicator.
Mid-storey cover	Cover of species between 2 and 5 m tall with single or multiple stems – includes immature trees and shrubs.
Molonglo Conservation Group (MCG)	Formerly the Molonglo Catchment Group. The coordinating organisation for the Vegwatch program. https://molonglo.org.au/.
Native species	A species that is indigenous to Australia and to the region
Natural Temperate Grassland (NTG)	A patch of grassland in which it is deemed tree cover is naturally less than 10% (i.e. that native trees do not establish unless by human action or change). It includes grasslands that meet the criteria as the critically endangered ecological community, Natural Temperate Grassland of the South-Eastern Highlands (EPBC Act).
Overstorey cover	Cover of species over 5 m tall, includes trees and tall shrubs.

Perennial plants	Plants that live for more than one season and reproduce for more than two seasons. Includes trees and shrubs and herbaceous perennial species including forbs and grasses. Biennial plants reproduce for up to two seasons.
Plot	A defined area in which measurements are taken.
Reference condition	The condition of the indicator that is considered the likely condition prior to European settlement.
Stressors	Factors or variables that may impact the condition of ecosystems, and include invasive weeds, pest animals, adjacent land uses, fragmentation and biomass manipulation.
Threatening processes	Processes that reduce the values and resilience of ecosystems; they include decreased native diversity, simplified habitat and soil disturbance.
Transect	A line along which measurements are taken.

LIST OF ABBREVIATIONS

Plot code	Sites
ASG_V_1	Aranda Bushland Nature Reserve
BLM_V_S BLM_V_C BLM_V_A	Black Mountain Nature Reserve
BMY_V_1 BMY_V_3	Bullan Mura Yarralumla
CFC_V_1	Captains Flat Cemetery
CFH_V_1	Captains Flat property
CRA_V_2 CRD_V_1	Cooleman Ridge Nature Reserve
IWW_V_1 IWW_V_2	Icon Water Williamsdale
ISR_V_1	Isaacs Ridge Nature Reserve
KA1_M_1 KB1_M_1	Kama Nature Reserve
MD1_M_1 MK2_M_2	Molonglo River Reserve
MLP_V_1 MLP_V_2	'Millpost' Bungendore
MAI_V_1 MAI_V_2	Mt Ainslie Nature Reserve
MMA_V_1	Mt Majura Nature Reserve
MPA_V_1 MPA_V_2R MPA_V_2C MPA_V_3 MPA_C_1	Mt Painter Nature Reserve
MTA_V_1	Mt Taylor Nature Reserve
RSR_V_1	Royalla Swainsona Reserve
STM_V_1 STM_C_1	St Marks Grassland
TSF_V_1	Tennant St Grassland Fyshwick
TPI_V_1 TPI_C_1	The Pinnacle Nature Reserve
TUH_V_1	Tuggeranong Hills Nature Reserve
UMG_V_1	Umbagong Grassland, Latham
WAN_V 1 WAN_V_2	Wandiyali Reserve, Googong
YAG_V_1 YAG_V_2	Yarramundi Grassland

Code	Source of data
V	Vegwatch program data
C	Conservation Research data
M	Molonglo River Reserve data

Code	Attributes calculated from metrics
AIC	Introduced annual groundcover
BEC	Bare earth cover
BENCH	Benchmark (reference) score
INDI	Number of important (indicator) species (BGW Critically Endangered Ecological Community (CEEC) criteria, Australian Government 2006)
IFS	Introduced floristic score (Appendix)
ISR	Introduced species richness
LITC	Litter cover
NFC	Native forb and sub-shrub cover
NGC	Native grass cover
NFS	Native floristic score (Rehwinkel 2015)
NOSC	Native overstorey cover
NSR	Native species richness
NUC	Total native understorey cover
PIC	Introduced perennial groundcover
PNUC	Proportion of native perennial groundcover
THEM	*Themeda triandra* (Kangaroo Grass) abundance

Code	Vegetation Structure	Code	Vegetation ass'n
GL	Grassland	**NTG**	Natural Temperate Grassland
GW	Grassy woodland	**YBRG**	Yellow Box – Red Gum Grassy Woodland
DerGL	Derived grassland	**SGW**	Snow Gum Woodland
FOR	Forest	**MBSF**	Mealy Bundy – Broad-leaved Peppermint shrubby forest
SW	Shrubby woodland	**BGSOF**	Brittle Gum shrubby open forest
		RSF	Red Stringybark dry sclerophyll forest
		SGCB W	Snow Gum – Candlebark tall woodland
		ENP	Environmental native plantings
		NG	Native grassland

EXECUTIVE SUMMARY

The report reviews the effectiveness of a large-scale (in both duration and area) citizen science program for monitoring vegetation condition. The Capital Region Landkeepers Trust and the ACT Environment Grants Program partially funded the preparation of this report, the first of its kind in the ACT and region.

Volunteers from community groups (ParkCare, Landcare and Friends groups) have been involved in the program to monitor sites in the Molonglo River catchment area and beyond since 2011. They used the Vegwatch methodology published in the *Vegwatch Manual* (Sharp and Gould 2014).

The Vegwatch program was intended to guide and help people to quantitatively measure changes to vegetation attributes over time, to help identify whether on-ground management activities were achieving the desired outcomes. In addition, the program was developed to provide data that could contribute to a larger dataset in order to guide adaptive management of conservation areas.

This report assesses the characteristics of the program during 2011–2018, including the robustness of the program, the drivers that are affecting vegetation condition and the effectiveness of vegetation attributes in identifying ecological change in condition. The report describes changes in condition in 33 plots in 22 sites in ACT and the surrounding region, using Vegwatch monitoring data from 2011 to 2018, and has tested the ecological validity by comparing these data with data collected by ACT government ecologists. It summarises participants' feedback on their own experiences and what they gained from participating, and what problems or issues they faced. The report recommends changes to make Vegwatch more a more effective citizen science monitoring program.

From this report, other citizen science monitoring programs can gain insights to ensure government and community can work together most effectively to achieve improved conservation outcomes.

The Vegwatch program has been successful in a number of ways:

1. Its methods are consistent, robust, and compatible with methods common in other programs.
2. Citizen scientists have shown they are capable of monitoring vegetation and habitat change.
3. Participants have gained knowledge and understanding of ecological processes occurring in the sites that they are involved in managing.
4. The data are comparable with data collected by professional ecologists.
5. Changes in condition due to natural ecological drivers or historical processes have been quantified and identified for all plots and distinguished from changes as a result of other factors, particularly management.
6. There are possibilities for wider application of the updated Vegwatch. It could be incorporated into other programs, including to provide quantitative monitoring of outcomes of on-ground activities undertaken as a part of grant reporting.
7. Vegwatch monitoring data may be used as a component of other monitoring programs for identifying changes in condition as a result of particular management interventions.

Weaknesses in the program implementation have been identified:

1. Some data proved difficult for participants to record accurately; for example, some people found species identification and estimating abundance and cover challenging.
2. The lack of on-going support to participants has decreased motivation and compromised the quality of some data.
3. Lack of resources has limited opportunities to communicate the results to volunteers, community, government and other groups, to share the data with other organisations or otherwise promote the program.
4. While the program was effective in identifying change in condition in the individual monitored locations, the lack of balanced replication has limited the ability to generalise about the impacts of management interventions on those changes. Possible trends are suggested but need further testing and potentially more replication built into the program or data combined with larger datasets.

Changes to the program are identified to make it more effective: more robust and simpler metrics, simpler collation of condition indicators and a more refined method of communication of results. As a result, the program's data will be able to be easily shared with other scientists and practitioners to improve management outcomes.

1. VEGWATCH PRACTICE AND FINDINGS IN THE ACT REGION OVER THE EIGHT YEARS 2011–2018

1.1 INTRODUCTION

Monitoring plays a key role in the application of adaptive management. As management actions are implemented, monitoring is a strategic tool used to measure changes in defined attributes, to identify whether the specified desired outcomes are being met. Effective monitoring not only identifies that actions have occurred (e.g. revegetation has been undertaken), but what changes to ecological attributes have occurred (e.g. the percentage survival of which species). While monitoring identifies and measures change and can help to identify which variables (drivers) may be related to those changes (short-term and long-term weather patterns, landscape features, historical land use and disturbance), other tools, importantly research or trials, are required to identify the reasons why the changes have occurred. Together with research, quantitative monitoring is a tool that justifies remedial actions (National Environmental Science Programme, undated).

The Vegwatch program was initiated in 2011 by the Molonglo Conservation Group (formerly Molonglo Catchment Group, MCG) to support an adaptive management approach to conservation of ecological systems. The program was designed to enable community groups to identify and measure quantitative changes in condition in locations in which they are applying active management, to help identify whether the actions were achieving defined outcomes. Additionally, the program was developed to contribute the data to a larger pool in order to detect generalised responses in condition across a wider sample of vegetation types. The Molonglo Conservation Group continues to facilitate Vegwatch.

Participants and other stakeholders contributed to the development of the Vegwatch processes and methods, which were published in 2014 (Sharp and Gould 2014). Vegetation attributes measured and methods used are consistent with other existing monitoring and vegetation assessment programs, and include identification of plant species abundance, quantitative measures of vegetation cover and collation of data on structural and habitat features.

The plots were established in locations of specific interest to the participants in the program, where the participants were undertaking on-ground work, usually as ParkCarers, Landcarers or Friends groups. The majority of the plots were established within reserves, either government reserves or in some cases, leased (ACT) or privately owned (NSW) sites managed primarily for conservation.

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1.2 PURPOSE OF THIS REPORT

This first review of data from the Vegwatch program has provided the opportunity not only to report and summarise the findings of the monitoring undertaken to date in 33 Vegwatch monitoring plots between 2011 and 2018, but to also investigate the methodology and commonly applied inferences behind change in condition. Future reviews will utilise recommended changes to the metrics and data analysed. This review also identifies the value of the citizen science program to support conservation-based management.

It is important to take into account that between two and seven years of monitoring in sites is a very short period to gain useful results (Krebs in Lindenmayer and Gibbons 2012 reported that interesting results didn't appear in a monitoring program he ran until after about 10 years). Thus, the result findings reported are preliminary.

The aims of this report are to identify if the Vegwatch program is effective and whether it is achievable. More specifically the aims were to:

1. Identify and acknowledge the contribution of citizen scientists in collecting vegetation data to assist in conservation of native ecosystems;
2. Review the methods used and the effectiveness of the indicators used to measure vegetation condition;
3. Make recommendations that will improve on-ground management applied by volunteers and others to enhance the condition of the conservation areas;
4. Describe the changes in condition in the locations being monitored;
5. Identify the data that can be incorporated into other studies, including the ACT Conservation Effectiveness Monitoring Program and the State of the Environment Report; and
6. Recommend changes to improve and expand the Vegwatch program.

Table 1.1 summarises the major characteristics of the Vegwatch plots, including their overall condition and trend. Full reports on each plot are presented in Chapter 5.

Table 1.1. Characteristics of the Vegwatch plots included in the statistical analysis and summary of condition and trend. Plots that meet the criteria as endangered ecological communities in one or more surveys in bold. See the list of abbreviations for names for vegetation associations and vegetation structure. Where measurements were only made twice the trend is questionable; where only once, or data was deemed inaccurate no trend is identified.

Site	Participants	Land use	Plot	No surveys	Management	Vegetation association	Veg struc-ture	Overall condition and trend
Aranda Bushland	Friends of AB	N. reserve	ASG_1	4	SJW control	SGW	GW	←→
Black Mountain NR	Friends of BM	N. reserve	BLM_S	5	Control burn 2014	RSF	FOR	↑
			BLM_C	5	None (control)	RSF	FOR	←→
			BLM_A	5	Control burn 2012	RSF	FOR	↑
Bullan Mura Yarralumla	Sharp (MCG)	Open space	BMY_1	5	Woody weeds 2014	**YBRG**	GW	↑↓
			BMY_3	2	Cool burn 2018	**YBRG**	GW	↑?
Captains Flat cemetery	Capt. Flat Landcare	Cemetery	CFC_1*	2	No mgmt	SGCBW	FOR	←→?
Captains Flat property	CF Landcare	Farm	CFH_1*	3	Woody weeds '15, livestock	NG	GL	←→
Cooleman Ridge NR	CR ParkCare	Nature reserve	CRA_2	5	Control burn 2017	**YBRG**	GW	↑
			CRD_1	5	SJW control	YBRG	DerGL	↑
Icon Water Williamsdale	Sharp (MCG)	Cons'n (offset)	IWW_1B	2	Cool burn 2018	**YBRG**	GW	←→?
			IWW_2C	2	Control plot	**YBRG**	GW	←→?
Isaacs Ridge NR	IR ParkCare	N. reserve	ISR_1	5	SJW control	NG	DerGL	↑
'Millpost' Bungendore	Sharp (MCG)	Farm	MLP_1B	2	Cool burn 2018	BGSOF	SW	←→?
			MLP_2C	1	Control plot	BGSOF	SW	
Mt Ainslie NR	MA ParkCare	N. reserve	MAI_1*	3	Reveg: shrubs, trees 1980s	EPN	SW	←→
			MAI_2*	2		EPN	SW	←→
Mt Majura NR	Friends of MM	N. reserve	MMA_1	3	Reveg: forbs 2013	**YBRG**	GW	←→
Mt Painter NR	Friends of MP	N. reserve	MPA_1	7	Weed control	**YBRG**	GW	←→
			MPA_2R	6	Reveg: forbs 2011	NG	DerGL	←→
			MPA_2C	6	Control plot	NG	DerGL	←→
			MPA_3	6	Control burn 2014	**YBRG**	DerGL	↑↓
Mt Taylor NR	MT ParkCare	N. reserve	MTA_1*	3	Wildfire 2003	MBSF	SW	
Royalla Swainsona Res.	Royalla Landcare	Reserve (offset)	RSR_1	1	Revegetation, date unknown	MBSF	SW	
St Marks Grassland	Sharp	Uni campus	STM_1	2	Ecological burn 2018	**NTG**	GL	←→?
Tennant St Fyshwick	Sharp, MCG	Unleased	TSF_1	2	No mgmt	**NTG**	GL	←→?
The Pinnacle NR	FOTPIN	N. reserve	TPI_1	7	Reveg: woody 1980S, forbs 2011	**YBRG**	SW	←→
Tuggeranong Hills NR	TH ParkCare	N. reserve	TUH_1	2	No mgmt	**YBRG**	GW	←→?
Umbagong G'l Latham	FOG	Open space	UMG_1	2	Ecological burn 2018	**NTG**	GL	←→?
'Wandiyali' Googong	Sharp (MCG)	Cons'n reserve	WAN 1B	2	Cool burn 2018	**YBRG**	DerGL	↑?
			WAN_2C	2	Control plot	YBRG	Der GL	←→?
Yarramundi Grassland	FOG	Cons'n reserve	YAG_1	2	Control burns '11 '17	**NTG**	GL	←→?
			YAG_2	2	Control burns '11 '17	**NTG**	GL	←→?

Key: **Condition**: dark green: very good condition; green: good condition (with some concerns); orange: moderate condition; red: poor condition. **Trend**: ←→: stable; ↑: improving; ↓: declining; ↑↓: variable; ?: trend uncertain due to lack of repetitions.
* indicate completed monitoring projects.

Structure of this report

Chapter 1: An overview of the outcomes of the program so far, in relation to the six aims listed above.
Chapter 2: The background to monitoring and the application of the Vegwatch program.
Chapter 3: Detailed statistical analysis to identify which factors most influenced changes measured and the identification of the most effective indicators of change.
Chapter 4: Feedback provided by participants and other stakeholders on their experiences using the program.
Chapter 5. Plot by plot description of plot condition and change in condition, based on the factors influencing condition and described as changes to particular indicators.

1.3 SUMMARY OF THE OUTCOMES OF THE VEGWATCH PROGRAM TO 2018

Plots were measured in seven vegetation associations and two modified associations (Table 1). The majority of monitoring plots were located in Yellow Box – Blakely's Red Gum grassy woodland (YBRG, nine plots in seven locations in grassy woodland, four plots in three locations in derived grassland (DerG) and natural temperate grassland (NTG, five plots in four locations). Plots were also measured in Snow Gum Woodland (SGW, one plot), Mealy Bundy – Broad-leaved Peppermint shrubby mid-high open forest (MBSF, two plots in two locations), Brittle Gum – Scribbly Gum tall dry open forest (BGSOF, two plots in two locations), Scribbly Gum – Candlebark Woodland (SGCBW, one plot in one location), in disturbed native grassland (NG, four plots in three locations) and in environmental native plantings (EPN, two plots in one location). Vegetation structure in these plots were grassland (13 plots of which seven contained derived grassland), grassy woodland (nine plots), shrubby woodland (seven plots) and forest (four plots). Five plots in three sites met the criteria as Natural Temperate Grassland of the South-Eastern Highlands critically endangered ecological community (Australian Government 2016). Eleven plots met the criteria for the White Box – Yellow Box – Blakely's Red Gum Grassy Woodlands and Derived Native Grasslands (YBRG) critically endangered ecological community (Australian Government 2005).

Management included interventions resulting in biomass reduction (burning and woody weed control) or revegetation and more incremental management such as reduction of weeds, general management, and on-going livestock grazing as well as varying levels of intensity of grazing by kangaroos.

Data from 31 Vegetation plots, and also data from seven plots sourced from ACT Government monitoring programs were combined in analyses to compare quality of data and to identify the indicators of change in condition. Sub-sets of the data based on vegetation structure were analysed to identify the impacts on condition of natural drivers such as climate and landscape features and imposed drivers including historical management and disturbance, stressors including invasive weeds and changes resulting from imposed management. The most effective measures of condition were identified.

1.3.1 The contribution of citizen scientists in collecting vegetation data to assist with conservation of native ecosystems (Chapters 3, 4, 5)

Vegwatch is the only citizen science-based vegetation monitoring program that has been undertaken within this region. The program was established to provide community volunteers who work on-ground the opportunity to quantitatively monitor vegetation attributes to see whether their on-ground actions are making a difference to the condition of the vegetation. Such monitoring is made more powerful by applying the same measurements across multiple locations, thus allowing for inter-plot and inter-site comparisons.

Like other citizen science programs in the ACT and region, such as Waterwatch and Frogwatch, Vegwatch provides opportunities for non-scientists to be involved in scientific studies that produce critical information to assist in conserving biodiversity. More than 80 participants have been involved in undertaking the surveys in the Vegwatch Program. Scientists or other trained practitioners have been a key part of ensuring accuracy and consistency of the data collected and giving confidence to the participants, providing training or assistance with surveys and with species identification. Data included in this report were collated from 114 surveys in 33 plots, measured between one and eight times between 2011 and 2018. The volunteers have provided valuable data that can now be incorporated into the implementation of an adaptive management program.

Feedback was obtained from participants and other stakeholders involved in the program (Chapter 4). Many participants stated that as a result of implementing the monitoring in their sites they have learnt a great deal about the species and processes occurring over time and have enjoyed contributing to the program. However, many participants, often those with less experience in scientific process, found the program challenging, citing difficulty in remembering what to do from year to year, and their problems in plant identification, as well as in understanding the methodology.

The challenge of plant species identification and scientific process was anticipated, but unfortunately there have been fewer resources than expected for providing consistent on-ground assistance to undertake training, calibration of field measurements and assistance with species identification to ensure data integrity. An effective citizen science program requires consistent help, to ensure participants retain their skills, are given feedback and maintain motivation, in order to provide useful data that are well managed, reported on and integrated into land management.

Even with the difficulties some participants identified, the data collected in the Vegwatch program compared well with data collected by professional ecologists. The data are of similar integrity, and therefore have provided valid and useful results. Vegwatch plots are frequently within locations that would otherwise not be monitored and that are in a wider range of conditions than would be prioritised in government-led studies. Such data are important for conveying greater understanding of the dynamics of different vegetation communities. The wider range of locations can add value to monitoring and research programs implemented by government and research institutions.

1.3.2 Identification of the most effective indicators to measure change in vegetation condition (Chapter 3)

Methods used to survey the data were consistent with methods used in other surveys undertaken within this region. Data were collected within permanently marked plots of 0.1 ha (or of 0.04 ha if not containing vegetation over 2 m tall), and also along transects within that plot. The plot locations were selected by the participants, to ensure they provided information that was relevant to those participants' on-ground work. Monitoring was undertaken in plots in seven vegetation associations and two modified vegetation types (native plantation and degraded native grassland). The vegetation structure present in the plots were native grassland (natural grassland or derived grassland) grassy woodland, shrubby woodland and forest. The plots were located in nature reserves, rural land, private conservation reserves and urban locations.

Data collected from 108 surveys at 31 plot locations were used to analyse the effectiveness of the proposed indicators to measure change (data from two plots were not included in the analyses due to concerns about misidentification). Additional data were included from a further 36 surveys from 7 plots from monitoring programs undertaken by ACT Government, to test whether the quality of the data in the Vegwatch program were equivalent to data from other studies.

Multivariate and univariate statistical analyses were applied to assess whether the methods used to collect the data were robust, the data accurate and the results useful in identifying change in condition. Other data were investigated using descriptive statistics such as scatter diagrams and column graphs.

Potential variables – 'drivers' – causing change in vegetation condition were tested and the ones most influencing current condition and condition change were identified. Primary drivers are those that cannot be modified and that characterise each location. They include natural ecological factors (e.g. slope, aspect, geology, soils, climate conditions and climatic variation) and historical processes (historical land use and management). Secondary drivers include conservation management that aims to enhance the natural values by modifying stressors (e.g. control of invasive weeds).

A critical initial factor was to assess the robustness of the program and accuracy of the data collected to determine whether the data measured by citizen scientists could be usefully used to interpret change in the data over time. This was assessed by several means and it was concluded that the Vegwatch data were of equivalent quality as ACT Government data, and can be used in interpretation.

The drivers that were deemed to have the most influence on changes in condition, in order of their degree of influence were:

1. Unique plot characteristics (proposed in particular to relate to each plot's historical management and disturbance);
2. Structural formation (that reflect landscape characteristics);
3. Seasonal weather variability (measured as root zone soil moisture levels); and
4. Interventionist management (management that resulted in significant measured alterations to biomass and/or composition, in this program being burning, woody weed removal and revegetation).

Sixteen attributes or scores were developed from species abundance data and cover, and cluster analysis, correlation analysis and Principal Components Analysis were used to determine which were the best indicators of ecological condition. Further consideration was given to selecting those indicators that were most likely to result in the most accurate and consistent data across all surveyors, that is, those that are simplest to collect, are based on the least amount of qualitative assessment, and are the easiest to calculate. The most useful indicators of condition were identified as native species richness (species composition in plots), introduced species richness (species composition in plots), and groundcover attributes (native and introduced growth forms, bare ground and litter), measured at multiple points along a transect (Table 1.2).

Other attributes can be derived from these indicators: for instance, indicator species, and non-grass species richness (for calculating scores against listings for threatened ecological communities), and invasive species richness and composition, the frequency and composition of other species of interest and structural diversity.

Several attributes currently included in the program are deemed suitable for measurement only by skilled practitioners, and may be measured less frequently or omitted from the Vegwatch program (Table 1.1). They are species abundance scores used to calculate floristic value scores, upper and mid-storey cover, benchmark condition score and habitat condition.

Other indicators such as revegetation success should be measured using consistent methodology such as that described in the Vegwatch Manual (Sharp and Gould 2014).

Table 1.2 Metrics and condition indicators proposed for future application in Vegwatch

Basic method: annual measurements	**Condition indicators**
Species richness: (presence data only) in a 0.1 ha plot	1. Native species richness 2. Invasive species richness 3. Structural diversity +. YBRG plots: Indicator species richness +. NTG plots: Non-grass species richness
Transect: at 80 – 100 points within or bordering the plots, presence of groundcover attributes: Native grass cover, Native forb cover, Native sub-shrub cover, Introduced annual cover, Introduced perennial groundcover, Bare ground and/or algae, Cryptogams (excluding algae), and Litter cover Rocks (permanent non-vegetative cover)	4. Native groundcover 5. Introduced annual groundcover 6. Introduced perennial groundcover 7. Bare groundcover + other cover attributes to answer specific questions
Advanced method: initial, mid and final measurements	
Native species abundance (Braun-Blanquet) Benchmark/BAM attributes: Native overstorey cover Native mid-cover Introduced mid-cover Introduced overstorey cover No. trees with hollows Fallen timber (m) Habitat attributes	8. Floristic value score 9. Benchmark score 10. Habitat condition score
Revegetation (annual)	11. Revegetation success

1.3.3 Management applied to enhance the condition of the conservation areas (Chapters 3, 5)

The indicators of change in condition, identified from the analyses, were used to interpret changes occurring as a result of the three management interventions applied in 26 plots in the program – burning, woody weed control and revegetation. While changes in the condition of the indicators are apparent, results were difficult to interpret conclusively because of the lack of replication of plots subject to different management, and the different timing of application of the treatments. Data from trials and research and/or more specific monitoring programs are required to provide more definitive recommendations.

The seasonal climatic conditions were highly variable during the monitoring period 2012 to 2018. The weather conditions were quantified by calculating the root zone soil moisture levels using methodology accessed from the Bureau of Meteorology (http://www.bom.gov.au/water/landscape). Soil moisture levels in the ACT and region were average between 2012 to 2015, well above average in 2016, below average in 2017 and well below average in

2018. The effects of the varying soil moisture levels were identified in the analyses, and were found to impact the changes in condition in sites subject to management interventions.

Burning

Burning was the most frequently applied treatment in the Vegwatch program between 2012 and 2018, with 11 plots being monitored to assess the change after burns. Only three of these plots were monitored for three years or more after the burns were applied, the others were only monitored for one or two years after the burns were undertaken. Control (unburnt plots) were established at five of the locations. The burns were applied in different years, but the majority, including all the cool – cultural – burns, were applied in mid-2018, so although more comparable across locations, only one season's post-burn data were available for these eight locations for this review. As a result of the variability in time and place, only descriptive interpretation was possible. Continuation of monitoring of these sites will provide more information on the effects of the burns over longer periods of time.

Regeneration of shrubs was very high in forested plots after the burns, and native species richness increased significantly; introduced species cover and richness in these plots was low initially, and did not change. In grassy ecosystems there were much more varied responses at the plot level. Generally, across all the plots an initial decline in both native and introduced species cover post burn was followed by an increase in subsequent years.

In the plots for which data are available for more than three years native species richness decreased in 2017 and 2018, however, which may have reflected response to the burning or may have reflected low soil moisture availability. In the sites subject to cool burns, applied and measured during seasons of very low soil moisture, (with only one season's post burn data available), the response to the burns were mixed – in two of the four plots there was little difference in richness in the burnt or unburnt plots, but in two there was an increase in native richness in the burnt plot. Continuation of monitoring is warranted to determine whether the variability from year to year is strongly influenced by seasonal condition and intensity of the burns.

Woody weed control

The two sites subject to woody weed control were very different from each other. The site at Bullan Mura in Yarralumla in which woody weeds (mainly tall shrubs and small trees) were removed was a native species dominated grassy woodland. Monitoring indicated that both native and introduced species richness and cover increased slightly after two years, but annual introduced species cover increased to high levels in 2016, when soil moisture levels were very high. The reduction of mid-storey vegetation may have exacerbated the impacts of high and low available soil moisture. After four years the woody weeds were re-appearing in low numbers, presumably from root stock. This underlines the need to undertake follow-up control within a few years of initial control. After woody weed control the Button Wrinklewort population in Bullan Mura was re-surveyed, and the numbers had increased from 61 plants counted in 2014 to 140 plants in 2016, although at least some of these plants may have been more visible after woody weed control.

The Captains Flat property had a very low native species diversity and cover. There was no increase in native or introduced species richness in the two years following the woody weed control.

Revegetation

Five plots were established to monitor change in species richness following revegetation of herbaceous and sub-shrub species. A general trend was apparent, with an increase in species richness followed by a reduction in richness after several years. Given the dry seasonal conditions, survival may have been reduced by a lack of moisture, but these trends follow patterns identified in other studies, in which there is a drop in survival of herbaceous species in particular, unless there is thorough preparation of the revegetation site and on-going weed control. In one plot (The Pinnacle Plot 1) the survival rate of 213 herbaceous and shrub seedlings was monitored: after eight years 66% of the original plantings were alive, with individual species' survival rates varying from 0% to 91%. Of the 11 species planted, four species had regenerated, varying from one to 17 plants established. In Mt Painter there was a 44% survival rate measured in 2016, prior to the severe dry conditions.

This latter study demonstrates the need to monitor plant survival in revegetation programs, to identify the rate of survival as well as identifying which species survive better than others and whether some species regenerate more regularly than others. This monitoring should be in conjunction with monitoring of the general condition of a site.

Conclusions

One of the key characteristics of the Vegwatch program was that the participants self-selected areas in which to establish monitoring plots, according to their own interests and in relation to what they wanted to find out. As a result, the plots differed in terms of vegetation composition, condition, past management and the management applied during the program. In many sites, only one plot was established. Thus, unlike more structured monitoring programs or research, in which key factors are replicated and timing of management intervention is controlled, this study has not been compatible with analyses from which to suggest causes of change that occurred. However, some general findings can be summarised.

1. Biomass manipulation resulted in a dramatic change in the amount of vegetation and litter and consequent exposure of bare ground. The impacts of biomass reduction are likely to be higher in years of very low soil moisture conditions, so implementing biomass reduction during poor seasons or just prior to poor seasons may result in moderate to long-term reduction in condition until groundcover increases. Cool burns in which a larger amount of ground cover is maintained may have reduced impacts from low soil moisture conditions on regrowth of vegetative matter, compared to low-intensity control burns which tend to burn larger areas and remove more biomass.
2. Five of the twelve plots that were burnt increased in overall condition over the eight years; no other plots subjected to management interventions increased in condition, although all remained stable.
3. Revegetation of herbaceous species should be monitored to record the success of establishment (survival and regeneration), with particular observations over multiple sites to identify the species most successfully establishing. Revegetation programs required considerable preparation and on-going management, including weed control in the site prior to planting, and commitment to on-going weeding and/or watering if required.
4. Replication of plots and more specific identification of management objectives are required to improve the capacity of monitoring to measure changes in condition as a result of management. However, this will be more effective if better coordinated with management research.
5. Three to five years of monitoring data are inadequate to monitor the effects of biomass manipulation; variability remained high for many years in plots subjected to burns and woody weed control, and the plots were particularly susceptible to variations caused by very low available soil moisture.

1.3.4 Changes in condition in the plots being monitored (Chapter 5)

The change in condition of indicators in each plot were calculated. To represent background variability in the data caused by primary drivers, 95% confidence intervals were calculated for the main condition indicators identified in the analyses. For each structural formation, data from plots in good condition, that had not been subject to management interventions and from the years of average soil moisture conditions were used to calculate the confidence intervals for the plots for eight indicators of condition. That outcome was then graphed with the data from each plot, together with the calculated soil moisture level for each plot. The timing of interventionist management was identified. Any variation beyond this range is deemed to reflect significant change, either reflecting management intervention or variability in seasonal conditions.

Condition levels were identified as poor (well below the confidence interval), moderate (below the confidence interval), good with some concerns (within the confidence interval), and good (above the confidence interval) (based on the classifications defined by ACT Government) against the confidence intervals and against existing values. The trend in change in condition over time was identified as stable, improving, declining, variable, questionable for plots measured only twice and no trend identified for those measured only once or where data were deemed inaccurate. The combined condition and trend of each plot is presented in Table 1.2.

Vegetation attributes and condition indicators varied most in the plots within the grassy ecosystems. The monitored plots in derived grasslands tended to contain the highest component of introduced species, particularly introduced annual species, but many also had a very high native species richness and diversity. The four forested plots contained very low introduced species richness and cover, and very little bare ground.

Of the eight plots in good condition, four were forested plots in Black Mountain (BLM_A, BLM_C, BLM_S) and Captains Flat Cemetery (CFC_1), two were shrubby woodlands at Mt Taylor Nature Reserve (MTA_1) and Royalla Swainsona Reserve (RSR_1) and two were natural grassland plots at Umbagong (UMG-1) and Yarramundi Grassland (YAG_2).

The plots that demonstrated an increase in condition were five of the burnt plots in Black Mountain (BLM_S, BLM_A), Cooleman Ridge (CRA_2), Mt Painter (MP_3) and Wandyali Conservation Reserve (WAN_1B) and two other plots at Isaacs Ridge (IR_1) and Cooleman Ridge (CRD_1), in which control of St John's Wort was undertaken. Condition was stable in 23 sites, seven of which were burnt sites, three of which were revegetated, two subjected to woody weed control and ten subjected to no management interventions. No plots were declining in condition overall, although native species richness declined in two burnt sites over the period of monitoring.

1.3.5 Value of the citizen science for incorporation into other studies (Chapters 3, 5)

The value of the data lies in its application to improve conservation outcomes. The results of the Vegwatch monitoring can be applied by the community groups to modify their management on site or the results could be used in combination with other data to identify broader inferences.

For example, the citizen science data could be included in metadata analyses that contain other monitoring data collected using the same methods, to allow more robust statistical analysis that is not possible for smaller data sets. The data from this study have been provided on request to ACT Government for consideration for incorporation into a metadata analysis.

Other uses include incorporation into reports such as the State of the Environment reports, or for reports on the condition of particular sites or groups of sites (e.g. reserves) and to identify outcomes of implementing action plans for threatened species and ecological communities.

Information on the outcomes of on-ground management can be used to inform invasive species control programs, biomass control programs and single species management. Examination of the data could also assist in developing research programs.

The data or any sub-set of the data can simply be retrieved from the database. Any changes to the way data are collected would need to take compatibility issues into account.

1.3.6 Recommended changes to improve and expand the Vegwatch program (Chapters 3, 4, 5)

The results of the detailed analysis of the data have demonstrated the most effective way to continue, improve and expand the Vegwatch program. The review has identified what has been achieved and some weaknesses and, importantly, what is required if the Vegwatch program is to continue most effectively.

For the Vegwatch program (or any citizen science program to be successful) the people involved must gain personally from the surveys, for example, in enjoyment, education, better understanding of the results of their management applied on ground, sharing experiences, as well as in knowing that they are providing valuable information that will ultimately result in better conservation outcome.

The Vegwatch program aimed to use methods that require no in-depth botanical knowledge (Sharp and Gould 2014), however the difficulty of some participants identified this as a key problem to maintain motivation. It was concluded that the monitoring requires at least a moderate level of botanical knowledge and the skills (and interest) to follow identification of unknown specimens; it also requires help from others to ensure consistency and accuracy with plant identification and or measurement techniques. In addition, simpler methods, that retain consistency at least with a sub-set of data collected by more experienced ecologists, ensure greater accuracy (for example, not collecting abundance data for species).

Vegwatch should now move to a new phase, to be further expanded. If strengthened by increasing the number of groups involved, the extent of sites being monitored and the data being shared, then it can be more widely utilised in Government, scientific and community research and planning.

For Vegwatch to continue successfully, it is recommended that the following processes are implemented or strengthened:

Collaborate with managers and other stakeholders to support the Vegwatch monitoring program

1. Provide the data regularly to government for incorporation into larger data sets.
2. Ensure the Vegwatch program is undertaken in collaboration with other natural resource monitoring programs, including monitoring of single species, habitat or other function.
3. Promote opportunities for Vegwatch monitoring to be incorporated into other studies; for example, as part of NRM and other grant reporting.
4. Work towards establishing a coordinated approach between ACT Government and Vegwatch participants to undertake monitoring in select locations to fill gaps in broader programs.
5. Coordinate Vegwatch with other programs, for example:
    - Enter monitoring plot details onto the Collector app (used in ACT to identify on-ground work such as weed control) to link the monitoring with other actions including other surveys, management being applied, type of vegetation, protected plant locations;
    - Encourage use of Canberra Nature Map to record species locations; and
    - Enter data into the Atlas of Living Australia.
6. Encourage utilisation of the data by research scientists to help formulate research programs

designed to support adaptive management.

7. Ensure the results are used to improve management.

Ensure there is a facilitator to coordinate the program implementation

8. Encourage and support existing volunteers to continue monitoring at existing locations.
9. Ensure there is on-going support to participants to:
   - Promote consistency of data collection and data management,
   - Provide assistance on the ground,
   - Provide or facilitate initial and refresher training,
   - Ensure timely data entry, and
   - Support a group of skilled volunteers to help with plant identification or other matters;
10. Hold regular refresher training sessions.
11. Ensure there is long-term maintenance of the Vegwatch database and facilitation of data migration so that data are not lost.
12. Encourage other groups to instigate monitoring where interventionist management is occurring.

Improve frequency of feedback to participants and other stakeholders

13. Provide regular feedback to participants and to managers to improve effectiveness of management.
14. Use the Internet and websites more effectively to provide updates and enable groups to stay in touch: Ensure regular reports are available on the website so all groups can see the results in a timely way. Include key documents on websites, including this report, plot reports, talk presentations, articles, guidelines and contact details.
15. Hold workshops, give presentations to participants, community and government to encourage collaboration.
16. Ensure participants are acknowledged for their involvement and how this benefits management outcomes.
17. Ensure no-one feels 'obliged' to undertake monitoring; ensure careful preparation and planning so that the monitoring is relevant and useful to the participants.

Modify the metrics used in the program to ensure data are robust, provide consistent results, and are useful to answer pertinent questions

18. Ensure data to be collected are as simple as possible, and require the least amount of decision making so that the data are easier to collect and are more consistent.
19. Coordinate a group of skilled practitioners to assist with more complex data measurements across a range of plots, enabling the simpler data to be collected by volunteers at each plot.
20. Simplify plant identification. Several options are:
   - Identify those species that only need to be identified to genus level
   - Have designated persons to help with post-survey species identification
   - Encourage better use of existing species identification resources (training, Canberra Nature Map, field guides and other websites)
   - Provide identification guides relevant to each plot species list, at least for those species that are hard to tell apart or where they need to be identified as native or introduced.
21. It may be relevant to apply Vegwatch at several different levels based on the levels of skills required or particular outcomes of the monitoring, from photomonitoring to more complex data measurements.
22. Ensure plots are optimally situated based on the group's aims and so that results can feed into a broader data set. Encourage the establishment of replicate plots within sites and between similar sites to enable more complex statistical analyses.
23. Ensure methodology and data entry guidelines are clear and consistently presented and well understood.
24. Prior to development of modified guidelines and incorporation of changes, involve relevant stakeholders that include ACT Government, catchment groups and participants to evaluate the findings of the analyses and recommendations provided in this review.

2. THE VEGWATCH PROGRAM

2.1 THE IMPORTANCE OF MONITORING ECOLOGICAL PROCESSES

Adaptive management requires a strategic approach (Figure 2.1) and monitoring plays a key role in the application of adaptive management. The process is based on knowing what is present, defining what is to be conserved, identifying drivers and threats, and preparing a plan to undertake actions that address known threats and meet conservation objectives and desired outcomes. As actions are implemented, monitoring becomes a fundamental way to measure whether the actions are meeting the desired outcomes, and then, if required, to review the plan and modify the plans and/or actions. Monitoring, together with research, provides reliable evidence to justify remedial actions (National Environmental Science Programme, undated).

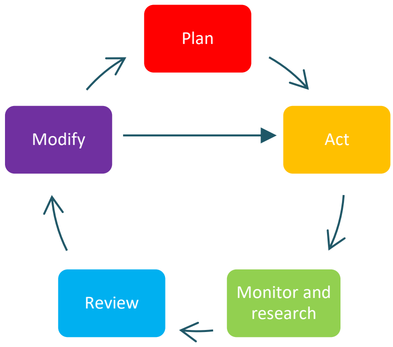


Figure 2.1. Applying the adaptive management process.

Monitoring is a tool used to guide conservation management, together with research, identifying changes in condition whether related to vegetation and habitat or particular fauna or flora species. Monitoring needs to differentiate between short-term responses to natural events (for example climatic variation) and long-term changes in condition as a result of intervention. Together with research, these results can facilitate changes in management at the plot level and landscape level. The strength of monitoring lies in repetition over some years and repetition across many locations, to identify key changes.

A successful monitoring program needs to be:

- Valuable and utilised;
- Scientifically robust;
- Shared; and
- Accountable (Lindenmayer and Likens 2018).

2.2 VEGETATION MONITORING

Monitoring is used to measure change in condition over time. In the Vegwatch program, this relates to change in vegetation condition indicators. The factors that impact ecological values are presented in Table 2.1, as adapted from Brawata et al. (2017a). Change is driven by primary drivers that include natural landscape features including geology, topography, soils, hydrology and climate (causing long-term change), past land uses and disturbance (causing medium term change) and seasonal climatic variation (causing short-term change). Stressors include invasion of weeds, biomass alteration (including grazing, fire, slashing) and impacts of introduced pest animals. Stressors can be reduced or eliminated by management (e.g. biomass manipulation or pest animal and plant control).

Monitoring of vegetation is often more complex than other forms of monitoring, because changes to vegetation attributes at any one time may be due to a range of factors. Also, changes to some vegetation attributes do not necessarily reflect changes in other attributes. Therefore, a successful monitoring program requires careful investigation to determine which factors are likely to be influencing changes in condition, so as to differentiate whether actions applied on the ground are effective.

A successful program as defined by Lindenmayer and Likens (2018) must include consideration of how both drivers and stressors are likely to be influencing the results. Methods must be able to differentiate between drivers and stressors, and interpretation of the data must include consideration of these factors.

Table 2.1. Factors that influence ecological values and can cause long- or short-term change to vegetation (adapted from Brawata et al. 2017a).

Primary drivers	Ecosystem stressors	Threatening processes that caused by stressors	Management	Ecological values that are changed by drivers, stressors and management
Climate Weather variability Geology Topography Soils Hydrology Past land uses Disturbance	Invasive weeds Invasive pests Inappropriate or unsuitable management Soil disturbance Vegetation clearing	Changes to hydrology Soil compaction Erosion Loss or modification of habitat Loss or reduction in native species Competition by invasive species	Grazing Fire Slashing Control of plant and animal pests Revegetation Reintroductions Rehabilitation	Native fauna Native flora Structure and habitat Soil condition Ecological function

2.3 THE CONTRIBUTION OF CITIZEN SCIENCE PROGRAMS IN THE CONSERVATION OF NATIVE ECOSYSTEMS

'Citizen science involves public participation and collaboration in scientific research with the aim to increase scientific knowledge' (https://citizenscience.org.au, accessed March 2020). The experience of citizen scientists in scientific process varies from nil to very high, reflecting a wide range of interested volunteers from many walks of life.

The two key elements of ecological citizen science programs are that they facilitate participants' understanding of ecology, ecological processes as well as scientific process, and that they provide valuable scientific information to improve ecological management and conservation of biodiversity. Citizen science programs are opportunities for community members to be involved and engaged in environmental work, to feel more connected to natural processes and biodiversity, to learn more about biodiversity and importantly, to contribute to a better understanding and protection of biodiversity.

The Vegwatch monitoring program was designed to provide the opportunity for community to undertake vegetation and habitat monitoring. Before the implementation of Vegwatch, there were no programs within the ACT region for citizen scientists to participate in monitoring changes to vegetation diversity, composition and structure and habitat in areas in which conservation management is undertaken. In its development Vegwatch drew on knowledge gained from existing citizen science programs such as the Frogwatch and Waterwatch programs as well as other vegetation monitoring and site assessment programs, in particular Croft et al. (2005), ACT survey program.

2.4 THE VEGWATCH MONITORING PROGRAM

Vegwatch is a citizen science monitoring program facilitated by Molonglo Conservation Group (MCG). The program was developed between 2011 and 2013 with assistance from the Australian Government's Caring for Our Country and the ACT Government. This grant funded the development of the Vegwatch Manual (Sharp and Gould 2014) which guides the methodology, including planning, establishment, methodology, on-ground measurements, data collation and data interpretation.

In 2017 two grants of $7000 in total were provided to MCG through the ACT Environment Grants Program to establish and test a database for storage of the data and to provide simple reports, which has in turn, made the data more easily extracted, comparable and useful.

Vegwatch was designed to be used as a collective project to support multiple volunteers to monitor vegetation attributes and habitat at a range of locations managed for conservation outcomes, and to support the volunteers in the provision of training and resources to assist annual monitoring and the collation and analysis of results. It can also be used by individuals to monitor at single sites. Vegwatch is one of a number of monitoring programs that provide information to contribute to a larger pool of data to inform conservation of natural assets (Brawata et al. 2017a).

The goals of the Vegwatch program (Sharp and Gould 2014, p.3) are:

1. To allow users to gather vegetation and environmental data with relevance to ecosystem conservation and management;
2. To provide the tools and guidance to assess whether changes in condition are occurring, so that management and resources can be better targeted towards enhancing elements of biodiversity;
3. To enable useful, quantitative and comparable monitoring of vegetation to be carried out using practical, simple but effective standardised assessment methods;
4. To encourage and support a range of people in gaining the skills to assess environmental condition, and in doing so, develop their understanding of the natural processes occurring within sites; and
5. To ensure more consistent interpretation of changes and to provide justification for undertaking certain activities (such as effectiveness of management in achieving on-ground results.

To ensure compatibility with existing programs, consultation and research was undertaken during development of the program to ensure that there was, as much as possible, consistency in metrics and identification of attributes measured and condition indicators used. While the ACT Government's Conservation Effectiveness Monitoring Program (CEMP) was not developed by the time the Vegwatch manual was published and implemented, the Vegwatch program contained the basic metrics used in other monitoring programs applied in ACT Government conservation programs. Vegwatch also contained metrics to enable the vegetation condition to be compared to the 'benchmark' condition applied in biometric assessment program in NSW (DECCW 2011), which applied weighted scores given to ten metrics to give a single value (% of the benchmark condition) (see Appendix).

Since implementation of the Vegwatch program there have been further changes and additional monitoring programs established in the region, including the development of a CEMP grassland monitoring program and the implementation of the Molonglo River Reserve monitoring program, which is based on the Vegwatch methods (Sharp and Milner 2014; ACT Government 2018). Also, since 2014, the biometric program used by NSW Government has been modified (the Biodiversity Assessment Method, NSW Government 2017), but the Vegwatch attributes measured remain consistent with those measured within these NSW and ACT monitoring and assessment programs.

Participants

The Vegwatch program encourages and supports citizen scientists to measure attributes used to assess various measures of vegetation and environmental condition before and after specific on-ground actions are applied.

Participants became involved in the program for a variety of reasons. The majority of participants were members of ParkCare or Landcare groups who are undertaking management activities on-ground and were interested in quantitatively measuring the changes to the vegetation and habitat following those inputs. Other groups were asked to be involved, and in some cases their involvement was a requirement of funding received or as part of another program. Other plots were monitored for comparative purposes in sites in good condition by participants with a high level of field survey experience.

The Vegwatch program guidelines (Sharp and Gould 2014) have also been used in several MCG projects, including the cool burn project, included in this analysis. The monitoring program for sites in the Molonglo River Reserve offset areas used a subset of the methods of the Vegwatch program (Sharp and Milner 2014). The results of five years monitoring in the Molonglo River corridor were published in 2018 (ACT Government 2018).

Implementing the Vegwatch program

Full details of the implementation of the program are in Sharp and Gould (2014). A summary is provided below of the process ideally undertaken by all users.

Planning

Prior to undertaking the monitoring at a particular site, participants meet to plan the program. This step helps each group decide and define what it wants to get from the program. Generally, the program is applied to measure what changes occur to the vegetation composition after a particular management event: for example, a burn, weed control or revegetation. Ideally every monitoring program would be based on clearly defined, measurable objectives and identification of what is to be achieved, including clearly articulated outcomes (Sharp et al. 2015). The guidelines encourage participants to maintain details of management actions applied, including timing, need to be recorded to ensure changes can be compared to when management or other disturbance events occurred. The methods and indicators to measure are determined based on the objectives (Sharp and Gould 2014).

The planning helps to clarify what the group is aiming to achieve from the management applied. The plan guides the best location of the plot/s where the measurements will be undertaken, what measurements will be made and an estimate of the duration of the monitoring into the future. Other attributes to monitor, such as changes in abundance of a particular species or revegetation success are identified. Details are recorded and maintained in the database to ensure all aspects important for success over several years are maintained and communicated. The group identifies who is involved in the planning, contacts, where the data will reside, the proposed time frame (which will depend on the particular program's aims) and who will be involved in the monitoring – important information if there are changes of personnel.

Establishing the plots

The plots are established and permanently marked, and the location described for future relocation. Several measurements are made initially to describe and quantitively record the attributes that indicate condition of the plot at the beginning of the program, including a score against benchmark condition (see the Appendix for more information). An initial photo is taken at the photo-point to guide photomonitoring in future. The location of the plot and transects in which measurements are undertaken are determined by the planning process.

The area in which all the monitoring occurs is a 0.1 ha plot. Generally, this is established as a 20m x 50m plot. The measurements relating to vegetation over 2 m tall are made within this 0.1 ha plot. Measurements relating to vegetation that is less than 2 m tall are made within a sub-plot of 0.04 ha (generally 20m x 20m). In sites where there is no vegetation taller than 2 m only the sub-plot is established. One measurement, species cover, is measured at points along two or more transects, which generally run parallel or along the 50m edge of the plot; in the case of the smaller 0.04 ha plot, they can be measured along all four edges or in parallel lines. This design (Hnatiuk et al. 2009) is standard across the majority of vegetation surveys.

Surveys

Vegwatch surveys should ideally be undertaken each year between late October and mid-November when the greatest number of plants are recognisable (forbs and grasses are difficult to identify when not in flower or seed and many native herbaceous species only emerge during spring and early summer). Consistency of timing ensures data are comparable from year to year, even though at any time some herbaceous species will not be visible.

The basic attributes collected in the field are:

1. Plant species diversity (richness and abundance)
2. Structural diversity of native and introduced plants
3. Condition of native trees and shrubs
4. Species cover (grouped by growth form, life form and origin)
5. Terrestrial habitat condition

Photomonitoring is also undertaken annually in every plot.

Guidelines are available for additional measurements that could be assessed in the field:

6. Revegetation success
7. Distribution and abundance of a species
8. Waterbody habitat condition

Most data collected are quantitative, so that they can be compared and analysed. The base measurements collected annually in the Vegwatch program are plant species abundance measured in the plot, and cover measures of elements of the groundcover. The other three basic attributes were initially measured annually, but as the program progressed attributes that changed more slowly were less frequently measured (for example, overstorey and mid storey cover and terrestrial habitat condition).

Data collation

The data and photos are supplied to MCG and the data entered into the Vegwatch database. While electronic Excel-based recording sheets have been available since 2016, all participants have elected to fill out hard copy sheets in the field, and they either provide these hard copy sheets to MCG or transfer the data onto the Excel sheets, which then can be entered directly into the Vegwatch database. Alternatively, the data can be entered manually onto the database. Transcribing the data provides an opportunity to check the data are consistent and complete. The database is used to record all the raw quantitative data, descriptive information about the plot and site, and photomonitoring.

Survey sheets for each plot for the next survey can also be produced from the database. These include existing descriptions of the vegetation and condition, information collected previously on the location of the plots, and a collated list of species recorded from previous surveys.

Calculation of attributes and condition indicators

Some attributes, including plant species abundance, are used more than once to calculate different condition scores. For example, native and introduced species abundance data are used to identify the number of indicator species (a criterion for identifying if a location contains the critically endangered Yellow Box – Blakely's Red Gum Grassy Woodland listed under the EPBC Act), number of non-grass species (a criterion for identifying if a location contains the critically endangered Natural Temperate Grassland listed under the EPBC Act), the number of transformative invasive species and floristic value scores for native species (Rehwinkel 2015) and the data to calculate a floristic score for introduced species (see the Appendix for an explanation of how these are calculated). Groundcover attributes measured along the transect can be used as individual attributes (e.g. native grasses, bare ground) or can be combined (e.g. native groundcover).

Summarising and interpreting the data

The database provides an efficient way to summarise the main attributes of the data. Outputs from the database for each plot include summary reports of the attributes for each year, a summary of what data have been collected, a species list for each plot for each year and species lists for multiple plots. Summary reports and descriptive statistics can be used to identify changes in the data over time within plots, whether they are indicating an increase, decline or no change for the attribute as a result of management or other actions (e.g. disturbance). These statistics can be provided on a regular basis to participants. Simple graphic representation of the summary reports also can be automatically produced. Additionally, a report can be generated that lists all species surveyed in all plots or a selection of plots for every year. The data were accessed from the database to collate a species list for every survey used in the analyses and the summary data to identify the attributes.

The Vegwatch manual explains how to interpret the results on a plot by plot basis. However, more detailed statistical analysis is required to determine whether these measured responses are meaningful. It is important not to over-interpret changes – i.e. not to apply causation when it is not warranted, although speculation is important, and will lead to questions that may be better answered by research or further monitoring (Sharp et al. 2015).

This review presents the opportunity to review how well the program has met its aims. Chapter 3 presents the results of analyses to identify the importance of particular attributes as indicators of change in condition. Chapter 5 uses these results to describe the trends of change and their likely sources of change, applied to individual plots and sites.

3. REVIEW OF THE DATA FROM THE VEGWATCH MONITORING PROGRAM, 2012 TO 2018

3.1 INTRODUCTION

The review was based on comprehensive statistical analysis and scientific interpretation of the data collected by citizen scientists and collated into the Vegwatch database. This assessment tested whether the Vegwatch program successfully identifies changes in condition in monitoring plots, and whether the changes can be related to particular factors.

Participants from 15 community groups have been involved in collecting data included in this review. The majority of plots were surveyed by ParkCare or Landcare groups which are undertaking on-ground management activities and were interested in measuring the changes to the vegetation and habitat following those inputs. In addition, the data set included measurements used to monitor outcomes of two MCG projects. Additional reference plots were monitored by experienced volunteers, representing plots in good condition and subject to regular conservation management. All the reference plots were in grassy woodlands or derived or natural grasslands.

The Vegwatch program was not established as a pre-defined balanced program designed to measure particular management outcomes, but was led by the groups themselves. The location of plots was self-selected by each group, chosen by the participants to suit their own objectives. There was limited replication of plots at the site level sites (only eight out of 31 Vegwatch plots had multiple equivalent plots established within a site). Plots were established in different vegetation associations, had different historical management and disturbance levels and were established at different times to measure a variety of management inputs. Thus, there were multiple factors (drivers and stressors) which would be impacting on the measured changes to vegetation attributes over time. An additional factor that was considered was the range experience of the volunteers in species identification and survey methodology, which may have affected the quality of the data collected. Various mechanisms were applied in the study to counter these shortcomings, enabling the changes in data and condition indicators in each plot to be interpreted over time.

The review initially aimed to identify the degree of variability in the data that corresponded to changes in drivers and stressors. Following that, the review aimed to identify whether the remaining variability corresponded to other defined factors including experience levels of the volunteer groups, seasonal weather variability and most specifically, to management actions applied during the course of the monitoring program (burning, revegetation and removal of woody weeds). The results were then used to identify how change at a plot level may be interpreted. Confidence intervals were calculated around variability in key drivers and stressors. Then the attributes (identified in the analysis) that best reflect changes in condition over time were applied to describe changes in condition in each plot. These results are presented in Chapter 4.

3.2 OBJECTIVES

The objectives of this study were:

1. To identify the main characteristics of the monitoring plots, including initial condition.
2. To identify the importance of the following drivers in relation to change in condition of plots over time:
    a. Differences in responses of plots according to the vegetation associations and/or vegetation structural formations present in each plot;
    b. Seasonal climatic variation measured as root zone soil moisture levels; and
    c. Potential variation in the quality of the data collected.
3. To identify the attributes that provide the most accurate and functional measures of condition of the plots.
4. To use these measures of condition to investigate the changes that correspond to management actions applied during the monitoring period.

3.3 METHODS

3.3.1 Surveys included in the analyses

The data included in the analyses were sourced from 108 Vegwatch surveys carried out between 2012 and 2018 in 31 plots located in 20 sites, 14 of which were in ACT and 6 in surrounding NSW (Table 3.1). In the majority of sites, only one monitoring plot was established.

Data from some plots from the Vegwatch program were not included in the analyses: data collected in 2011 in three plots to trial methods were excluded, because the methods varied slightly from surveys undertaken from 2012 onwards. All data from five plots were excluded as the data were deemed to be incomplete or inaccurate and from two additional plots as the data were not available in time to be included.

The nature of the program, that it is guided by the needs of the participants, meant that the monitoring plots were not all established at the same time; new Vegwatch monitoring plots were established each year until 2018 (Tables 3.1, 3.2). Following commencement of the monitoring of the plots, some plots were not surveyed every year and some monitoring projects ceased before 2018. As a result, there were annual survey data from approximately 2/3 of the plots for each year (Table 3.2). Eighteen plots were monitored five or more times. One plot was surveyed once in 2014 and 13 plots were monitored only twice, 11 of these commencing in 2017 and 2018. Inclusion of these plots with limited or no replication over time constrained the inferences that could be drawn from the results of the analyses.

One of the questions identified for investigation was whether the data collected by citizen scientists was of varied quality, thus compromising the strength of statistical analyses. Additional data from 36 surveys in seven plots that was measured using the same methods and surveyed by professional ecologists as part of government monitoring programs were included in the analyses (Tables 3.1, 3.2): from four plots in the Molonglo River Reserve monitored by Parks and Conservation Service (ACT Government 2018), and from three plots monitored by Conservation Research in the Environment, Planning and Sustainable Development Directorate. For ease of differentiation, the sources of the data were included in the plot names: those surveyed in Molonglo are indicated with a M, those by Conservation Research by a C and Vegwatch plots are indicated by a V, for example the Conservation Research Plot Mount Painter Plot 1 is annoted to MPA_C_1, and the Vegwatch Mt Painter Plot 1 is annotated to MPA_V_1 (Table 3.1).

The final data set used for analyses, therefore, comprised data from a total of 144 surveys in 38 plots monitored between 2012 and 2018 (Table 3.2). Species cover was not surveyed in every plot each year, so there was a reduced data set available for analyses based on cover (from 115 surveys).

3.3.2 Data included in the analyses

Data were generally measured in spring, between late October and mid-December. The four cool burn plots (seven plots in four sites) were established and initially surveyed in March and April 2018, and the burns were undertaken in late winter of 2018. In these plots, the pre-burn data were deemed to be most similar to data from the previous spring/summer growth period, so were defined as having occurred in the 2017 measurement period.

Survey data were measured within a permanently marked 0.1 ha plot (generally 20m x 50m); species richness and abundance of plants more than 2 m in height were assessed in the 0.1 ha plot; plants less than 2 m in height were surveyed in a 0.04 ha sub-plot (generally 20m x 20m) (Table 3.3). If no vegetation over 2 m occurred in the plot only the 0.04 ha sub-plot was established. Species cover was measured at 80 to 100 points along transects in or at the border of the plot.

Species abundance or presence data only (in some surveys) were measured at each event. Cover values for groundstorey variables were collected in most years. Other variables used to calculate other condition indicators including mid- and upperstorey vegetation cover were collected once or more during the survey period (Table 3.3). A summary of the methods used, and data collected are in Table 3.1 and more fully described in Sharp and Gould (2014).

Some data collected in the surveys were not included in the analyses as the data were unreliably collected, and at times inaccurate. These data included structural diversity, terrestrial condition diversity and condition of native trees and shrubs. Additionally, cryptogam cover was considered in many cases to be inaccurate, as it was likely that in most cases only highly visible lichen or mosses would have been recorded as cryptogams.

Table 3.1 Characteristics of the plots included in the statistical analysis. Vegetation that meet the criteria as endangered ecological communities in one or more surveys are indicated in bold. Full names of the vegetation associations and vegetation structural forms included in the analysis are in Table 3.8. SJW: St John's Wort; ST: Serrated Tussock.

Site	Plots	Monitoring period	Vegetation association	Vegetation structure	Management being monitored
Vegwatch plots					
Aranda Bushland NR	ASG_V_1	2013-2016	SGW	GW	SJW control
Black Mountain NR	BLM_V_S BLM_V_C BLM_V_A	2014-2018 2013-2018 2013-2018	RSF	FOR	Control burn 2014 None Control burn 2012
Bullan Mura Yarralumla	BMY_V_1 BMY_3	2014-2018 2017-2018	**YBRG** **YBRG**	GW GW	Woody weeds 2014 Cool burn 2018
Captains Flat cemetery	CFC_V_1	2014, 2016	SGCBW	FOR	No mgmt
Captains Flat property	CFH_V_1	2014-2016	NG	GL	Woody weeds 2015 Livestock
Cooleman Ridge NR	CRA_V_2 CRD_V_1	2011 -2018 2014-2018	**YBRG** YBRG	GW DerGL	Control burn 2017 SJW control
Icon Water Williamsdale	IWW_V_1 IWW_V_2	2017-2018	**YBRG** **YBRG**	GW GW	Cool burn 2018 ST control 2018
Isaacs Ridge NR	ISR_V_1	2012-2016	NG	DerGL	SJW control
'Millpost' Bungendore	MLP_V_1 MLP_V_2	2017-2018	BGSOF	SW	Cool burn 2018 Livestock occasionally
Mt Ainslie NR	MAI_V_1	2012-2014	EPN	SW	Reveg: shrubs, trees 1980s
Mt Majura NR	MMA_V_1	2014-2016	**YBRG**	GW	Revegetation: forbs 2013
Mt Painter NR	MPA_V_1 MPA_V_2R MPA_V_2C MPA_V_3	2012-2018 2012-2018 2013-2018 2013-2018	**YBRG** NG NG **YBRG**	GW DerGL DerGL DerGL	Weed control Revegetation: forbs 2011 Control plot Control burn 2014
Royalla Swainsona Reserve	RSR_V_1	2014	MBSF	SW	Revegetation, date unknown
St Marks Grassland	STM_V_1	2017-2018	**NTG**	GL	Ecological burn 2018
Tennant St Fishwick	TSF_V_1	2017-2018	**NTG**	GL	No mgmt
The Pinnacle NR	TPI_V_1	2012-2018	EPN (**YBRG**)	SW	Revegetation: woody 1980s, forbs 2011
Tuggeranong Hills NR	TUH_V_1	2017-2018	**YBRG**	GW	No mgmt
Umbagong G'l Latham	UMG_V_1	2015, 2018	**NTG**	GL	Ecological burn 2018
'Wandiyali' Googong	WAN_V 1 WAN_V_2	2017-2018	**YBRG** YBRG	DerGL DerGL	Cool burn 2018 No mgmt
Yarramundi Grassland	YAG_V_1 YAG_V_2	2017-2018	**NTG** **NTG**	GL GL	Control burns 2011, 2017
ACT Government plots					
Kama NR	KA1_M_1 KB1_M_1	2013-2017	**NTG** **YBRG**	GL GW	Weed control
Molonglo River Reserve	MD1_M_1 MK2_M_2	2013-2017	YBRG NTG	DerGL GL	Weed control
The Pinnacle NR	TPI_C_1	2013-2018	**YBRG**	GW	Weed control
Mount Painter NR	MPA_C_1	2013-2018	**YBRG**	DerGL	Weed control
St Marks Grassland	STM_C_1	2012-2015	**NTG**	GL	Ecological burn 2014

Table 3.2. Numbers of plots included in analyses, indicated by the source of the data (Vegwatch or ACT Government programs) and the number of plots surveyed in each year.

Year		2012	2013	2014	2015	2016	2017	2018	total
Vegwatch plots surveyed total (N=31)		6	11	18	14	16	19	24	108
ACT Gov't plots surveyed (N=7)		1	7	7	7	6	6	2	36
Total plots surveyed (N=38)		7	18	25	21	22	25	26	144

Table 3.3. Metrics and methods used to collect data used in the analysis of condition.

Metric	Frequency	Method
Plant species richness	Annually	Native and introduced species in the plot and sub-plot, including their abundance assessed in four classes (Abundant: >75% cover; Common: >25 – 75% cover; Occasional: >0 – 25%, more than 3 specimens; Rare: less than 3 specimens); on some occasions only presence data were recorded.
Groundcover	Annually	Herbaceous vegetation grouped by native grasses, native sub-shrubs, other native forbs, introduced perennial and introduced annual grasses and forbs, bare earth, litter, cryptogams and rocks tallied at intervals along transects within or on the boundary of the plot; multiple attributes may be scored at a single point.
Upper and mid-storey cover	Initially, then every few years	An estimate of percentage foliage cover of native and introduced mid-storey and upper-storey cover along the transect at ten points.
Structural variable	Initially, then every few years	The total length of fallen timber over 10 cm in diameter within the plot. The count of trees with hollows. Regeneration stages present.

3.3.3 Data preparation

Prior to analyses, data were standardised to correct for slightly different methods being used, and because there were issues related to species identification and recording practices.

Standardisation of species data

Various types of inconsistencies occurred across all surveys, regardless of the source of the data. Some revisions required a level of interpretation, and this was implemented according to the criteria defined below.

1. Inconsistencies in taxonomy were corrected.
2. All sub-species references were removed unless a particular sub-species was obviously different from other species also recorded (for example, all records of *Eucalyptus macrorhyncha* subsp. *macrorhyncha* was amended to *E. macrorhyncha*).
3. Obvious misidentifications were amended.
4. An additional category of '<u>Lomandra bracteata coriacea</u>' was introduced and applied to all records of *Lomandra* sp., *Lomandra filicaulis* and *L. bracteata*, as these are frequently misidentified.; it is less likely to include specimens of *Lomandra filiformis* subsp. *filiformis*, as this has distinctly different coloured and sized leaves than the other two small *Lomandra* species. If several species were surveyed in one site they were identified as Lomandra sp. 1, Lomandra sp. 2 etc.
5. Grouping by genus. This practice is applied by many surveyors for species that are difficult to identify in the field. This includes species in the genera *Trifolium*, *Rytidosperma* and *Wahlenbergia*, but other species are also often only identified to genera (e.g. *Vulpia* sp. or *Bromus* sp.). If it was deemed that they had the same origin (native or introduced) and the same growth form they were combined, for example *Bromus* sp., *Vulpia* sp. and *Avena* species. If more than one species of these genera was recorded at a plot they were identified as sp. 1, sp. 2, or where it was likely there were more than one species, as multiple species (spp.).
6. Species that were not identified in the field and could not be retrospectively identified were collated into four groups: unknown native grass, thistle, unknown introduced species, unknown native species.

The output of 373 species was collapsed to 345 species or genera and four groups of unidentified species:

Standardisation of cover/abundance classes

To reduce the amount of decision making required by the volunteers, in Vegwatch, species cover/abundance data are allocated to one of four classes (Table 3.4), based on a merged form of the Braun-Blanquet cover classes (Hnatiuk et al., 2009). Additionally, in some years some Vegwatch participants only recorded species presence. ACT Government metrics include the measurement of cover/abundance based on the seven classes of the Braun-Blanquet measure.

An abundance score needed to be retrospectively applied to species data in which no abundance score was recorded. An abundance rating of Occasional (up to 25% cover), was imposed in the majority of cases, as this range of values (>0 to 25% cover, more than 3 specimens) covered the greatest majority of records of abundance across sites and species. Another rating could be applied if there was good reason from other records of that species that another rating was more appropriate (for example, if all other measurements at that plot had recorded an abundance rating of Rare for that particular species, it would be recorded as Rare).

The seven Braun-Blanquet classes used in the government surveys were grouped into the four abundance classes that were applied in the Vegwatch surveys (Table 3.4), so only ratings for those four classes were applied when assessing floristic value scores.

Although not set up to be used for forested or shrubby woodland communities, floristic value scores (FVS) (Rehwinkel 2015) were calculated for surveys from all vegetation plots to provide a comparison of all data across all plots. Almost all species within the surveys in forest were already listed in the spreadsheet used in ACT studies to calculate FVS. The calculation applies a different weighting to a species depending on its abundance based on the seven classes of the Braun-Blanquet score (Table 3.4). Reducing the scores to four classes, therefore, meant that the FVS scores for ACT Government plots as applied in this study may not correspond exactly to the scores applied in their own analyses.

A detailed explanation of how the calculations for FVS and the score against benchmark condition (BENCH) are derived is provided in the Appendix.

Many Vegwatch participants found it difficult to estimate cover/abundance classes, even when using only four classes. Therefore, the data were also converted to presence only, to identify whether abundance records provided additional information to presence only records, which do not have the added issue of applying a relatively subjective value.

Table 3.4. Standardisation of abundance classes for this study

Braun-Blanquet classes (quantitative classes recorded)	Cover-abundance (modified Braun-Blanquet) (ACT Government data)	Vegwatch abundance classes	Standardised abundance scores used in this study
r (1)	<5% cover, 1 to 3 specimens	Rare (<5% cover and <4 specimens	1
+ (2)	<5% cover, up to 15 specimens	Occasional (<25% cover, and 4 or more specimens)	3
1 (3)	<5% cover, >15 specimens		
2 (4)	5 – 25% cover		
3 (5)	>25 – 50% cover	Common (>25-75% cover)	5
4 (6)	>50% – 75% cover		
5 (7)	>75% cover	Abundant (>75% cover)	7

Calculation of vegetation attributes

The attributes used to evaluate their value as condition indicators were either derived or calculated from the metrics are presented in Table 3.5. These attributes are those commonly applied in other monitoring or assessment studies (for example, as used for the Molonglo River monitoring assessment (ACT Government 2018).

Table 3.5. Metrics used to calculate quantitative attributes

Metric	Attributes calculated from metrics (code used in text)	Data used
Native species richness and abundance	1. Native species richness (NSR) 2. Number of important (indicator) species (BGW Critically Endangered Community criteria, Australian Government 2005) (INDI) 3. Native floristic score (Rehwinkel 2015) (NFS) 4. *Themeda triandra* (Kangaroo Grass) abundance (THEM)	Data from all surveys (n=144)
Introduced species richness and abundance	5. Introduced species richness (ISR) 6. Introduced floristic score (Appendix) (IFS)	Data from all surveys (n=144)
Percentage groundcover	7. Proportion of perennial groundcover that is native (PROP_NC) 8. Total native groundcover (NC) 9. Native forb and sub-shrub cover (NFC) 10. Native grass cover (NGC) 11. Introduced annual groundcover (AIC) 12. Introduced perennial groundcover (PIC) 13. Bare earth cover (BEC) 14. Fine litter cover (LITC)	Data from a sub-set of surveys (n=115)
Percentage overstorey cover	15. Native overstorey cover (NOSC)	Data from a sub-set of surveys (n=115)
Native species richness Native mid- and upper-storey cover Ground cover grasses Ground cover shrubs	16. Condition score against reference (benchmark) score (Appendix; Gibbons et al. 2008 DECCW 2011) (BENCH)	Data from a sub-set of surveys (n=115)

Metric	Attributes calculated from metrics (code used in text)	Data used
Ground cover other (forbs) Introduced mid- and under-storey cover No. of large trees or trees with hollows Proportion of overstorey regenerating Length of fallen timber		

Calculation of other variables

Potential drivers or other factors were tested whether they influenced changes in condition:

1. Vegetation association (based on ACT Government 2017a);
2. Vegetation structure (Hnatiuk et al. 2009);
3. Surveyor experience;
4. Root zone soil moisture levels; and
5. Management applied (and the dates of management interventions were identified).

Vegetation association and vegetation structure

Vegetation associations based on ACT Government (2017a) and vegetation structure were identified from the data and/or checked with the monitoring groups or against existing records such as ACTMapi (http://www.actmapi.act.gov.au).

Surveyor experience

To test whether a lack of scientific experience of the participants could result in data of lower quality (accuracy and reliability) which then may compromise the results, three classes of experience were defined. No data was included that was considered to be compromised in terms of accuracy.

Level 1: Vegwatch surveyors with moderate species identification skills and/or low experience in scientific methodology (data from 10 surveys);
Level 2: Vegwatch surveyors with good species identification skills and extensive experience in scientific methodology (data from 41 surveys); or
Level 3: Government and government contracted ecologists (data from 33 surveys).

A sub-set of Vegwatch data was used in the comparison so that all data included were from the same years (years 2013 to 2017) and only plots in grassland, grassy woodland and derived grassland were included. Additionally, only data from plots with a similar range of native species richness was recorded, thus excluding several with very low species richness (i.e. plots in very poor condition). Eighty-four surveys were included in this analysis.

Soil moisture availability

Root Zone Soil Moisture is the percentage of available water in the top 1 m of the soil profile. The shallow and deep-rooted vegetation can both draw on this combined layer. Actual soil moisture grids estimate the percentage of available water content rather than total soil water volume; a value of 0 represents no available moisture in the soil and 100 represents total available moisture in the soil (http://www.bom.gov.au/water/landscape accessed 2019).

The monthly root zone soil moisture data in the top 1 m of the soil profile were obtained from records for the Canberra Airport (S35.3 and E149.0) at http://www.bom.gov.au/water/landscape, accessed 2019). To calculate a root zone soil moisture value for each year related to the timing of the surveys the values for each month between July and November (i.e. the months most affecting growth of species) were averaged to derive the root zone soil moisture index for each year. Years 2012, 2013, 2014 and 2015 experienced average soil moisture availability, 2016 was well above average, 2017 was below average and 2018 was well below average (Table 3.6). More details on how soil moisture availability is calculated, accessed from the BOM website, is in the Appendix.

Table 3.6. Soil moisture availability collated from data from Canberra Airport. The annual figure is calculated from the average soil moisture availability for each of the months, July to November, representing the main growth period.

Year	Percentage soil moisture saturation	Comparison to ACT long term average soil moisture
2012	49.7%	Average
2013	33.8%	Average
2014	35.7%%	Average
2015	40.4	Average
2016	91.1%	Well above average
2017	26.9%	Below average
2018	3.0%	Well below average

Management information

Information on management applied in the sites was provided by the Vegwatch groups and others and various ACT Government resources such as ACTMapi (http://www.actmapi.act.gov.au/). Management was defined as interventionist management if the application of management caused a significant change to biomass and/or caused an applied change in species composition (revegetation). Other management that has a less immediate influence on biomass, such as spot spraying or hand weeding was defined as incremental management, and may include no management actions being applied if not required.

3.3.4 Statistical analyses

Data sorting was undertaken in the MCG Vegwatch database and in Microsoft Excel (Office 365).

Multivariate statistical analyses were undertaken by Dr Jessie Au, Division of Ecology and Evolution, Research School of Biology, ANU College of Science, with advice provided by Dr Danswell Starrs, ecological statistician, ACT Government. The multivariate analyses were undertaken in the R statistical environment (R Core Team 2019). Additional exploratory analyses were undertaken using the multivariate analysis program, Primer (Multivariate Analysis for Ecology, https://www.primer-e.com) with the assistance of Dr Jane Roberts, ecological consultant. Descriptive statistics and univariate regression and correlation analyses were undertaken in Excel (Data Analysis package 2016, downloaded 2019).

Exploration of patterns in the data

Hierarchical cluster analysis was performed on the species abundance data and converted presence only data to investigate how sites clustered based on the species composition. R packages "stats" and "dendextend" were used.

Principal components analysis (PCA) was performed to determine which attributes (Table 3.5) influenced how the surveys were grouped in the cluster analysis and their level of influence on the groupings. Cover data for groundstorey species (used to calculate attributes 7 to 14 (Table 3.5)) were not available for the 16 surveys undertaken by Conservation Research and were not collected in 13 surveys undertaken by Vegwatch participants. Therefore, two PCA analyses were undertaken: using data from 115 surveys for all 16 attributes that required species cover measurements as well as abundance or presence data; and data from all 144 surveys for six attributes (Table 3.7). Patterns in the data were also investigated using R packages "FactoMineR" and "factoextra" to investigate if the clustering could be explained by other attributes including vegetation structure and the soil moisture index.

Table 3.7. Number of surveys for which data were available for analyses for all 16 attributes (Table 3.5) or for a subset that excluded attributes requiring cover data.

Source of data	Cover and abundance data, 16 attributes	Abundance data, 6 attributes
Vegwatch	95	108
Molonglo	20	20
Cons Research	0	16
Total number of surveys	115	144

A correlation matrix was used to investigate correlations between the 16 attributes using the R package "PerformanceAnalytics". The correlated attributes were also graphed on scatterplots to review their relationships beyond the general linear relationships identified by correlation analysis.

Box and whisker plots of the species abundance data were calculated against five independent drivers (soil moisture levels, experience level, management type, vegetation association and vegetation structure) using the entire data set from 144 surveys. These were used to identify whether any attributes reflected trends in the data at the broad scale.

Further investigation of the multivariate data undertaken in Primer investigated patterns in the data in sub-groups of plots. Sub-groups included native species only, species with frequency across all surveys greater than 1, 2 and 10 and woodland and grassland sites only. Non-metric MDS was used to consider relationships between survey data and selected variables.

Correlation between variables

Linear regression analysis was used to determine whether statistical relationships could be identified between independent variables and selected vegetation attributes. Correlation analysis was used to identify relationships between the vegetation attributes for plots grouped by structural formation and condition and tested using Analysis of Variance for significance level of relationships. Other data were compared using box and whisker plots.

These analyses were undertaken within the Excel Data Analysis package (2016).

3.4 RESULTS AND DISCUSSION

3.4.1 Vegwatch plot characteristics

The descriptive characteristics of the 108 surveys from the 31 Vegwatch plots and the 36 surveys from the seven ACT Government plots are summarised in Table 3.1. Although the Vegwatch program monitored within seven vegetation associations and two degraded associations, the sampling effort across these was uneven. The majority of the plots occurred within two vegetation associations – Natural Temperate Grassland and Yellow Box -Blakely's Red Gum woodland (24 out of the total 38 plots), but plots occurred within three other woodland associations, two forest associations and two modified vegetation types (Table 3.8). Three associations were only monitored in one plot, and five were only monitored in one site. Five structural formations were represented, including native grassland (18 plots, of which 10 were derived grassland), grassy woodland (11 plots), shrubby woodland (5 plots) and forest (4 plots).

Eleven Vegwatch plots and three ACT Government plots met the criteria as critically endangered White Box - Yellow Box - Blakely's Red Gum Grassy Woodland (Australian Government 2005) and four Vegwatch plots and two ACT Government plots met the criteria as critically endangered Natural Temperate Grassland of the South-Eastern Highlands (Australian Government 2016) (Table 3.1).

Table 3.8 Vegetation associations and vegetation structure included in the analysed plots.

Vegetation association	Vegetation structure	Vegwatch plots (sites)	ACT Govt plots (sites)
Natural Temperate Grassland (NTG)	Grassland (GL)	5 (4)	3 (3)
Yellow Box- Blakely's Red Gum +/- White Box tall grassy woodland and derived grasslands (Yellow Box – Red Gum woodland (YBRG)	Grassy woodland (GW) Derived grassland (DerGL)	8 (6) 4 (3)	2 (2) 2 (2)
Snow Gum mid-high grassy woodland (Snow Gum woodland SGW)	Grassy woodland (GW)	1 (1)	
Mealy Bundy – Broad-leaved Peppermint shrubby mid-high open forest (Mealy Bundy shrubby forest MBSF)	Shrubby woodland (SW)	1 (1)	
Brittle Gum-Scribbly Gum shrubby tall dry open forest (Brittle Gum shrubby open forest BGSOF)	Shrubby woodland (SW)	2 (1)	
Red Stringybark – Scribbly Gum – Red-anthered Wallaby Grass tall grass-shrub dry sclerophyll open forest (Red Stringybark dry sclerophyll forest RSF)	Forest (FOR)	3 (1)	
Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies (Snow Gum – Candlebark tall woodland SGCBW)	Forest (FOR)	1 (1)	
Environmental native plantings (ENP)	Shrubby woodland (SW)	2 (2)	
Native grassland (NG)	Derived grassland (DerGL)	4 (4)	

Management actions applied in the plots

Management actions applied to the plots just prior to and during the monitoring period are listed in Table 3.1. More information on management applied in the individual Vegwatch plots is in Chapter 5.

Interventionist management undertaken in the plots during the period included burning, woody weed control and revegetation. Control burns for ecological outcomes or wildfire mitigation, or cool (cultural) burns were undertaken between 2011 and 2018 in 11 Vegwatch plots. All but one plot was monitored prior to the burns as well as following the burns. Data have been collected for up to five years following a burn, although six of the plots were most recently burnt in 2018, so post burn information for those plots is limited to one survey, limiting opportunities to interpret the changes. Extensive woody weed control occurred in two plots during the survey period. Five plots had been revegetated with trees, shrubs and/or forbs prior to the monitoring having commenced.

Incremental management (see 3.3.3) applied in the plots included ongoing grazing, weed control targeted to specific species and general weed control. Two plots were subject to on-going grazing by livestock. All the plots were accessible to kangaroos. Intensity of grazing by herbivores varied across the plots. General weed management was undertaken in the majority of plots over the period from 2012 to 2018. Four plots were subject to specific weed control, for St John's Wort and Serrated Tussock. No active management was applied in the remaining four plots, although grazing by kangaroos and rabbits was likely occurring to some extent.

3.4.2 Identification of key drivers

Relationships between the plots according to vegetation structure and associations

The Vegwatch plots were established by the participants to investigate changes in condition as a result of their activities, therefore there was no a priori designation of replication of the main primary drivers (landscape, vegetation associations and past management history and disturbance). In addition, monitoring projects were established at sites in different years. This significantly limited the ability to undertake detailed, balanced analyses using the drivers as variables. Therefore, initially, multivariate analyses were used to detect the key relationships between all the plots based on species data, and to identify the major factors relating to those relationships. Differentiation at this level could then be used to enable further investigation to clarify changes in condition.

Cluster analysis of the species data from all surveys (plot by year) was undertaken to determine if patterns were evident. Initially the analyses were undertaken using all species data (349 species or groups) from all 144 surveys from the 38 plots. Dendrograms were produced using species abundance data and also using the species data converted to presence/absence data (produced in R code).

A very clear pattern was evident at the plot level: almost all surveys within a plot were grouped together, and plots within a site were generally grouped closely. Surveys from three sites (three plots in one site (Black Mountain forest plots), all but one survey from another plot (The Pinnacle planted shrubby woodland) and the single survey from Royalla, Figure 3.1)) were consistently differentiated from each other and the rest of the surveys in all iterations. Analyses using presence only data had similar outcomes as using abundance data, indicating that abundance was not a differentiating factor.

Several more iterations were undertaken in Primer using sub-sets of the plots and species data to test if other relationships could be identified: plots containing grassy ecosystems; records of native species; and species that were recorded a minimum of 10 times across all surveys. Cluster analysis using all data sets and only species that occurred more than 10 times across the surveys showed the clearest differentiation of plots was based on vegetation structure. Even so, fidelity remained similar to the analysis using all data, indicating that species with low frequency were not contributing to the clustering. Cluster analysis using native species also provided no clearer differentiation. Several iterations demonstrated a weak fidelity of plots with lower native species richness and cover.

Multi-dimensional scaling (MDS) using abundance data reiterated these same results (Figure 3.2), indicating grouping of the forested plots (three plots from Black Mountain Nature Reserve and to a lesser extent the other forested plot, from Captains Flat Cemetery) and looser grouping the plots containing shrubby vegetation. There was considerable overlap between the shrubby and grassy sites, with or without trees. The same MDS analysis classified the plots by vegetation association, but these were not differentiating features of the clusters (not shown).

The major factors driving grouping in the clusters was therefore determined to be individual plots and structural formations (forest, to some extent shrubby woodland, and grassy ecosystems).

Seasonal climatic variation measured as soil moisture levels

The high level of fidelity of surveys within plots indicated that the grouping based on species data from all the plots was not strongly influenced by temporal factors (indicated by the year of the survey in the plot titles), which in turn reflect the soil moisture conditions (Figure 3.1).

To determine how much influence relative available soil moisture related to changes in vegetation attributes in relation to plots grouped by structural formation, regression analysis of the vegetation attributes against the annual soil moisture levels was calculated (Table 3.9). Attributes based on cover data were not calculated in the regression analysis for plots within forests because the introduced species cover was so low. In Table 3.9 the slope of the regression is shown as positive (+) or negative (-). The statistical significance of these results should be treated with caution, however, and interpreted as suggestive of relationships.

The results indicated that there was a positive relationship within the woodland and grassland formations between most introduced vegetation attributes and soil moisture levels, particularly in shrubby and grassy woodlands. Introduced species richness increased as soil moisture levels increased in all but forest, particularly within woodland formations. Introduced annual cover increased as soil moisture levels increased in all non-forested formations. In grassy woodland introduced perennial herbaceous cover also increased as soil moisture levels increased, but not in shrubby woodland or derived or natural grassland.

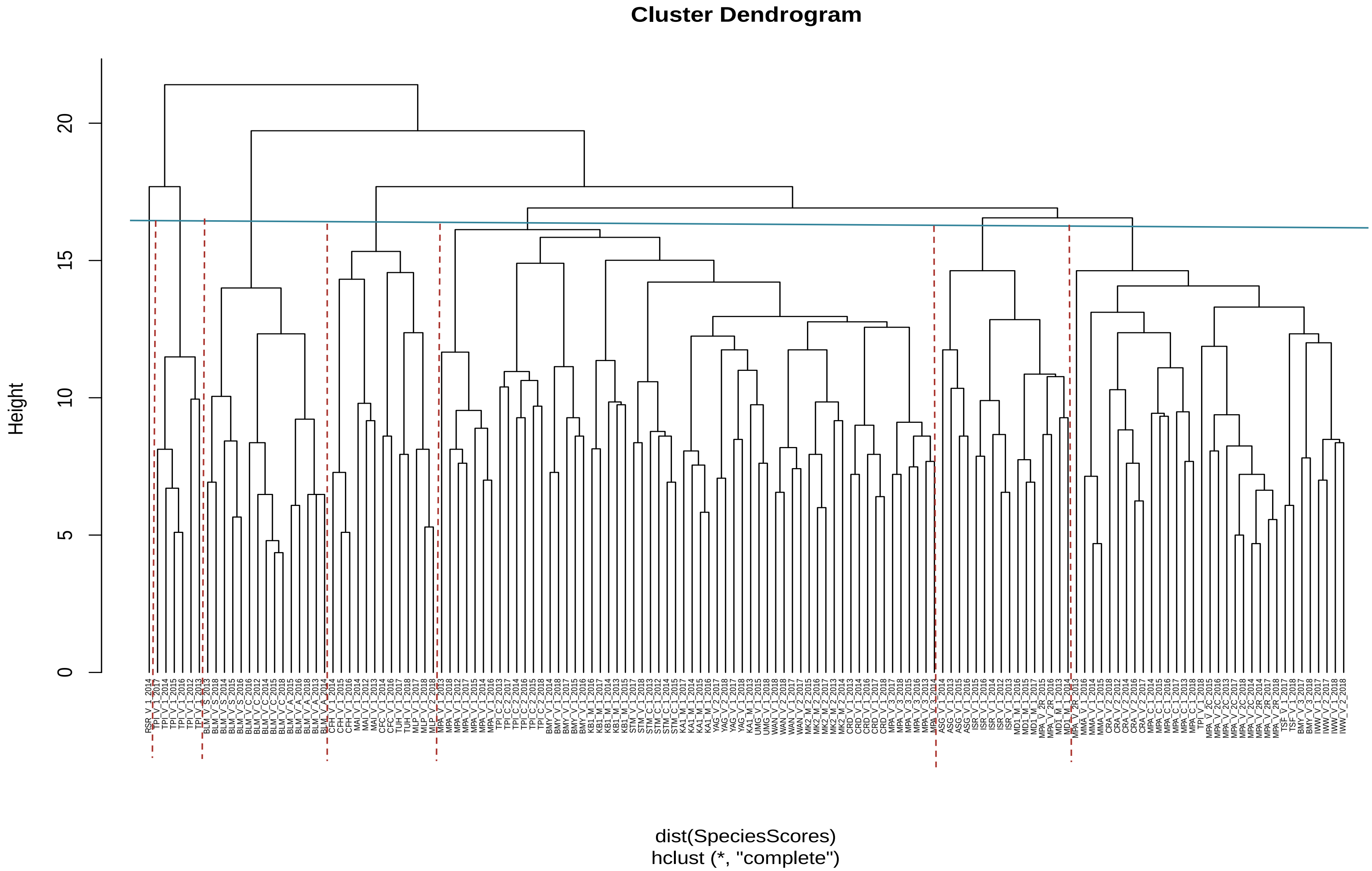


Figure 3.1. Cluster analysis of all species data from all plots, analysed as abundance data. The lack of pattern is clear, beyond the strong fidelity of individual surveys within plots. Plots surveyed by ACT Government are indicated with a C or M following the site and plot code, Vegwatch plots by a V.

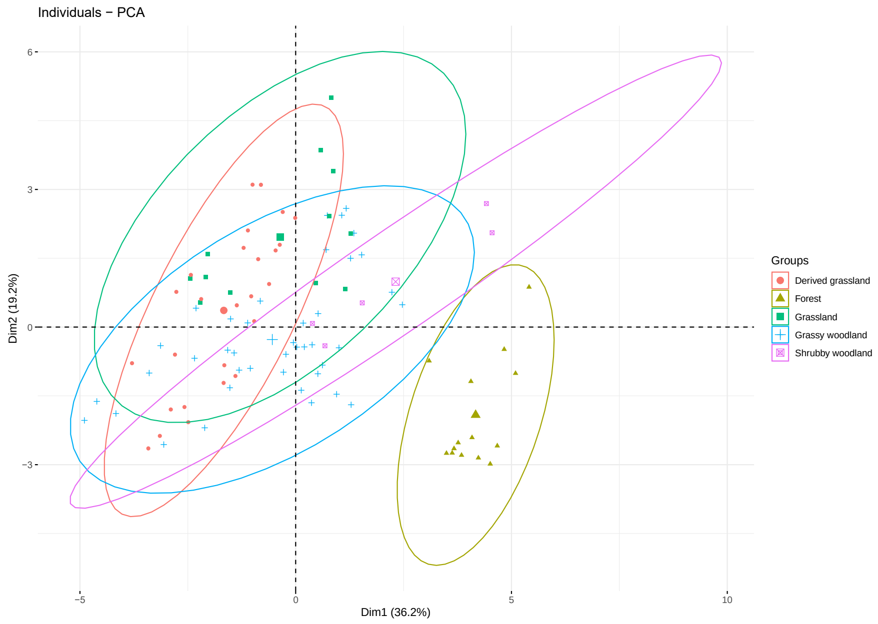


Figure 3.2. MDS of the species data grouped by structural formation. The plots on the positive side of Dimensions 1 contain a higher native species richness and cover; those on the negative side of Dimension 2 contain a higher proportion of introduced species richness. The only group that is clearly different is the forested communities, in Black Mountain.

While there was a positive trend between native species richness and soil moisture levels in all structural formations except grassland, only the proportion of native groundcover in grassy woodland had a significant, negative, relationship with levels of soil moisture, presumably influenced by the relationships between soil moisture and increased introduced perennial cover.

Table 3.9. Regression analysis of soil moisture levels compared to survey data grouped by structural formation for selected vegetation attributes. Empty cells indicate attributes that were not relevant or could not be calculated for that structural formation due to low values or inadequate samples. The slope of the regression is indicated as positive (+) or negative (-) where significant relationships were identified.

Vegetation attribute	Grassy woodland	Derived grassland	Grassland	Shrubby woodland	Forest
Native species richness	NS	NS	NS	NS	NS
Native groundcover	NS	NS	NS	NS	
Proportion of native groundcover	- **<0.001**	NS	NS	NS	
Introduced species richness	+ **<0.001**	+ **0.05**	NS	+ **0.001**	NS
Introduced annual cover	+ **<0.001**	+ **0.01**	+ **0.02**	+ **0.006**	
Introduced perennial groundcover	+ **<0.001**	NS	NS	NS	

Surveyor experience

Plots surveyed by ACT Government ecologists (experience level 3), indicated by the initial 'M' or 'C' in the plot name (e.g. MPA_1_C_2014) were not differentiated by clusters in the dendrogram (Figure 3.1). The cluster analysis did not demonstrate any level of grouping of plots surveyed by the three classes of experience: Further, there were no significant associations determined by regression analysis between the level of experience and the resulting values in the surveys, as indicated against five vegetation attributes in Table 3.10.

A further sub-set using all the data only from one year was analysed, to determine if differences in values of attributes may have been compromised by other factors. Data from 2017 was chosen as there were a high number of surveys undertaken, including surveys from six ACT Government plots and it was a year of low soil moisture, meaning identification of species was made more difficult due to reduced growth and flowering. These analyses also showed no significant differences in the data collected by Vegwatch participants and ACT Government ecologists (Table 3.10).

Table 3.10. Regression analysis of experience classes compared to vegetation attributes based on species presence and/or abundance in grassy ecosystems.

Experience analyses	Native species richness	Native floristic score	NTG indicator species richness	Introduced species richness	Introduced floristic score
Data 2013 to 2017, n=84	NS	NS	NS	NS	NS
Data 2017, n=25	NS	NS	NS	NS	NS

Discussion

The key drivers relating to changes in vegetation attributes identified in these analyses were plot fidelity, site fidelity, vegetation structure and soil moisture levels.

The characteristics of the groupings based on species data from all plots and surveys combined were difficult to explain. Surveys from each plot demonstrated strong fidelity based on species composition, which, given the lack of patterning related to external drivers such as geology, soils, landscape elements and current management interventions, is likely to be corresponding to their individual condition, reflecting unique past management and disturbance history. Beyond that, the only strong patterns of fidelity related broadly to structure: forested sites were separated out, and to some extent, shrubby woodlands; grassy associations, whether treed or not, did not demonstrate any clear differentiation.

On that basis, further analyses were undertaken on groups classified by structural formation. This grouping provided replication that was considered acceptable for further analyses.

Data were not clustered at all by the years the surveys were undertaken. The lack of grouping by seasonal conditions was unexpected, given the very variability in the seasonal conditions experienced during the seven years. However, soil moisture levels did influence individual attributes, particularly in relation to introduced annual cover, and in grassy woodlands, introduced perennial groundcover. There were no significant relationships between soil moisture levels and native species attributes. Decline in native species richness in grassland plots was evident when soil moisture levels were low (2017 and 2018), but regression analysis indicated that the variability between plots was high. No relationships between soil moisture levels and vegetation attributes were evident in forested plots.

The inclusion of data provided by ACT Government gave the opportunity to compare the data collected by volunteers with that of government ecologists. The participants in Vegwatch had a range of experience, although in the majority of cases there were one or more volunteers present with moderate to high skills in scientific methodology and botanical knowledge. In all cluster analyses plots were not separated out by experience levels. This was confirmed in the regression analysis of data restricted to similar ranges of native species richness, measured over the same years. No differences were detected between the data collected by Vegwatch participants and ACT Government ecologists.

It is therefore concluded that the data measured by citizen scientists were consistent with those of professional ecologists. This is even though it is likely that a greater number of species would be identified correctly by people with more experience in recognising species when the plant material lacks distinguishing features. It is probable that a low level of misidentification makes little difference in the resulting relationships and trends.

Minor errors and differences in observation of species present did occur but were not restricted to Vegwatch surveyors. These errors became evident when the data were compiled for analysis. Clearly, irrespective of who undertakes surveys, all data require checking prior to applications of analysis and interpretation, in case errors in identification or in recording have occurred. Anomalous data should then be interpreted with care or not included in analyses.

It is hoped that the results indicated in this study will encourage the utilisation of data collected by citizen scientists in broader studies.

3.4.3 Identification of key condition indicators

Principal Components Analysis (PCA) was undertaken using cover and richness data (a subset of 98 surveys). Many of the attributes were closely grouped (Figure 3.3). The groups of attributes influencing the patterns were, in order of their contribution to grouping in the cluster analysis:

1. Native grass cover (NGRC), Native groundcover (NGC), Themeda cover (THEM) and to a lesser extent, bare earth cover (BEC)
2. Benchmark value (BENCH), native species richness (NSR), native floristic score (NFS) and Indicator species richness (INDI)
3. Native overstorey cover (NOSC) and litter cover (LITC)
4. Introduced species richness (ISR) and introduced floristic score (IFS)
5. Perennial introduced groundcover (PIC) and annual introduced cover (AIC)
6. Native groundcover as a proportion of total perennial groundcover (PROP_NC)
7. Native forb cover

Correlation analysis was used to further investigate relationships between the vegetation attributes. A correlation score of greater than 65% was taken as a measure of moderate to high linear correlation. The initial analysis looked at correlations between the data of all the surveys combined. Several attributes were correlated within all plots across all formations, as was also reflected in the PCA of all the cluster analysis of all the data (Figure 3.3).

The attributes that were calculated from other attributes were strongly positively correlated. Included in this, there were strong relationships between native species richness and native floristic score (correlations of over 75%) and introduced species richness and introduced floristic score (correlations of over 70%). Similarly, the attributes NTG indicators and BGW indicators were also correlated with native species richness, and the number of introduced significant species was also correlated in some structural formation groups. Scatter groups indicated negative non-linear relationships between native and introduced attributes.

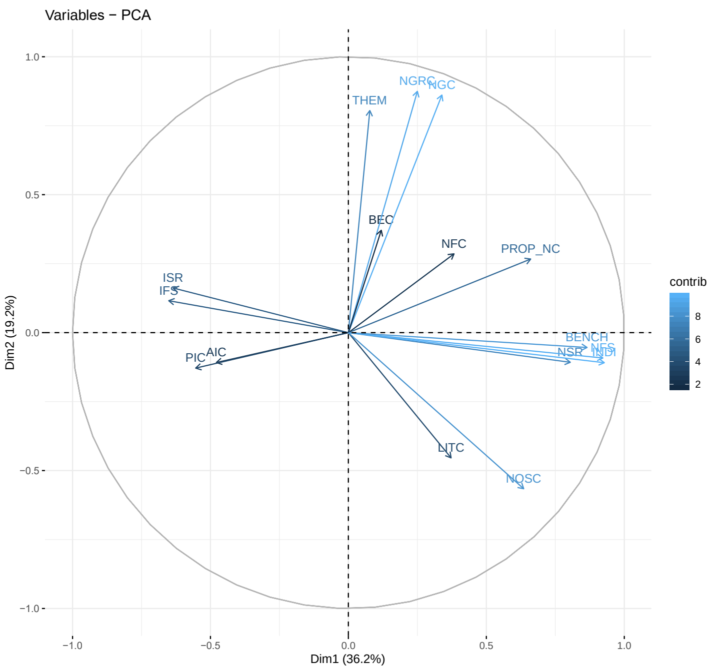


Figure 3.3. PCA of 98 surveys containing species abundance and cover data. Correlation between groups of attributes is demonstrated and the contribution of the attributes to the grouping in cluster analysis. The key to the attribute codes is in Table 3.2.

Table 3.11. The major relationships between vegetation attributes identified from correlation analysis and inspection of scatter plots.

Correlating attributes, with correlation co-efficient indicated		Data used in correlation analysis
Native species richness	Native floristic score (90%) BGW indicator richness (89%) NTG non-grass species (65%)	Combined, all structural groups
Benchmark score	Native species richness (75%) BGW indicator richness (84%) Native floristic score (83%)	Combined, all structural groups
Native ground cover	Native grass cover (94%)	Combined, all structural groups
Native overstorey cover	Native species richness (65%) BGW indicator richness (66%) Native floristic score (66%)	Grassy woodland, shrubby woodland
Introduced species richness	Introduced floristic score (89%)	Combined, all structural groups
Introduced species richness	Introduced floristic score (86%)	Shrubby woodland, derived grassland, grassland

Relationships between native and introduced species richness and cover

No linear relationships were identified between native species richness and cover and introduced species richness and groundcover attributes. However, scatter plots revealed non-linear relationships. To test this further, using data from grassy ecosystems, native species richness was plotted against introduced species richness and cover attributes (Figure 3.4). Native species richness of 2–12 species was classified as low; 13–19 species as moderate; 20–25 species as high; and over 25 species as very high (the maximum was 43 species).

Introduced species richness did not change with the level of the native species richness, indicating a level of independence between native and introduced species richness. Introduced perennial cover was more variable, but was lower in surveys with very high native species richness. Introduced annual cover was higher in surveys with low native species richness.

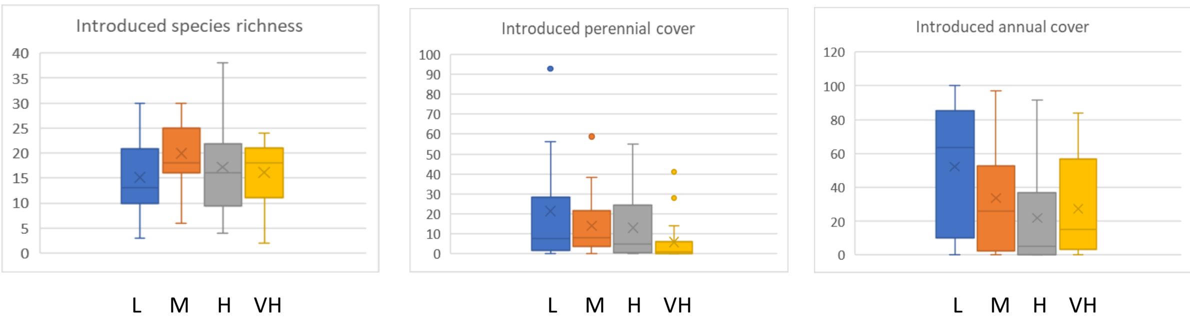


Figure 3.4. Comparison of attribute values and low (L), moderate (M), high (H) and very high (VH) native species richness of surveys within grassy ecosystem plots.

Discussion

The cluster analyses, ordination and correlation analyses demonstrated relationships between vegetation attributes as follows:

1. Native species abundance and composition and associated attributes including floristic score, benchmark scores and NTG and BGW indicator species were correlated;
2. Native understorey cover attributes were correlated;
3. Introduced species richness, floristic score and introduced floristic score were correlated; and
4. Introduced species attributes and native species attributes were not correlated, demonstrating that sites with high native species richness and/or cover did not necessarily contain a low introduced species richness and/or cover.

Relationships between introduced and native species richness and cover varied according to the structural formations, and there are discrepancies between different attributes, with some indicating positive and some indicating negative relationships. While relationships were evident between native and introduced values, the results indicate that changes in the native and introduced species composition and cover occur differently over time and as a result of past management and disturbance, other stressors and/or management applied. On the basis of these results it can be concluded that there is a broad level of independence between native and introduced species attributes. It is important to measure change in the condition of plots in terms of both native and introduced attributes.

Because of the strong correlations between groups of attributes, it is possible to decrease the numbers of indicators measured, calculated and applied. This provides the opportunity to select attributes that demonstrate change in condition on an annual basis, are the easiest to measure, most likely to be consistent across surveyors, and that are simple to calculate. This means that change in condition in plots can be calculated with less effort and more accuracy, so can be calculated more regularly. The indicators of condition recommended for inclusion for measurements annually and the metrics required to measure these are shown in Table 3.12.

Table 3.12. Metrics and condition indicators proposed for future application in Vegwatch.

Basic method: annual measurements	**Condition indicators**
Species richness: (presence data only) in a 0.1 ha plot	1. Native species richness 2. Invasive species richness 3. Structural diversity (documented species growth and life form used to calculate structural diversity score) 4. YBRG plots: Indicator species richness 5. NTG plots: Non-grass species richness
Transect: at 80 – 100 points within or bordering the plots, presence of groundcover attributes: Native grass cover, Native forb cover, Native sub-shrub cover, Introduced annual cover, Introduced perennial groundcover, Bare ground and/or algae, Cryptogams (excluding algae), and Litter cover Rocks (permanent non-vegetative cover)	6. Native groundcover 7. Introduced annual groundcover 8. Introduced perennial groundcover 9. Bare groundcover + other cover attributes to answer specific questions
Advanced method: initial, mid and final measurements	
Native species abundance (Braun-Blanquet) Benchmark/BAM attributes: Native overstorey cover Native mid-cover Introduced mid-cover Introduced overstorey cover No. trees with hollows Fallen timber (m) Habitat attributes	10. Floristic value score 11. Benchmark score 12. Habitat condition score
Revegetation (annual)	
No. plants x species: alive, dead, stressed	13. Revegetation success

Indicators of condition that change slowly over time are not as useful attributes to monitor regularly, and also proved difficult for Vegwatch participants to measure accurately (some were not included in the analysis because they were not accurate, including annual assessments of overstorey and mid-storey cover, structural diversity and habitat scores). It may be adequate to take measurements and calculate these indicators only at the initial and final surveys, although some may be measured more regularly if interventionist management will alter these attributes (such as resultant structural changes from woody weed control), others could be omitted. It is proposed that only participants with high levels of survey skills should undertake these measurements. These include:

1. *Species abundance* (using Braun-Blanquet classes) to calculate native and introduced species floristic value scores: used mainly to calculate the Floristic Value Score; requires estimates of cover that vary widely between surveyors;
2. *Floristic value score*: highly correlated with native species richness, does not provide added value, but is used in other studies, so could be included for comparative purposes; requires cover/abundance data;
3. *Overstorey and mid-storey cover*: estimates of cover vary widely between surveyors, change slowly over time (a more accurate and consistent method to measure this is required);
4. *Benchmark score*: some parameters used to calculate the benchmark score (e.g. length of fallen timber and number of trees with hollows) change very slowly, an overall score may be useful, but has limited value for non-woody vegetation; and

5. *Habitat diversity score:* changes slowly over time but consideration of particular habitat attributes that get low scores or may be missing can engender opportunities for habitat enhancement.

3.4.4 Changes in condition related to application of interventionist management

Management interventions applied to the sites just prior to or during the period of the monitoring included burning, extensive woody weed control, and revegetation of trees, shrubs and groundflora. Many sites were subject to on-going invasive species control and two plots also were subject to sheep or cattle grazing, one intermittently and one with an unknown regime. Probably all the plots were also subject to a variable (unmeasured) level of herbivory by kangaroos, rabbits and hares.

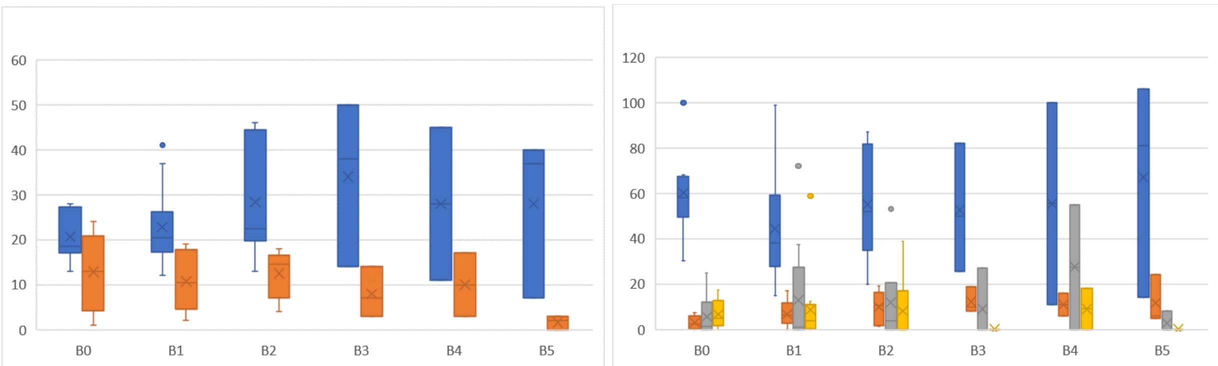
Management has the potential to change vegetation structure, abundance and composition. For the purpose of this analysis, plot management actions were grouped into 'interventionist' management that results in significant changes to structure and/or composition – burning, woody weed control, shrub and understorey revegetation (identified as interventionist management) – and 'incremental' management actions that had smaller impacts on vegetation condition. 'Other' management included on-going grazing by livestock and kangaroos, general weed control, no applied management, and established plantations or revegetation plots.

With the exception of burning management, few plots were subject to each management action, and there were differences in the years that management actions were applied in the plots and in the number of times the plots were monitored after the treatment (between one year and seven years). Therefore, it was not possible to undertake statistical analyses to identify any significant trends. All results are describing trends only.

Changes in condition indicators in burnt plots

To investigate whether there were trends in the response of selected vegetation attributes across 11 burnt plots, the data were grouped according to the time since burning (Figures 3.5A and B). Code B0 indicates before the burn; B1 means up to a year following the burn; B2 means up to two years following the burn, and so on up to B5 for 54 months after the burn. The results are indicative only, as the years the burns were undertaken vary, so the changes do not take into account other variables, most particularly soil moisture availability following the burns. The number of replicate plots varied by year, and six burns occurred in 2018 so that data from only one survey post-fire are available.

The overall trend identifies that in the second year after the burn there was an increase in native species richness and a moderate decrease in introduced species richness. Native groundcover also increased but was highly variable, but native forb cover increased each year. Drops in native and introduced species richness four years after the burn were probably related to the lower soil moisture conditions than in previous years. Introduced annual cover also increased annually, but was much lower in the fifth year after the burn (presumably due to the low soil moisture at that time). Perennial groundcover was variable across the period.



A. Native species richness (blue) and introduced species richness (orange)

B. Change in native groundcover (blue), total native forb cover (orange), introduced annual groundcover (grey) and introduced perennial groundcover (yellow)

Figure 3.5. Changes in values of native and introduced species attributes in all plots in the time since burning. The number of plots at each time period was B0: N=8; time B1: N=12; time B2: N=6, time B3: N=3, time B4: N=2 and B5: N=3.

The data were investigated plot by plot to look at trends within the plots. The comparison of the plots within forest with or without burns applied (Figure 3.6) indicated that plot BMV_V_S had a higher native species richness following the burn and species richness was similar in the plot burnt before monitoring began. Species richness was lower and less variable year to year in BLM_V_C, and similarly less variable in the two years data measured in CFC_V_1. In both burnt plots there was a greater decline in native species richness in the very dry year, 2018, than in the unburnt plot BLM_V_C.

Changes in native species richness and introduced species richness were investigated for each burnt non-forested plot for which two years or more post monitoring data were available (Figure 3.7). In 3 of the 4 plots total native species richness decreased in the first year after the burn, then increased, reflecting the trends demonstrated in Figure 3.5.

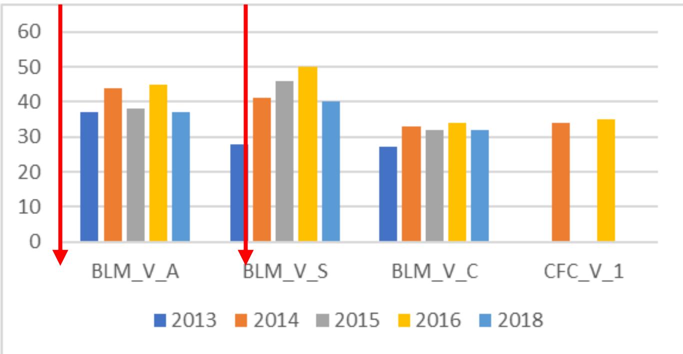
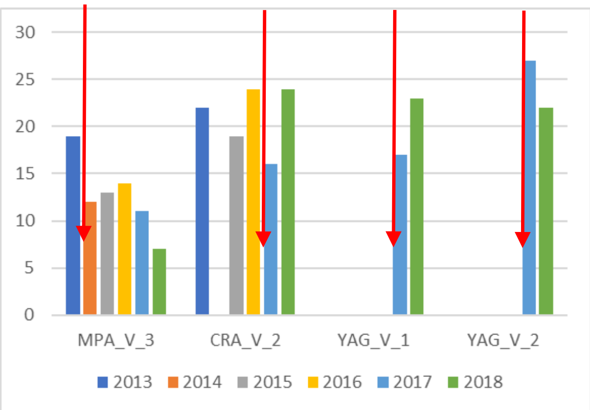
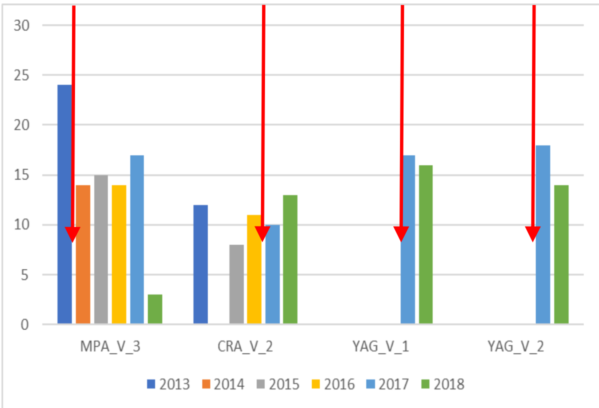


Figure 3.6. Changes in native species richness in two burnt plots and two unburnt in forested plots. As indicated by the arrow, BLM_V_A was burnt in 2012 (eighteen months before the first survey); BLM_V_S was burnt in autumn 2014).



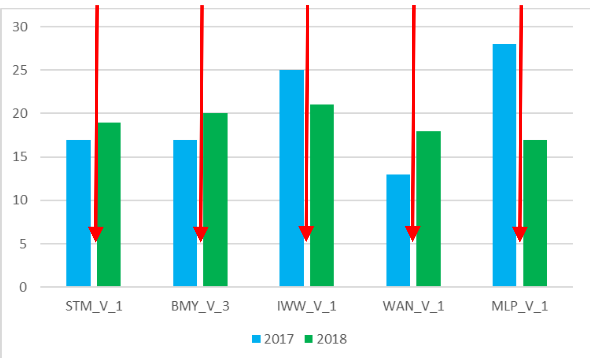
A: Native species richness



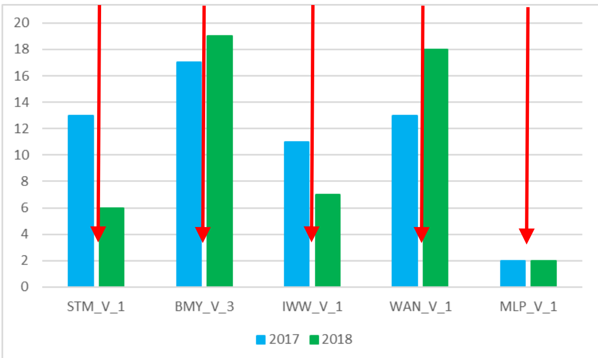
B: Introduced species richness

Figure 3.7. Change in native species richness and introduced species richness over multiple years following implementation of burns. The red arrows indicate when the burn occurred.

In five plots in which only one year's data was available post burn (Figure 3.8) there was a mixed response, with an increase in native species richness directly after the burn in three plots and a decrease in two plots. Introduced species richness decreased in two plots, increased in two plots and stayed the same (very low) in one plot. Given these burns occurred during years of low and very low soil moisture conditions, soil moisture availability may have influenced the responses of native and introduced species to the burn. The four plots subject to cool burns, BMY_V_3, IWW_V_1, WAN_V_1 and MLP_V_1 had not been burnt for many years, while the grassland at St Marks (STM_V_1) has been burnt at approximately 5–8 year intervals since the 1990s (author personal knowledge).



A: Native species richness



B: Introduced species richness

Figure 3.8 Change in native and introduced species richness one year following implementation of burns. The red arrows indicate when the burn occurred.

A comparison of native species richness in burnt and unburnt plots in two of the cool burn sites indicated differences in responses (Figure 3.9). In the Icon Water site native species richness was the same in both burnt and unburnt plots, indicating that the burn may not have made any difference, but at the burnt plot at Wandiyali native species richness was higher after the burn, after which the plot met the criteria as critically endangered Yellow Box – Blakely's Red Gum Grassy Woodland (Australian Government 2005).

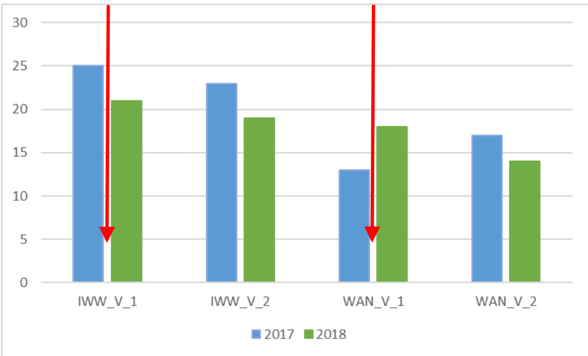


Figure 3.9. Change in native species richness within sites, in which one plot was subject to a cool burn and one plot was not burnt. The red arrows indicate when the burn occurred.

Changes in condition in plots subjected to woody weed control

The two plots subjected to woody weed control showed different responses.

At Bullan Mura (BMY_V_1) extensive woody weed control was undertaken in mid-2015. After the weeds were removed native species richness and groundcover initially was reduced, then increased within two years of the clearing, but again reduced in 2017 and further in 2018 (Figure 3.10). Native groundcover, however, remained below the pre-woody weed control cover for the next four years. Introduced species richness and groundcover cover increased considerably more than native richness and cover, but similarly, was lower in 2018 than earlier years, probably reflecting low soil moisture conditions.

In the Captains Flat property (CFH_V_1), native richness remained low but steady, while native groundcover increased initially, with a decline in 2016. Introduced groundcover increased but introduced species richness remained stable.

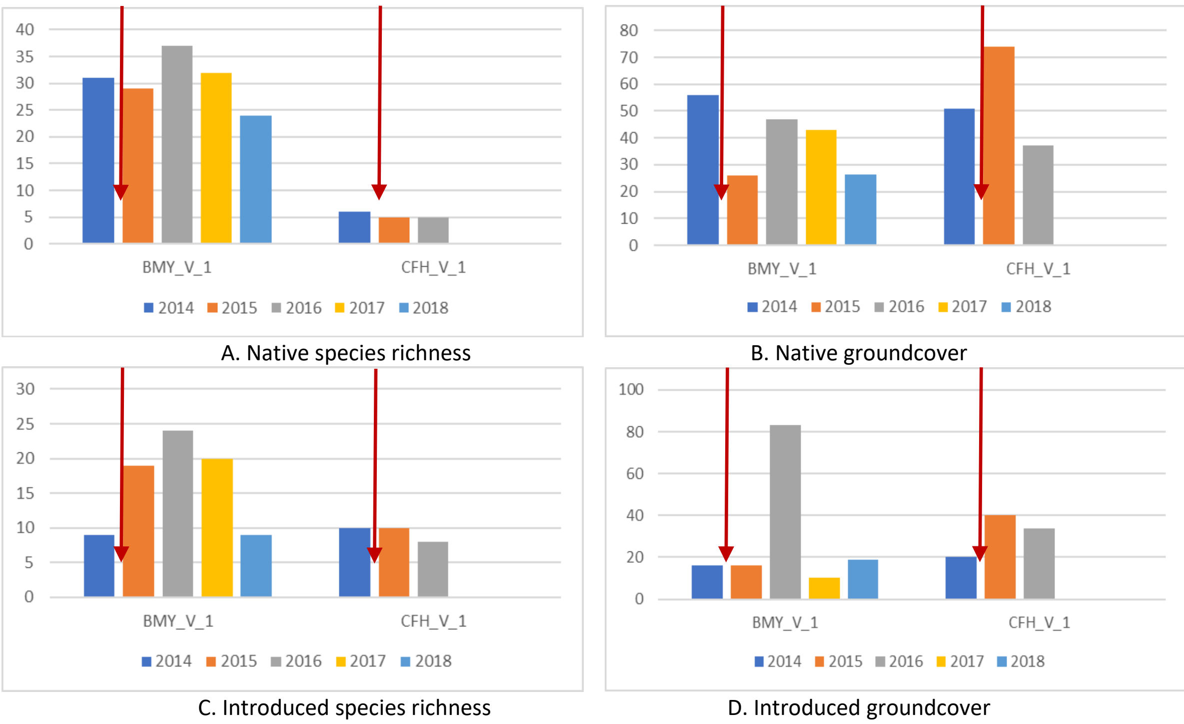
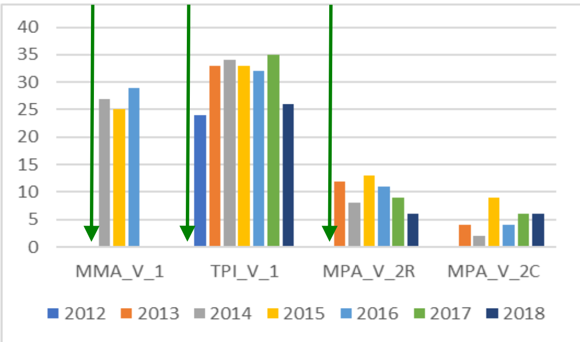


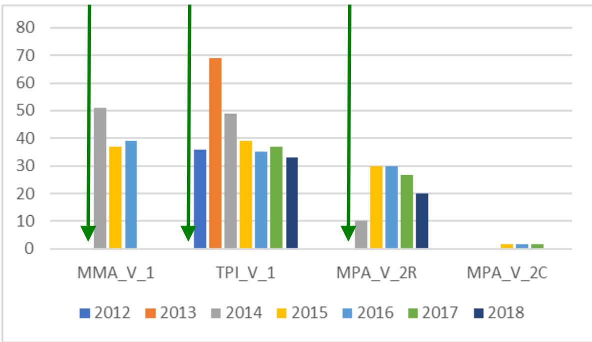
Figure 3.10. Changes to vegetation attributes after woody weed control. The maroon arrow indicates when woody weed control was undertaken.

Changes in condition in plots subjected to revegetation of forbs and sub-shrubs

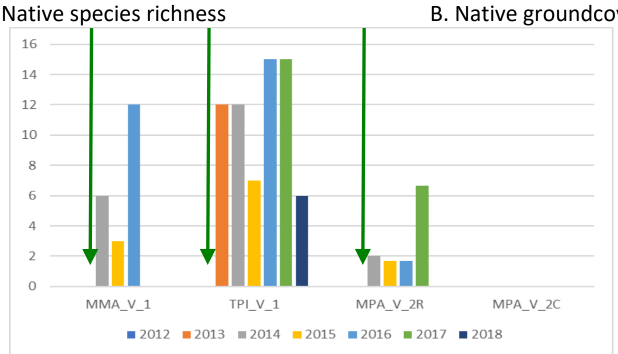
In the three plots in which revegetation with forbs and sub-shrubs had been undertaken in the year prior to monitoring, native species richness, native groundcover and native forb cover all increased. Native richness and native groundcover declined in the years of low soil moisture availability, but native forb cover increased substantially in two plots, at Mt Majura (MMA_V_1) and Mt Painter (MPA_ V_1) (Figure 3.11). The control plot in Mount Painter (MPA_V_2C), in which no revegetation had been undertaken, demonstrated a variable composition, and a stable native groundcover (grasses only). Increases in composition were likely to have been the planted species, with the decreases relating to the non-survival of those plantings.



A. Native species richness



B. Native groundcover



C. Native forb cover

Figure 3.11. Changes to native species richness, native groundcover and native forb cover in relation to time since planting: The green arrows indicate when the revegetation occurred. MPA_V_2C was established as a control site to the revegetated site in MPA_V_2R. The green arrows indicate when the revegetation occurred.

Discussion

The cluster analyses indicated that plots subject to similar management were not grouped together, suggesting that effects of management are not greater than similarities within plots and between plots. However, more detailed analyses indicated that changes had occurred in vegetation attributes following management intervention. Vegetation attributes appeared to be responsive to variation in soil moisture availability after being subjected to management intervention: generally native and introduced vegetation cover and diversity demonstrated a decline in the seasons of very low soil moisture, and introduced species richness and groundcover increasing significantly in 2016, the year of very high soil moisture availability.

There were few consistent responses after burns, although there were clear changes in condition indicators over time after the burns were implemented. Multiple variables, including intensity of the burn, soil moisture availability, vegetation structure and probably condition levels of the individual plots were likely influencing the changes observed in each plot. While changes in condition in plots in which cool burns were applied in 2018 were inconclusive, these far less intrusive burns may minimise the impacts caused by significant loss of biomass particularly in times of low soil moisture.

Both native and introduced species richness increased after woody weed removal in the woodland, but cover was very variable, suggesting a strong relationship between soil moisture and clearance, probably caused by the decrease in tree and shrub cover protecting the ground layer from extremes of moisture (high and low).

Although not many plots were measured following revegetation with herbaceous species the trends indicated that there was a decline after several years in species richness, presumably through senescence of the planted species. These results were undoubtedly influenced by the low soil moisture conditions inhibiting growth or causing the death of plants. These results strengthen already existing information that successful establishment of herbaceous species is far more difficult than establishment of shrubs and trees.

Although the relationships couldn't be statistically analysed due lack of adequate replication, it was apparent that vegetation attributes in plots varied more after being subjected to interventionist management in relation to soil moisture availability. The interactions between interventionist management and variable soil moisture levels need to be investigated further.

In investigating changes reflecting interventionist management, the lack of balanced replication meant that there was no clear evidence of patterns of response, in particular suggesting that other drivers were influencing the outcomes, especially differences in condition. Analysis of larger data sets that provide better replication of key variables including vegetation structure and/or associations, timing of management application and consistency of application (type of burn for example), and more time to monitor change, will complement shorter research studies.

3.5 CALCULATION OF CONFIDENCE INTERVALS TO QUANTIFY BACKGROUND VARIABILITY

The key reason for using monitoring to assist in the application of adaptive management is to differentiate between changes in condition caused by primary drivers that cannot be manipulated ('background' or stochastic variability) and condition changes that result from management that reduces the impacts of stressors. The above analyses were used to determine what were the key drivers affecting condition, and the most useful indicators of change (Table 3.13).

Table 3.13. Factors that were identified in the Vegwatch review as key influencing vegetative condition of plots.

Primary drivers	Secondary drivers (applied actions)	Ecosystem stressors	Key indicators to differentiate change caused by applied actions
Seasonal variation in weather patterns Vegetation structure (reflecting other drivers including soils, aspect, geology, etc.) Past land uses and disturbance	Biomass manipulation Revegetation	Invasive weeds Soil moisture availability	Native species richness (and indicator species and non-grass species) Native species groundcover (total, grass, sub-shrub and forb) Introduced species richness Introduced annual groundcover Introduced perennial groundcover

The effects of these drivers were quantified in order then to interpret change in indicators over time in individual plots. In the analysis of change in vegetation condition in the Molonglo Valley (ACT Government 2018) stochastic variability was calculated from the standard deviations measured from the differences in attributes between the plots, so that the range relates to the range of drivers and stressors experienced in that plot.

Because there was effectively little or no replication in the Vegwatch plots an alternative approach to reflect the 'background' variability attributable to primary drivers was to utilise a data set collated from plots across multiple sites. Confidence intervals at the 95% level were calculated for each of the five vegetation structural units for the five condition indicators identified above, and for three additional indicators used in other comparative studies (e.g. the Molonglo Valley monitoring review (ACT Government 2018)). A subset of plots was chosen:

- Data from years of average seasonal conditions were included (2013–2015);
- No data were included from surveys in plots recently subjected management interventions;
- Plots with very low native species richness and cover were excluded.

After collating this sub-set, there were only two plots with a shrubby woodland structure. Therefore, data from these two plots were combined with data from the plots containing grassy woodlands and the confidence interval thus derived applied to plots containing both shrubby and grassy woodland.

The range of the confidence intervals varied considerably between the four groups (Table 3.14). The confidence intervals for each structural type were used in graphs of the plot results to compare the condition of the plots (good to poor condition and trends) to the selected confidence attributes (Chapter 4). Any variation beyond this range is deemed to reflect significant change.

Table 3.14. Range of 95% confidence limits used to identify reference variability for each of the attributes within the vegetation structural formations. For clarity, limits are rounded to whole numbers.

Vegetation structure	Native species richness	Native floristic score	Native gr'cover	Proportion native gr'cover	Introduced species richness	Introduced floristic score	Introduced annual gr'cover	Introduced perennial gr'cover
Forest	30–35	51–70*	7–92	100	0–2	0–1	0–7	0
Grassy woodland, shrubby woodland	21–30	25–39	44–67	77–98	16–20	11–15	14–42	8–31
Derived grassland	16–20	11–18	2–46	52–85	20–30	11–19	39–90	1–16
Grassland	12–20	10–30	26–63	50–80	14–25	8–18	19–66	11–42

* Native floristic score was not created for use in forest associations, but was included to provide comparison with values in the other structural formations; the majority of species that were encountered in forests were also in woodlands, and were often species identified as indicator species for woodland, hence the high FVS values in forest plots.

Discussion

The confidence intervals were used as a reference base against which the values of each condition index in each plot could be compared. Condition trend was based on the degree of change between monitoring events, beyond the range of the confidence intervals. Any variation beyond this range is deemed to reflect significant change.

The confidence intervals have been used to describe the condition and change in condition over the monitoring period in each plot, as presented in Chapter 5.

3.6 CONCLUSIONS

The analyses demonstrate that the majority of the Vegwatch data were comparable to data collected by government ecologists, and were, with several exceptions, robust, consistent and valid. Having established veracity of the data and taking into account variability caused by drivers and by stressors, some conclusions can be drawn about the results of the analyses.

The major drivers relating to condition and changes in condition identified in this study were plot individuality attributable primarily to historical land use and disturbance, structural formation, seasonal variation measured as soil moisture levels and interventionist management.

The type of species and the relative abundances of introduced and native species varied between the structural formations. The highest levels of variation of condition attributes were within the grassy ecosystems. Analysing data separately for each structural formation was necessary, but individual site and plot differences still need to be interpreted beyond the generalisations that can be derived from combined data, due to their strong individuality.

The analyses of the data in this study identified vegetation attributes that indicated ecologically significant changes in condition over time within plots. It was possible to identify changes in condition of these indicators using seven years of data, which enable fluctuations in drivers that cannot be changed, including soil moisture levels and other stochastic variables, to be differentiated from changes related to management.

Seasonal influences are well known to cause change in species richness and abundance, bare ground and litter levels from year to year, and are strongly evident in the photopoint monitoring. The root zone soil moisture measurements available from Bureau of Meteorology (accessed in 2019) provided a quantitative way to take into account variations in seasonal conditions. The variation in seasonal conditions across the seven years of this study was extremely high (varying within two years from 91% soil moisture to 3% soil moisture). Soil moisture levels were compared to changes in elements of vegetation and habitat condition. The results indicated that there was a lower impact of soil moisture levels on native species richness and on introduced perennial herbaceous plants, but a higher and more consistent impact on richness and cover of introduced annual species. Additionally, there was a likely relationship between soil moisture availability and responses of the vegetation to interventionist management.

The strong correlations between some attributes indicate that there is redundancy in using all the attributes as condition indicators. The ideal way of measuring and reporting on condition is to include attributes that do not overlap, and that provide specific information on key elements of the systems. It is suggested that scores that combine and weight a number of attributes (for example, benchmark scores) mask important information and that variables that best reflect the different elements of condition should be included, particularly those attributes that respond differently to stochastic or management impacts.

4. PARTICIPANT CONSULTATION

4.1 INTRODUCTION

The Vegwatch program has the goal of encouraging non-scientists to participate in quantitative vegetation monitoring (collection of data and feedback on the results) in order to increase their knowledge and understanding of the processes and to produce scientifically valid data to guide conservation management, by :

1. Allowing users to gather vegetation and environmental data with relevance to ecosystem conservation and management;
2. Providing the tools and guidance to assess whether changes in condition are occurring, so that management and resources can be better targeted towards enhancing elements of biodiversity;
3. Enabling useful, quantitative and comparable monitoring of vegetation to be carried out using practical simple but effective standardised assessment methods;
4. Encouraging and supporting a range of people in gaining the skills to assess environmental condition, and in doing so, develop their understanding of the natural processes occurring within sites; and
5. Ensuring more consistent interpretation of changes and provide justification for undertaking certain activities. (Sharp and Gould 2014 p. 3).

To what degree the program has achieved these aims for participants is discussed in this chapter. Ultimately, if the program of community monitoring is to continue, it is critical to support the volunteers who collect the data: to review the program against the aims above, identify what needs to be done better and then identify how to implement the changes. The chapter provides a summary of the major benefits that participants perceived as being part of the program, and problems that they encountered. Recommendations for changes to be implemented in the Vegwatch program are summarised in the Overview in Chapter 1.

Participants in Vegwatch since 2011 have included:

- volunteers who undertook the field work,
- volunteers who have assisted groups with field work and species identification,
- volunteers and paid staff who organised the annual program, liaised with field volunteers, helped design the database, entered data, extracted summary data and analysed results and communicated the results to participants and others; and
- Molonglo Conservation Group staff and board members who established and facilitated the program.

Representatives of all these groups have provided feedback that is reviewed in this chapter. Additionally, advice was sought from the Anke Maria Hoefer, facilitator of the Frogwatch program.

It is estimated that in the order of 80 participants have been involved in undertaking the surveys between 2011 and 2018, amounting to approximately 1300 hours of voluntary work. Collation of the data, preparation of site reports and annual assistance provided to participants (excluding resources obtained through grants from ACT Government and Landkeepers) is calculated as having taken approximately 2000 hours.

4.2 PROCESSES ESTABLISHED IN THE VEGWATCH PROGRAM TO SUPPORT VOLUNTEERS

The Vegwatch program identified ways to support volunteers undertaking work on the ground. The means developed to achieve this are listed below.

The Vegwatch Manual (Sharp and Gould 2014) explains in detail the reasons for monitoring and how participants could undertake monitoring. While it was never intended to be the only tool for teaching individuals to undertake the monitoring, the authors endeavoured to describe the methods in detail, providing photos and diagrams to help explain them and providing worked examples of the sheets. In addition, the manual provides information on how to develop simple descriptive statistics of the results. It was thought that someone with some training in field survey process would be able to follow the manual if no other resources were available.

Field sheets provided to the groups had brief instructions for collecting the data, to complement the more detailed instructions in the manual.

Training was provided to every group that was established. A meeting was held to plan the monitoring program for that site, considering why it was being undertaken, who would be involved, how long the program was expected to continue for, and who was the major contact for the group. This was all recorded on the planning sheet (Sharp and Gould 2014). Following this, the first monitoring event was overseen by a Vegwatch facilitator to establish the plot and undertake the initial monitoring with the group, to train, answer questions and demonstrate how the data are collected and recorded. Importantly, the planning process was used to identify where the plot/s would be established to best answer the questions identified.

Annual program: Prior to the survey season all groups were contacted to find out who intended to monitor that year, and whether they required assistance. Groups were advised what data to collect and field sheets were sent out.

On-ground assistance was offered to each group each year, usually provided by the facilitator. Other volunteers with plant identification skills also provided assistance in plant identification, in the field or following the event.

Plant identification was recognised as the key difficulty likely to be encountered. When the program was in its initial stages there were limited resources beyond a few field guides to help with independent identification. Since then, further resources, in particular more field guides, website plant photos and lists and Canberra Nature Map have become available to provide invaluable resources for identification. The Vegwatch manual provided a comprehensive list of species that were likely to be found and provided guidance to assist with collecting specimens for identification.

Species lists: A species list collated from previous surveys from that plot was provided each year with the survey sheets, as a guide to what was likely to be found, and ideally to help with identifying unknown species surveyed previously.

Collation of the data: the facilitator collated and entered the data. This was an opportunity to question the data and get additional information from the participants. The development of the database in 2016 meant the process of collation was much easier, and additionally, much easier to provide feedback to the participants.

4.3 COMMUNICIATION WITH THE PARTICIPANTS SINCE THE PROGRAM'S INCEPTION

Informal communication occurred during the organisation of annual programs and when data were collated by the facilitator. Some participants provided informal feedback about the process and about difficulties they had with implementing the project in their plots. Copies of written feedback have been retained, and have been considered in this review. As a result of such informal feedback, instructions on the field sheets were modified for clarity and some data collected were dropped or reduced in frequency of collection.

Participants forum, September 2017 organised by MCG, to which all participants were invited. This forum aimed to provide feedback to participants, and to get feedback from participants to include in implementing the project. Participants from eight monitoring groups, Government personnel and MCG staff attended the forum. An overview of the project was provided and two of the participants presented talks on the implementation of their monitoring project. A robust discussion on the program was undertaken.

Issues identified at the forum included:

- The monitoring can be quite complicated and remembering the process from year to year has been tricky;
- There was no access to an expert who can help in the field;
- Someone needs to follow up missing data and check for quality of the data;
- No analysis or feedback has been provided to volunteers; and
- It is important to give the data a home; ACT Government expressed interest in incorporating Vegwatch data into the ACT Conservation Effectiveness Monitoring Program (CEMP).

Data summaries sent out to all Vegwatch groups in 2017: The development of the Vegwatch database (2016–2017), funded in part by a grant from ACT Government's NRM program, was critical in ensuring that the data were entered accurately, relatively easily and were accessible for review and feedback. In 2017 the output from the database for each plot was sent electronically to the conveners of each participating group. The output included the species lists with abundance records, summaries of the key data collected, and the condition indicators that were calculated from the data. Very few participants responded to this material being provided to them, but when asked whether they received the report and what they thought about it, those participants that saw the reports responded that they were interested to see the results, although they did not necessarily pass on the report to other participants in the group.

Draft plot reports were prepared in 2018 and circulated to the Vegwatch groups in late 2018. The reports included ecological information about the site and management history collated from information provided by the groups and known by the volunteer preparing the reports. The reports also included summary information from the survey data and species lists. Groups were requested to provide feedback and fill unknown gaps. The additional information provided by the respondents was used to prepare the plot reports presented in Chapter 5.

4.4 PARTICIPANTS' FEEDBACK

Feedback received from participants in the Vegwatch project is presented below.

4.4.1 Monitoring groups

> JB: *As a ParkCare group that had just completed a revegetation planting aimed at enhancing woodland connectivity, the Vegwatch program provided us with an ideal system for monitoring the impacts and success of our revegetation project over the long term. Rather than using our own ad hoc monitoring program, which was fairly narrow in scope, we now have a set of tools that provides us with quite comprehensive vegetation data we can use to compare our progress with other similar projects in the region.*

> MC: *As complete novices in the area of revegetation, involvement in Vegwatch really raises our awareness of what we are doing, why we are doing it and whether our plan of action is appropriate. It adds rigour to what we do. It's easy for a ParkCare group to just keep doing what has always been done. Vegwatch makes us stop and think, "How can we better achieve our goals?". We have certainly become more aware of the variety of species on our patch as a result of the monitoring.* (both quoted from Sharp 2015, in Sharp et al. 2015)

Training and support

Training/guidance was mostly considered sufficient. Some parts of the manual were identified as not entirely clear. Summary instructions provided with the data sheets were revised after several years to address this, with advice from participants.

> *"All the volunteers felt that they were adequately trained"* (this group had assistance from a highly skilled botanist).

> *"I think the field data sheets are very good and people should be reminded that if they carefully follow what is written on the data sheets it helps a lot."*

Others found it more straightforward:

> *"It was highly educational and inspiring."*

> *"The survey was easy because* [a volunteer ecologist helped do the survey]. *I wouldn't necessarily feel confident on my own though."*

> *"Always difficult to find the time, but quite pleasant once up on the ridge. But note, we often do not fill out all the documents requested."*

There were concerns about the difficulties in carrying out the surveys. Some participants found the methods were too difficult, even with training provided and offers of on-going support.

> *"It's always hard to remember the process each year, but I think we manage it OK. However, whether we are consistent from year-to-year I am not sure; certainly need at least 2 people doing it so that you can rely on collective memory."*

> *"I was not involved in choosing the plots, [and] I have not been able to work out exactly why the 2 plots were chosen. This has made it difficult to be committed when I can't work out what results I am expecting/hoping for, and what actions would be expected/recommended as a result of the information. In other words, I don't see it as a useful tool in altering our management of [our plot].*

Species identification

Similar to the response to undertaking the surveys more generally, there was mixed responses about issues with species identification.

> *"I think everyone quite seriously attempts in the time available to get IDs correct but I'm sure you'll agree that decisions can be pretty tentative especially when the plant material available is not ideal, as is often the case."*

The issue of whether some plants have to be identified to species rather than genus only was raised:

> *"It would reduce the length of list and could reduce the time required by Vegwatchers to just count some genus groups at a single level and not require us to scratch heads to ID down to species".*

> *"All the volunteers asked felt that the surveys were moderately easy to implement. Having said that, we now*

> *have a regular band of about 6-8 people who take part each year and so we are all getting fairly experienced with the process and it is reasonably efficient. We are fortunate to have a few key people who are very experienced with plant identification which is an important part of the surveys."*

Improved knowledge of the flora was identified as a benefit to participants.

> *"We manage to ID most species but there are always a few difficult ones. We rely on kind but busy people to help out. It would be really useful to have a dedicated Vegwatch person to whom we could turn."*

> *"We are fortunate that we have* [X] *assisting us with plant identification, otherwise that would be a major obstacle. Most of the other aspects of the survey are fairly straightforward."*

One group has conducted plant recognition workshops in some years to assist Vegwatch volunteers.

Informing on-ground management

With one exception, respondents indicated that the survey results – and undertaking the process – helped inform groundwork. Survey results inform groundwork, for example identifying when invasive plants are a problem as well as identifying when species are flowering.

Participants indicated they were becoming more perceptive about differences in plant growth by season and by management. They have had to think about what management has been applied and when.

> *"The monitoring is measuring whether the broader impacts of management of the site are in accordance with the Management Plan."*

> *"The diversity of the species found on the plot and the seasonal variability in the species found from year to year… The surveys are also a useful tool for monitoring the impact of our weed control program on the survey area…. Management of weeds in the plot is dictated by the ParkCare group's weed management plan drafted back in 2011. However, the achievements in the Vegwatch plot have contributed to our overall weed management strategy for the reserve, particularly as regards the comparative success rates of different native plant species."*

Other comments

The groups were asked if they intend to continue the monitoring. Some indicated they wanted to continue, but some wanted to establish plots in new locations, from which the data would be more informative.

> "*Yes, with the proviso that I would like to see the final report on the data collected so far and be able to assess how useful the overall program has been. [We] had a discussion after last year's monitoring about the latter point, and both of us have some reservations which it would be good to put to rest. Making an exhaustive species list for each plot was the most informative aspect of what we were doing*."

Suggestions by participants for changes

Suggestions provided by participants are:

- Not having to identify all species to species level. Identify from the analysis of the data which are the critical elements to survey. If difficult, ensure there is help on-site.
- Ensure consistency through training. "*It would be really useful to have a dedicated Vegwatch person to whom we could turn*."
- In one group the highly experienced botanists participating provided a species identification guide relevant to the plant species encountered on their plot.
- Create a pool of volunteers with expertise to help groups – ensure these are adequately trained and supported.
- Better use of the website to show a schedule of who is doing what when, so groups can stay in touch.
- *"In the early days we recorded whether the plant was not flowering, in bud, flowering, or finished flowering, which is useful, e.g. re. climate change or climate watch. It is suggested that this information about the species be recorded in Indicator 1."*
- *"I think the method needs to be modified so that there are clearly 2 methods: one method for people with advanced plant identification and data collection skills and one method for people with basic skills. People would be able to choose what they do. At the moment, I think people think it is too difficult and so they do nothing, and no data are collected. You already currently help people by advising them which indicators to do but maybe it is not clear enough which indicators are simple and which are complicated."*

4.4.2 Volunteer botanist (Rosemary Purdie)

Rosemary Purdie, a highly skilled botanist, who has volunteered a great deal of time to help groups undertake the monitoring successfully at Black Mountain and elsewhere, has provided feedback as follows:

- The monitoring works best where the same (usually small) group of people return each year and are familiar with the measurements required; they don't necessarily remember the detail of what's required but understand it and pick up the skills again very quickly.
- People are very enthusiastic, but those just participating in Vegwatch with few other plant activities in between start from scratch each year in terms of recognising plants and knowing their names; the monitoring seems very dependent still on having access to a person or two with detailed plant knowledge (this mostly applies to indicator 1).
- For the Black Mountain (BM) plots running a plant identification training session a week before the plots are monitored helps, but mostly just with shrubs and juvenile eucalypt species – it doesn't help much with indicator 1, especially picking up the species that are infrequent in the plot. For this year's training I prepared a "quick guide" to all the plants recorded in the three plots (i.e. the guide is specific just to the three plots); that seemed to help but because conditions were so dry there was limited opportunity for people to use it for the forbs. Having plot-specific quick guides like this might help groups with less confidence about plants (though the guides are quite time consuming to prepare).
- People generally tend to overestimate cover/abundance – it's a spatial issue in regard to being able to visualise what proportion of the total plot would be covered by all plants of a species grouped together, i.e. what they see where they're standing; indicator 4 (interval point cover) is one of the most accurate because it's actually measured.
- I've found on BM that some of the apparent variability in data from year to year just reflects different people scoring things differently (e.g. young adult eucalypt trees c.f. mature adult trees) – it's easy to pick up the human influence (c.f. an ecological/population trend) if the total number of trees is the same each year (and the issue is probably more pronounced on BM because its open forest rather than grassland or grassy woodland).
- This year I was struck by how much the light conditions can influence the data: we had two days with full sunshine and very contrasting light which makes it more difficult to pick up small herbs tucked away among grasses; the third day was beautifully overcast, with even lighting that was perfect for finding everything!
- If there are particular idiosyncrasies at a particular plot it's important to keep a record of how they're handled so that the data can be obtained consistently from year to year: an example from BM is working out whether *Daviesia mimosoides* shrubs are juvenile, mature or senescent. I introduced a "rule of thumb" that if half or more of the mains stems were dead or dying, count the plant as senescent; if it's less than 10 cm tall, count it as a juvenile – this was just to try to get consistency (& I'm reasonably happy it is).

4.4.3 Volunteer facilitator (Sarah Sharp)

Facilitators, in volunteer or paid roles, since the establishment of the Vegwatch program, have:

a) Facilitated the design and overseen and tested the database;
b) Encouraged and facilitated the establishment of new groups and plots;
c) Run the annual program, provided field support and liaised with participants;
d) Provided initial training to all groups;
e) Entered data, checked data;
f) Undertaken surveys of reference plots;
g) Prepared and distributed results to participants; and
h) Prepared plot reports.

Resources to run the program day to day

Due to very limited funds, staff at MCG had little capacity to run the Vegwatch program or to oversee the program after 2014. As a result, program coordination and implementation has been largely achieved through volunteer input, to ensure the project and the volunteers are supported. While volunteers have maintained the program, and even facilitated the enlargement of the program, there are limitations in what volunteers can achieve over a long period of time, particularly and importantly with the lack of feedback to the supports of the program. This in turn has led to limitations on the support provided to the groups, which has impacted enthusiasm levels.

The program requires consistent, if only part time, attention as well as the time and resources to communicate results and to take opportunities to promote the program and work with other organisations.

Working with participants

Participants involved in the monitoring on site had a wide range of skills. As indicated above, those groups with experienced participants fared much better than those with more limited experience. Scientific method is unfamiliar to many people, including many who would be considered experienced field naturalists.

Some groups found it hard to remember what to do from year to year. Edits to instructions on the field work sheets after 2014 (implemented to make the instructions clearer and remove errors) caused confusion and created some errors in data collection (e.g. the change after 2011 to collect abundance data meant that some participants did not collect abundance data in future years). Many of these changes, however, improved the outcomes, included the provision of better directions and recommending to participants that they could reduce the data collected each year. Changes to the field sheets themselves were made after the database was developed to enable the participants to record directly onto Excel sheets or to provide the data on the Excel sheets so that data could be downloaded directly into the database. However, this was problematic and frustrating for some participants, mainly due to their lack of experience in using Excel.

A frustration was that the participants often did not read the instructions that were on the field sheets or the more detailed methods in the manual, copies of which were given to the groups and were on the website, which could have helped them. Others who were having difficulties could have signed up to on-ground assistance or training chose not to do so. Another difficulty was the lack of feedback from participants, probably due to hesitation about causing offence.

For participants, the program lacked a focal person/facilitator to be in contact with, as it was never clear who would be running the program each year.

Assistance from volunteers helping participants

Volunteers with a great deal of experience were invaluable in helping participants who lacked experience and, in some cases, confidence to carry out the monitoring without help. However, there was a lot of pressure on those few volunteers who helped, and who could not help consistently due to other commitments. A stronger push to get a larger base of volunteers who could help occasionally would help in future.

4.4.4 Molonglo Conservation Group

MCG Board perspective

Molonglo Conservation Group implements the Molonglo Catchment strategy using what we call an Interconnected Landscape Management (ILM) approach. ILM relies on careful and consistent monitoring to identify both tangible and intangible outcomes for managing the natural and human resources of the Molonglo catchment. The Vegwatch program is used to identify, measure and assess changes in vegetation condition that result from management practices or specific on-ground actions. We find that Vegwatch provides accounting effectiveness for NRM projects and for monitoring offset areas and cool burn plots.

Vegwatch is used in a range of collaborative partnerships between Molonglo Conservation Group, government, corporate and community stakeholders in the ACT and in NSW. Currently Vegwatch is funded through limited resources of project funding.

MCG Programs Management Perspective

- MCG currently hosts the Vegwatch database and website. The website remains relatively static and is not broadly known about by our member groups or broader volunteer community. MCG has not promoted Vegwatch in any concerted way through its social media channels.
- Communication with Vegwatch participants has been done in an ad-hoc and usually reactive way. This is in part due to the inclusion of Vegwatch in some, but not all, of the monitoring programs associated with our funded projects.
- Communications could be improved with inclusion of Vegwatch in MCG’s communications and marketing strategies which are still in progress.
- Sustained funding for a part time coordinator would provide consistent training and encouragement of groups and individuals for long term outcomes. Presently, Vegwatch is funded on a project by project basis, which means MCG struggles to maintain support for existing or new Vegwatch plots that fall outside projects and project completion dates.

- MCG staff have experienced that Vegwatch requires significant botanical knowledge to undertake. The rigorous nature of assessment requires staff to have experience and training to quite a high degree. The same applies to many of the volunteers involved in the program, who may struggle to undertake assessments without support from paid coordinators. The cost of facilitation is difficult to imbed in our project grants.
- Staff turnover and capacity is an ongoing issue. Several staff who have supported volunteers in Vegwatch have left the organisation where others have reduced capacity to assist.
- A fixed allocation of resources to the program cannot be achieved through our existing funding arrangements i.e. grants and contracted 'fee for service' programs.

4.4.5 Facilitator of the Frogwatch citizen science program (Anke Maria Hoefer)

Anke Maria Hoefer is the facilitator of the Frogwatch program (https://ginninderralandcare.org.au/frogs), based in Canberra. She provided advice on factors required to facilitate successful citizen science programs.

The Frogwatch program began in 2002, established with ACT Government funding. It aligns with government reporting requirements, and there is collaboration with CIT and universities. There are numerous sub-programs, including Tadpoles for Schools, a Frog Taskforce, and data are entered into Canberra Nature Map. The program takes place in and outside the ACT. It is a program that is highly regarded as a means to collect and collate high quality data that guide management and ecological understanding, while at the same time educating and involving non-scientists in conservation matters. Even so, funding to facilitate the program, provide resources and support review of the findings remains unstable, and ACT Government and University of Canberra have supported the data analysis and interpretation.

The major processes that Anke Maria believes makes the Frogwatch program work are that the participants get training annually, feedback is provided to the volunteers and the program has a profile. Anke Maria is an excellent communicator, using simple language, is enthusiastic and very entertaining.

A quote from a Canberra Times news story, on 6 August 2016, on the launch of a report on the findings of Frogwatch data analysis: "*I think it's been a long time coming*," she [Anke Maria] said. "*For many years it was almost like the data goes into a dark hole … people are happy now it is applied, and they can see results*."

Anke Maria said that participants need to feel that they personally get something out of their involvement, in addition to having a sense of doing it for the 'greater good'. They need to be aware of why they are doing the monitoring and that it will be used to achieve better conservation outcomes. They need to enjoy the experience, and Anke Maria stressed that it is important for participants to get to know quickly about the results in the plots they monitor, so they get feedback on what their data mean: "*People want to advocate for the environment – we need to encourage and help them be involved*". Anke Maria identified that it takes a few years to accumulate enough data to write it up and present meaningful results.

Anke Maria stressed that to help ensure data are accurate and consistent, methods need to be as simple as possible and data sheets self-explanatory and easy to fill out. The data collected also need to be seen as meaningful and useful. One possibility being considered in Frogwatch is that reference data to assist with interpretation of the frog data are collected by a few individuals across all sites, ensuring the more complex data are more accurately and consistently measured.

Note from author: a major difference between Frogwatch and Vegwatch is that Frogwatch program has far fewer species to identify, and the final identification is undertaken by Anke-Maria, and because lengthy data analyses are not required, feedback is quick.

4.5 DISCUSSION AND CONCLUSIONS

Most issues identified related to the lack of consistent support to participants. The lack of support meant that:

- There was no one to contact out of the field season to discuss it,
- There was no update material on the MCG website or advertising,
- Data were often collated some time after it was collected and it was hard to track down missing or inconsistencies in the data,
- Feedback wasn't provided regularly and frequently,
- Most participants relied on on-ground training to learn what to do, rather than written material and instructions, and
- Other than written reports there was only two opportunities for feedback from participants – at the 2017 forum and feedback requested from participants for the preparation of this report.

Two almost dichotomous viewpoints emerged from the feedback. Some participants were confident, enjoyed the process and learnt more about their sites and about species identification from the process; these participants were almost invariably part of groups that either included people with a high level of skills in plant identification and survey technique or were receiving help. Other groups found it difficult and were not inspired to continue. It is clear that many participants have gained experience and understanding and are interested in learning from the results and applying them in the management they implement in their sites.

Plant species data provide key indicators of condition for any vegetation monitoring. However, plant identification is difficult. Even quite experienced people may have difficulty, given many species are very similar and there are many species to differentiate between (over 370 were recorded in these surveys, although in each plot between about 15 and 60 species are encountered). Help from people with a high level of experience to provide immediate guidance with identification is critical. Post survey identification is always difficult and time consuming, and requires asking assistance from others ("*We rely on kind but busy people to help out"*). Those that either take up the offers of volunteer help with the surveys or have with them people experienced in survey methodology clearly feel more confident and motivated.

Despite the offer annually to provide on-ground volunteer help, not many groups took this up. Some groups have stopped monitoring and have advised they found it too difficult. Some groups have not monitored for some time, but haven't said that they wish to stop monitoring. The probable reason for this is at least some of these groups find it difficult and are discouraged, or there are not enough people available in a group to form a team and/or they don't find it personally of value.

Some participants have problems understanding what to do. This may well be related to their general lack of experience with scientific survey methodology and technique, large time lag between events and the lack of a designated coordinator/facilitator who is on-tap.

That groups would have difficulties with program implementation was not unexpected. Contrary to the hope that the manual would provide a useful, to some extent a stand-alone resource, it has been hardly used. The lack of consistent facilitation was unexpected, however, and remains the key matter that requires resolution if the program is to continue. One of the reasons for preparing this report was to determine if methods could be simplified without compromising the capacity to measure change in vegetation and habitat condition. Plant identification and measurement are difficult, and any program that includes these elements is going to cause concern and probably lack consistency. However, it is important to consider what could be simplified and/or what other resources can be used to make it easier. Recommendations in the overview in Chapter 1 address these issues.

Feedback and communication are critical to the success of a citizen science project. Participants need to feel that they are collecting the data correctly and accurately, that it is not confusing to record or collect, that their efforts are worthwhile (for the 'greater good') and that they are personally learning from the activity. Any program will fail, even if the data are useful and results are used, if the participants aren't encouraged and supported and if they don't feel that their concerns or problems are being taken into consideration.

5. CHANGES IN CONDITION BETWEEN 2011 AND 2018 IN THE VEGWATCH PLOTS

5.1 INTRODUCTION

This chapter describes the characteristics of each of the Vegwatch plots, the changes that have occurred during the time they have been monitored (between 2011 and 2018) and summarises the condition of the plots, based on the key drivers and condition indicators identified in chapter 3.

5.2 OBJECTIVES

The objectives of this chapter are:

1. To describe the major characteristics of the Vegwatch plots; and
2. To describe the condition and condition trends over time in each plot.

5.3 VEGWATCH PLOT CHARACTERISTICS

Data from 33 plots monitored in 21 sites between 2011 and 2018 are described in detail below and summarised in Table 5.1. Not all plots have been surveyed every year following their establishment. More details on the length of time of Vegwatch monitoring in individual plots is in the following descriptions of each reserve. Some monitoring projects have been concluded (indicated in Table 5.1 by *), some others have not been monitored for several years. Data from all projects, including several that contain only partial data and those that were abandoned, are retained in the MCG Vegwatch database.

The volunteers self-chose the location of the plots in which the Vegwatch monitoring was undertaken, in order to measure changes where they wished to find out the outcomes of management. Additionally, the volunteers often only established one plot in a site. In part to counter the lack of replication, in 2017 additional plots were established in grassy woodland and native grassland in good condition, as reference sites.

Locations

Twenty-four plots in fifteen sites occur in ACT and nine plots in six sites are in surrounding NSW. All the ACT plots are within peri-urban Canberra and all but one of the plots in NSW occur on rural properties (Table 5.1, Figure 5.1). Three sites are less than 5 ha in size, the remainder of the sites are much larger, from tens to hundreds of hectares.

Land use

All but two plots are in sites that are being managed primarily to conserve biodiversity values. Ten occur within Canberra Nature Park, a further five are being managed for conservation values, as offsets or other reserves. Three occur within ACT open space or unleased land, so have multiple uses. Two are on working rural properties and one is in a cemetery within an area that is not to be further disturbed. The time since any of the reserved sites have been used for agricultural or other land uses varies. The condition of the sites and plots within them varies enormously, depending on past land uses and levels of disturbances or management actions applied.

Vegetation associations and vegetation structure

Seven vegetation associations and two modified associations (Armstrong et al. 2012, ACT Government 2017a) occurred in the plots (Tables 3.8, 5.1). The majority of the monitored plots contained Yellow Box – Blakely's Red Gum Grassy Woodland (13 plots) and Natural Temperate Grassland (five plots). Some sites with more than one Vegwatch plot contained several vegetation associations and/or structural formation.

Vegetation structural formations represented in the plots are Grassland (GL) in 13 plots, of which seven contained derived grassland (DerGL), Grassy woodland (GW) in nine plots, Shrubby woodland (SW) in seven plots (including the native plantation plots) and Forest (FOR) in four plots (including the Snow Gum Candlebark tall grassy woodland, which had a forest canopy) (Table 5.1).

Threatened ecological communities

Five plots in three sites met the criteria as Natural Temperate Grassland of the South-Eastern Highlands critically endangered ecological community (Australian Government 2016) (NTG, Table 5.1). Eleven plots met the criteria for the White Box – Yellow Box – Blakely's Red Gum Grassy Woodlands and Derived Native Grasslands (YBRG) critically endangered ecological community (Australian Government 2005), although six of those plots did not meet the criteria each time they were surveyed; three plots met the criteria as the endangered community subsequent to being burnt.

Table 5.1 Characteristics of the Vegwatch plots and summary of condition and trend. Plots that meet the criteria as endangered ecological communities in one or more surveys in bold. See the list of abbreviations (p. v) for full names for vegetation associations and vegetation structure. Trend is questionable when only two years' data are available. * indicates the monitoring program has been concluded.

Site	Participants	Land use	Plot	No surveys	Management	Vegetation associa-tion	Veg. structure	Overall condition and trend
Aranda Bushland	Friends of AB	N. reserve	ASG_1	4	SJW control	SGW	GW	←→
Black Mountain NR	Friends of BM	N. reserve	BLM_S	5	Control burn 2014	RSF	FOR	↑
			BLM_C	5	None (control)	RSF	FOR	←→
			BLM_A	5	Control burn 2012	RSF	FOR	↑
Bullan Mura Yarralumla	Sharp (MCG)	Open space	BMY_1	5	Woody weeds 2014	**YBRG**	GW	↑↓
			BMY_3	2	Cool burn 2018	**YBRG**	GW	↑?
Captains Flat cemetery	Capt. Flat Landcare	Cemetery	CFC_1*	2	No mgmt	SGCBW	FOR	←→?
Captains Flat property	CF Landcare	Farm	CFH_1*	3	Woody weeds '15 Livestock	NG	GL	←→
Cooleman Ridge NR	CR ParkCare	Nature reserve	CRA_2	5	Control burn 2017	**YBRG**	GW	↑
			CRD_1	5	SJW control	YBRG	DerGL	↑
Icon Water Williamsdale	Sharp (MCG)	Cons'n (offset)	IWW_1B	2	Cool burn 2018	**YBRG**	GW	←→?
			IWW_2C	2	Control plot	**YBRG**	GW	←→?
Isaacs Ridge NR	IR ParkCare	N. reserve	ISR_1	5	SJW control	NG	DerGL	↑
'Millpost' Bungendore	Sharp (MCG)	Farm	MLP_1B	2	Cool burn 2018	BGSOF	SW	←→?
			MLP_2C	1	Control plot	BGSOF	SW	
Mt Ainslie NR	MA ParkCare	N. reserve	MAI_1*	3	Reveg: shrubs, trees 1980s	EPN	SW	←→
			MAI_2*	2		EPN	SW	←→
Mt Majura NR	Friends of MM	N. reserve	MMA_1	3	Reveg: forbs 2013	**YBRG**	GW	←→
Mt Painter NR	Friends of MP	N. reserve	MPA_1	7	Weed control	**YBRG**	GW	←→
			MPA_2R	6	Reveg: forbs 2011	NG	DerGL	←→
			MPA_2C	6	Control plot	NG	DerGL	←→
			MPA_3	6	Control burn 2014	**YBRG**	DerGL	↑↓
Mt Taylor NR	MT ParkCare	N. reserve	MTA_1*	3	Wildfire 2003	MBSF	SW	
Royalla Swainsona Res.	Royalla Landcare	Reserve (offset)	RSR_1	1	Revegetation, date unknown	MBSF	SW	
St Marks Grassland	Sharp	Uni campus	STM_1	2	Ecological burn 2018	**NTG**	GL	←→?
Tennant St Fyshwick	Sharp, MCG	Unleased	TSF_1	2	No mgmt	**NTG**	GL	←→?
The Pinnacle NR	FOTPIN	N. reserve	TPI_1	7	Reveg: woody 1980S, forbs 2011	**YBRG**	SW	←→
Tuggeranong Hills NR	TH ParkCare	N. reserve	TUH_1	2	No mgmt	**YBRG**	GW	←→?
Umbagong G'l Latham	FOG	Open space	UMG_1	2	Ecological burn 2018	**NTG**	GL	←→?
'Wandiyali' Googong	Sharp (MCG)	Cons'n reserve	WAN 1B	2	Cool burn 2018	**YBRG**	DerGL	↑?
			WAN_2C	2	Control plot	YBRG	Der GL	←→?
Yarramundi Grassland	FOG	Cons'n reserve	YAG_1	2	Control burns '11 '17	**NTG**	GL	←→?
			YAG_2	2	control burns '11 '17	**NTG**	GL	←→?

Key: **Condition**: dark green: very good condition; green: good condition (with some concerns); orange: moderate condition; red: poor condition. **Trend**: ←→: stable; ↑: improving; ↓: declining; ↑↓: variable; ?: trend uncertain due to lack of repetitions.

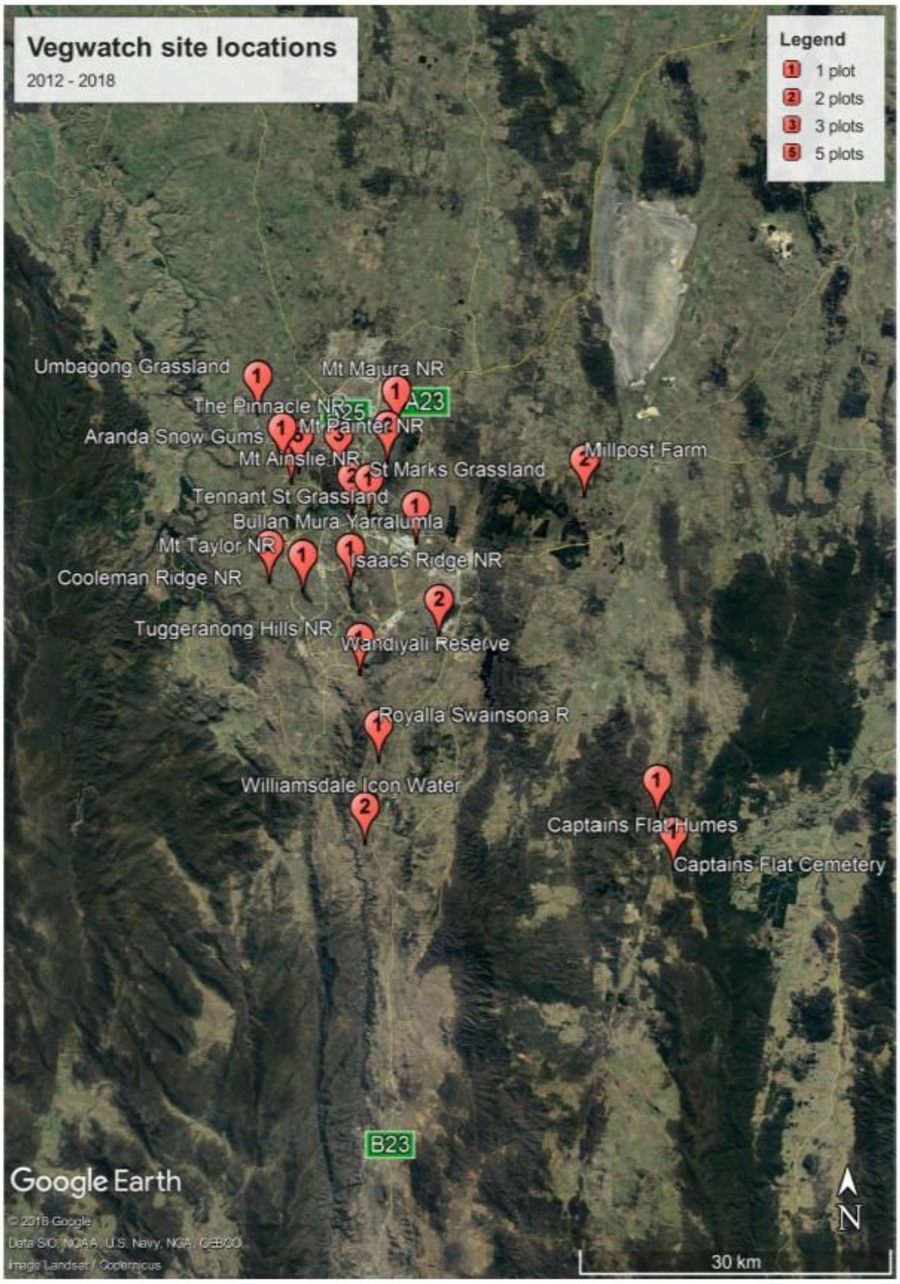


Figure 5.1. Location of the sites monitored in the Vegwatch program, 2011 – 2018. Several other plots established and then abandoned after one year are not included on this map.

Management

Only two sites were grazed with livestock occasionally (Captains Flat property and 'Millpost' property), although many have a history of grazing, with different lengths of time since they were last grazed. All plots were accessible by kangaroos. The intensity of management by herbivores varies considerably; several sites are heavily grazed by kangaroos (Aranda Bushland, Bullan Mura, Icon Water, Mt Ainslie, Mt Majura, Mt Painter, Tennant St Grassland and The Pinnacle). In the majority of the sites general invasive species management was undertaken. Four sites were subject to specific weed control, for St John's Wort (SJW) and Serrated Tussock (ST). No management was applied during the monitoring period in the remaining four plots.

Interventionist management, in which biomass was significantly reduced or composition increased by plantings was undertaken in 16 plots before or during the period of monitoring. Between 2011 and 2018, burns occurred in 12 Vegwatch plots (Table 5.1). Of these, all but one plot was monitored prior to the burns as well as following the burn. Five of those plots have been subject to multiple ecological burns over the past ten or more years. Data have been collected for up to five years following a burn, although five of the burns occurred in 2018, so only data from one post burn survey is available. Significant woody weed control occurred in two plots (Bullan Mura BMY_V_1 and the Captains Flat property) during the survey period. Three plots had been revegetated with trees, shrubs and/or forbs in the few years prior to the monitoring having commenced.

5.4 KEY FACTORS THAT WERE USED TO INTERPRET CHANGE WITHIN AND BETWEEN PLOTS

The review of the Vegwatch data presented in Chapter 3 identified the key factors associated with change in condition over time. These were:

- Plot condition (influenced by natural factors and historical land management and history)
- Individual structural formation;
- Soil moisture levels; and
- Changes related to interventionist management (management that results in significant biomass and composition modification, including burning, woody weed control and revegetation).

Vegetation condition indicators

Five of the vegetation attributes used to describe the changes in condition are those identified in the review as being the most explanatory quantitative attributes as determined from analyses undertaken (Chapter 3). In addition, three other attributes, native floristic value score (FVS) and introduced FVS and proportion of native groundcover, have been included. Floristic value score for native species (FVS) has frequently been used in other studies, and is an attribute used to identify whether native grasslands meet the criteria as the critically endangered ecological community. For these reasons it was included as a comparison, even though it is highly correlated with native species richness attributes, particularly the number of indicator species present (see Chapter 3). The native floristic score was not designed to be used in forest, but for comparative purposes they were included in the review of vegetation attributes. For comparison the Introduced FVS was also included, although this the species scoring was developed for this review (see the Appendix for an explanation of how it was calculated). Proportion of groundcover was also included as it is also a criterion for determining if sites contain either critically endangered grassland or box gum woodland.

The eight attributes chosen to assess condition and trends in condition were:

- Native species richness;
- Native floristic value;
- Native groundcover;
- Proportion of native groundcover;
- Introduced species richness;
- Introduced floristic value;
- Annual introduced groundcover; and
- Perennial introduced groundcover.

Other condition indicators

Benchmark condition and habitat condition were also reported on. Scores against benchmark condition were calculated (Gibbons et al. 2008) for each plot, using ACT benchmark values (ACT Government undated). Ten data parameters were used to collate the benchmark score as a proportion of 100 for plots containing trees and/or shrubs; the five parameters that relate to trees and or shrubs were omitted for plots containing grassland, so that the final score was calculated as a proportion of the potential score of 45. This latter modification of the benchmark score is not applied in other studies, but it was used as otherwise scores in grassland sites are biased by receiving a minimum score of 55%. More information on calculating the benchmark score can be found in the Appendix. Only the condition at the first time of monitoring was included.

Habitat condition scores (Appendix) from the initial survey were included.

Only the data from the initial surveys were included, as these were considered to be the most accurate data (measured or assessed by the facilitator or trainer). Therefore, there is no trend in condition identified.

Confidence intervals

Confidence intervals were used to differentiate between 'background' variability attributable to the drivers and stressors identified as key factors and other variability caused by management and/or biomass changes (e.g. burning). The methods used to develop the confidence intervals are described in Chapter 3.5.

The 95% confidence intervals that were calculated to identify reference variability for each of the eight condition indicators in each of the vegetation structural formations was graphed (Ch 3.5, Table 3.13). The confidence intervals were used as a reference base against which the values of each condition index in each plot could be compared.

The confidence intervals for each indicator for each structural type were graphed with the plot results to compare the condition of the plots (high to poor condition and trends). Annual soil moisture levels were also graphed for comparison. Any variation beyond the confidence intervals was deemed to reflect greater fluctuations than 'normal', as a result of variability in seasonal conditions and related to biomass manipulation.

Converting condition values to condition ratings

The four condition ratings (good, good with some concerns, moderate and poor) are used by ACT Government (Brawata et al. 2017a, ACT Government 2018a). The ratings are the same as those applied in the Molonglo Valley Vegetation Condition Monitoring Report (ACT Government 2018): Plant species richness ranges followed the ACT Government benchmarks, native score levels were based on Vivian and Baines (2014) and the Grassland Strategy (ACT Government 2017b). Other condition indicators were calculated as a percentage of the target of 100%: 75%; 60%; 45% and less than 45% (Table 5.2).

Condition state: The condition states used by ACT Government (Brawata et al. 2017a, 2017b, ACT Government 2018) have been applied, as follows: good (dark green), good with some concerns (light green), moderate (orange) and poor (red) (Table 5.2).

Table 5.2. The condition ranking system. These are calculated from the reference benchmark values scoring (Appendix, ACT Government, undated). Each ranking is a percentage of the benchmark reference condition.

Condition index	Vegetation	Condition targets	Good	Good with some concerns	Moderate	Poor
Plant richness	Native grassland	30	≥23	18-23	14-17	<14
	Box Gum Woodland and derived grassland	35	≥26	21-26	16-20	<16
	Shrubby woodland, forest	30	≥23	18-23	14-17	<14
	Snow Gum Woodland	22	≥16	13-17	10-12	<10
Floristic condition	NTG	20	≥15	12-15	9-14	<9
	Woodland	37	≥28	22-28	17-21	<17
Other vegetation attributes	All vegetation communities	100%	≥75%	60-74%	45-59%	<45%
Benchmark condition score	Forest, woodland Grassland	100 45*	≥75%	60-74%	45-59%	<45%
Habitat condition	All	100%	≥75%	60-74%	45-59%	<45%

* As described in the Appendix, only four of the ten parameters in the benchmark score are relevant to grasslands; if all ten parameters are used, the minimum score for a grassland is 55%, so therefore the score was calculated from the relevant four parameters only.

Condition trends: the same symbols used to identify the condition trends are the same as those used by ACT Government (Brawata et al. 2017a, 2017b, ACT Government 2018) (Table 5.3). For introduced indicators a decrease in values was related to an increase in condition.

Photomonitoring

Only a selection of photos is included in each plot report. These include the photomonitoring from the initial survey and the most recent photo. Other information including summaries of all the attributes and a species list for each survey and annual photomonitoring will be available on the MCG Vegwatch website by late 2020.

5.5 CHANGES IN CONDITION ACROSS ALL PLOTS

Table 5.1 presents the overall condition state and trend in each plot. Of the plots monitored more than twice, overall condition improved in six plots and remained stable in 14 plots; in two plots the data were considered inaccurate, so no assessment of condition was provided. Of the plots monitored twice, condition trends cannot be identified, but condition appeared to be improving in one plot and remained stable in eight plots.

Variation from year to year within the lower and upper range of values of the attribute confidence limits was common, and in 11 plots, this variation was related to soil moisture levels. In the majority of cases, plots with higher levels of variability or clear trends of change in the condition indicators were ones that had been subject to major biomass manipulations.

No plots demonstrated overall decline in condition state. However, there were declines in particular indicators. These are discussed in the plot descriptions. Causes of some declines would be due to the effects of soil moisture variability particularly on annual species cover and/or changes after application of burns.

5.6 DESCRIPTION OF CHANGE IN CONDITION OF THE VEGWATCH MONITORING PLOTS

Each plot is described., with changes in condition described against each condition index. The general Vegwatch plots are presented below alphabetically by name, but the four sites monitored to review the impacts of cool burns applied in 2018 are grouped together at the end, to enable easier comparison.

Interpretation of the plot descriptions and graphs

Symbology used to represent condition state at the end of the period of monitoring and the trend of change is shown in Table 5.3.

Table 5.3. Symbology used to represent condition and condition trend

Condition	Trend symbol
Good	Improving: 🡡
Good with some concerns	Stable: 🡠🡢
Moderate	Declining: 🡣
Poor	Variable: 🡡🡣
	Unknown: ?

Graph interpretation

- Rectangle: confidence interval for each attribute within the four vegetation types (forest, woodland, derived grassland and grassland);
- Dotted line: soil moisture level (derived from data at Canberra Airport); and
- Horizontal red line: time of biomass manipulation.

Aranda Bushland 2013–2016 ASG_1

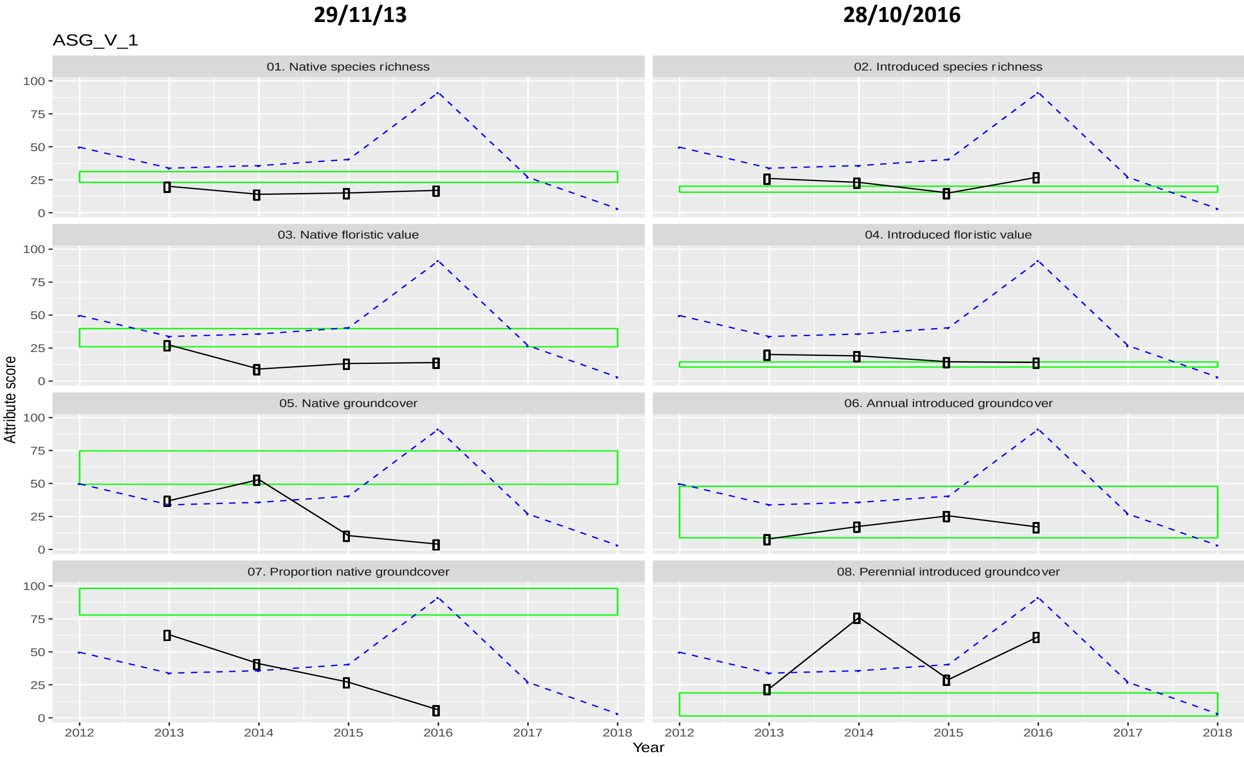
Monitoring undertaken by Friends of Aranda Bushland
Location Aranda Snow Gums
Vegetation Type Snow Gum Woodland **Vegetation structure** Grassy woodland
Management St John's Wort and other weed control; Kangaroo grazing levels are very high. Rabbit control is undertaken regularly.
Aim: To monitor change in vegetation and habitat condition following cessation of domestic grazing and undertaking invasive species control.

Condition Attribute	Condition, trend	Interpretation
Overall condition	←→	Introduced annual cover increase coincides with high soil moisture availability (refer to photomonitoring)
Native species richness	←→	Slight decrease after first year of monitoring
Native floristic score	↓	Decrease from moderate to poor condition
Native groundcover	?	Not calculated*
Proportion of native groundcover	?	Not calculated*
Introduced species richness	↓↑	Variable
Introduced floristic score	↑	IFS decreased over time; condition improved.
Introduced annual groundcover	?	Not calculated*
Intr. perennial groundcover	?	Not calculated*
Benchmark condition score	60%	Lacks mature trees and regeneration
Habitat diversity score	48%	Lacks rocks, mature trees, mid-storey and regeneration
St John's Wort		St John's Wort decreased from 2013 to 2016: none in 2016

*In three of the surveys introduced annual and perennial groundcover species growth form were incorrectly identified, so no groundcover analyses were assessed (see data in the figure below).


29/11/13


28/10/2016



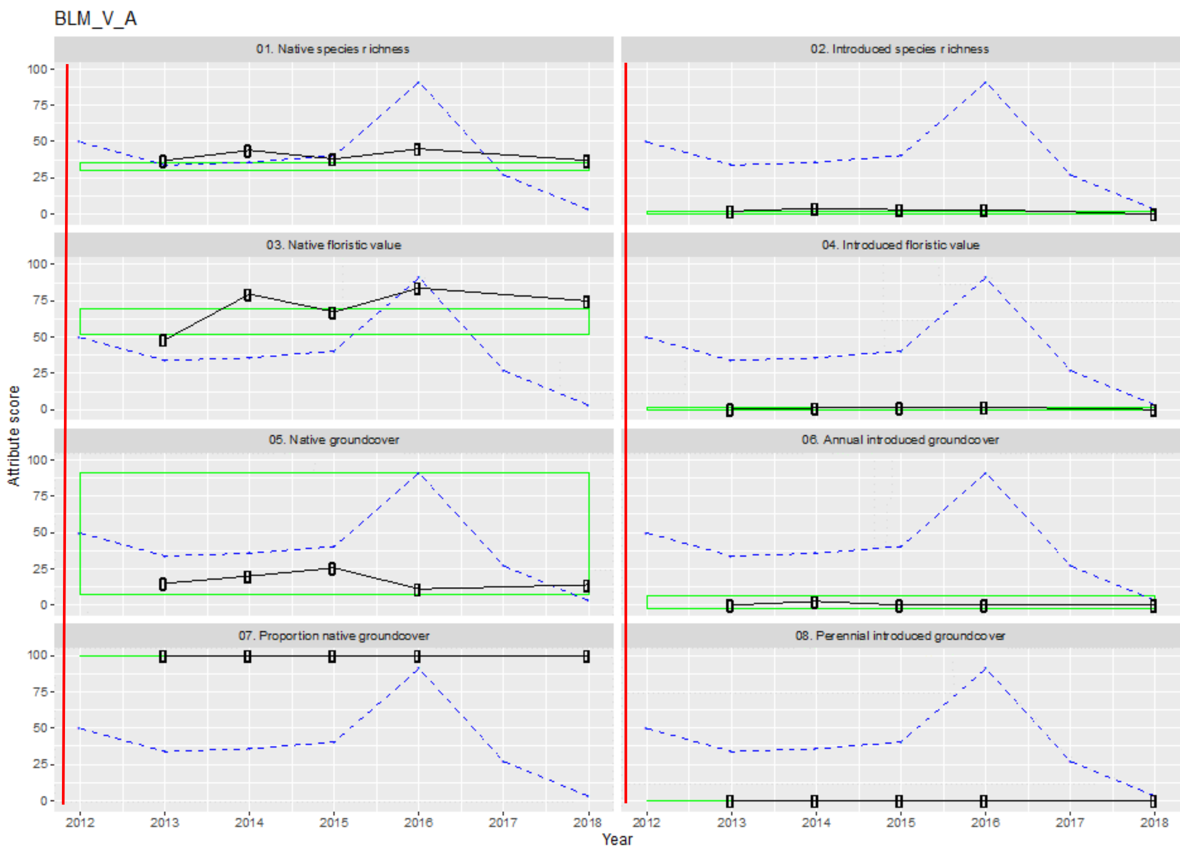
Black Mountain Nature Reserve 2013–2018 BLM_NEA

Monitoring undertaken by Friends of Black Mountain
Location: Eastern side of Black Mountain, accessed from Frith Road, along Little Black Mountain Track
Vegetation Type Red Stringybark - Scribbly Gum Dry Forest **Vegetation structure** Forest
Management Fire mitigation burn in autumn 2012, prior to the commencement of monitoring
Aim: To monitor change in vegetation and habitat condition following the burn.

Condition Indicators	Condition, trend	Interpretation
Overall condition	↑	Improving following the burn Regeneration of shrubs was high following the burn; senescence occurred over time. Changes in vegetation condition attributes did not reflect variations in soil moisture availability.
Native species richness	↑	Increase in NSR gradual over time.
Native floristic richness	↑	Strong increase after the first year after the burn.
Native groundcover	↑	
Proportion native groundcover	↔	100% native groundcover
Introduced species richness	↔	
Introduced floristic value	↔	
Introduced annual groundcover	↔	Very low annual groundcover
Intr. perennial groundcover	↔	No perennial introduced species
Benchmark condition score	98%	
Habitat diversity score	79%	

9/11/13

20/11/18



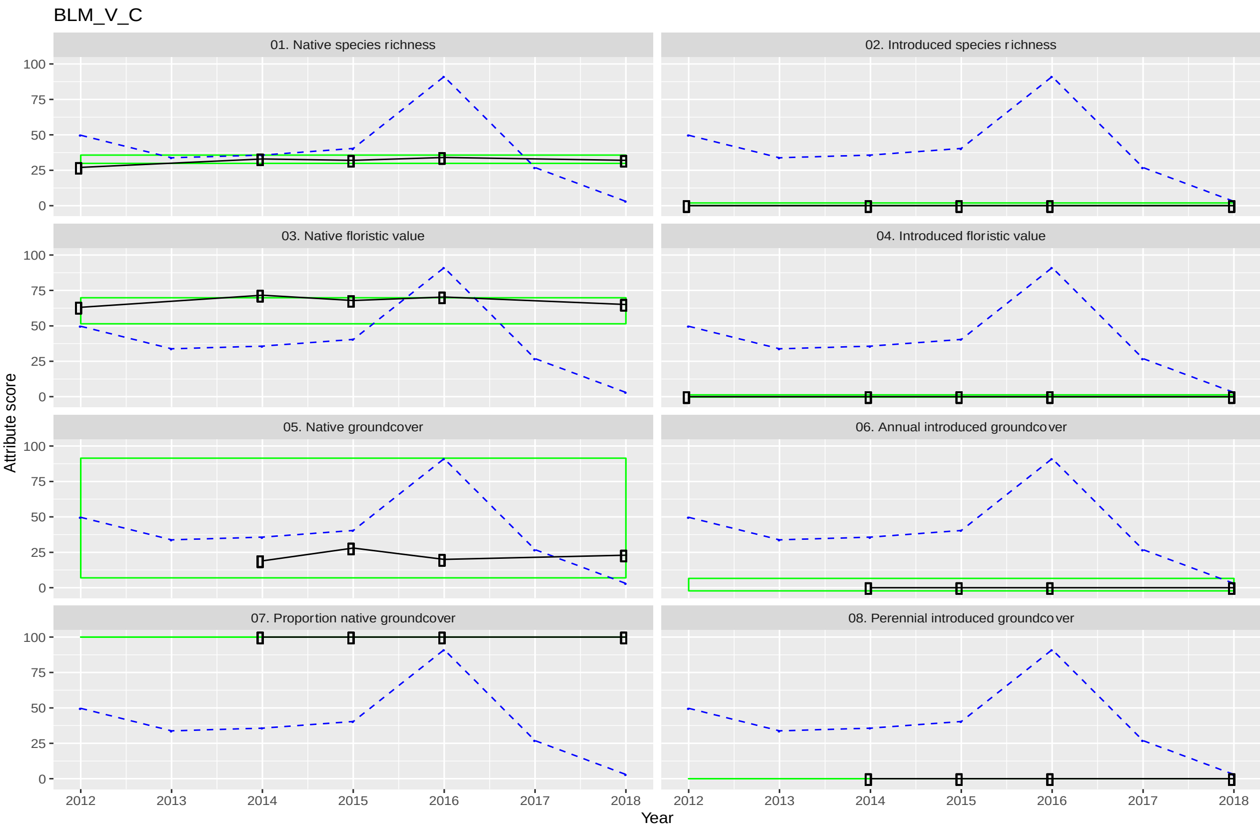
Black Mountain Nature Reserve 2013–2018 BLM_NEC

Monitoring undertaken by Friends of Black Mountain
Location: eastern slope of Black Mountain, accessed from Frith Road near the Powerline Trail
Vegetation Type Red Stringybark - Scribbly Gum Dry Forest **Vegetation structure** Forest
Management: the area was last burnt in 1991
Aim: To monitor change in vegetation and habitat condition in comparison to burnt areas (Black Mountain NR Plots NEA and SE)

Condition indicators	Condition, trend	Interpretation
Overall condition	←→	The variability of values of attributes are lower than in the two burnt plots. Changes in condition scores do not reflect variations in soil moisture availability.
Native species richness	←→	
Native floristic score	←→	
Native groundcover	←→	Sparse
Proportion native groundcover	←→	100%
Introduced species richness	←→	No introduced species recorded
Introduced floristic value	←→	
Introduced annual groundcover	←→	0%
Intr. perennial groundcover	←→	0%
Benchmark condition score	94%	
Habitat diversity score	82%	Structural complexity increased

26/2/2013

23/11/18



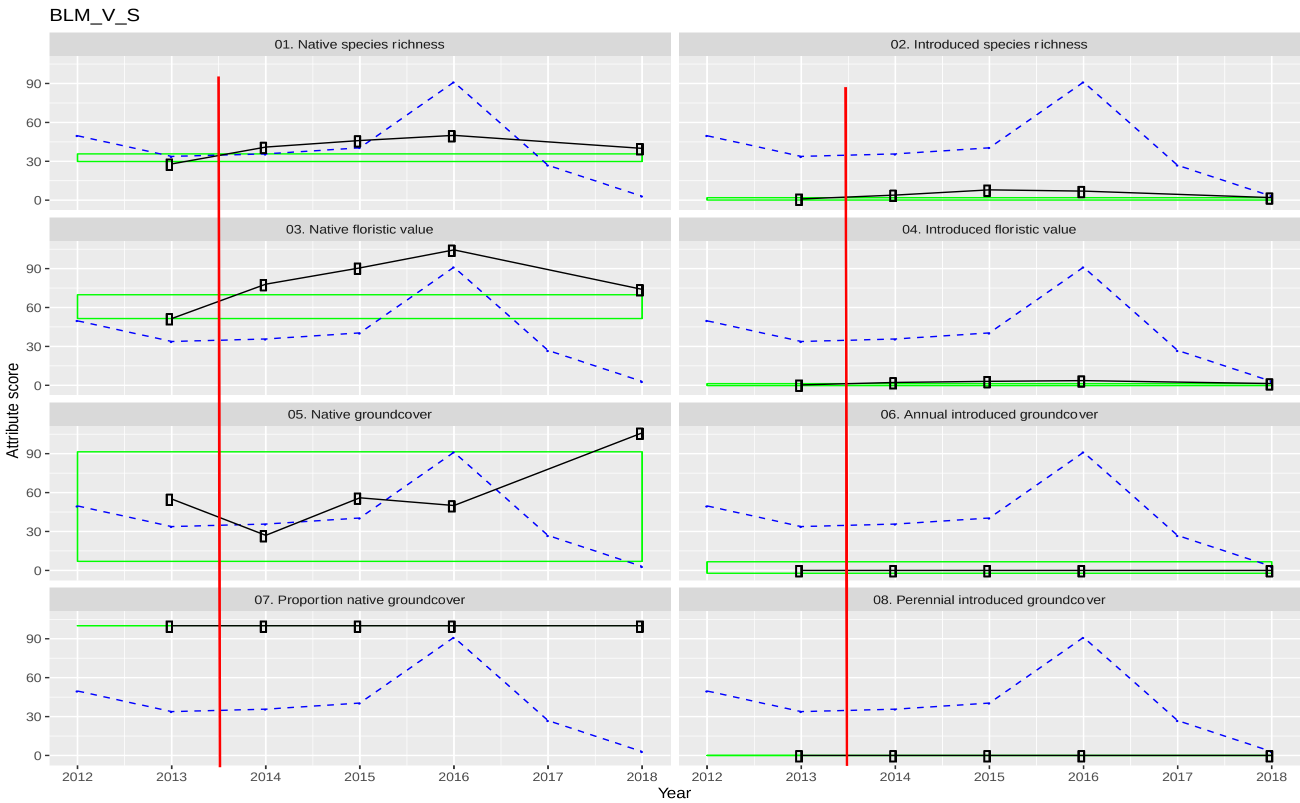
Black Mountain Nature Reserve 2013-2018 BLM_SE

Monitoring undertaken by Friends of Black Mountain
Location: The plot is on south facing slope on northside and about 20m above the first creek crossing, accessed from the Botanic Gardens Track.
Vegetation Type Red Stringybark - Scribbly Gum Dry Forest **Vegetation structure** Forest
Management: burnt for fire mitigation in autumn 2014.
Aim: To monitor change in vegetation and habitat condition following the burn.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑	Increase in condition following the burn; changes in vegetation attributes did not reflect variations in soil moisture availability.
Native species richness	↑	Increase post burn
Native floristic score	↑	Increase post burn
Native groundcover	↑	Reduction then increase post burn
Proportion native groundcover	↔	100% native groundcover
Introduced species richness	↔	Slight increase post burn
Introduced floristic value	↔	Slight increase post burn
Introduced annual groundcover	↔	Extremely low introduced species cover
Intr. perennial groundcover	↔	No introduced perennial species
Benchmark condition score	94%	
Habitat diversity score	79%	

26/2/2014 (2013 season), pre-burn

7/12/18



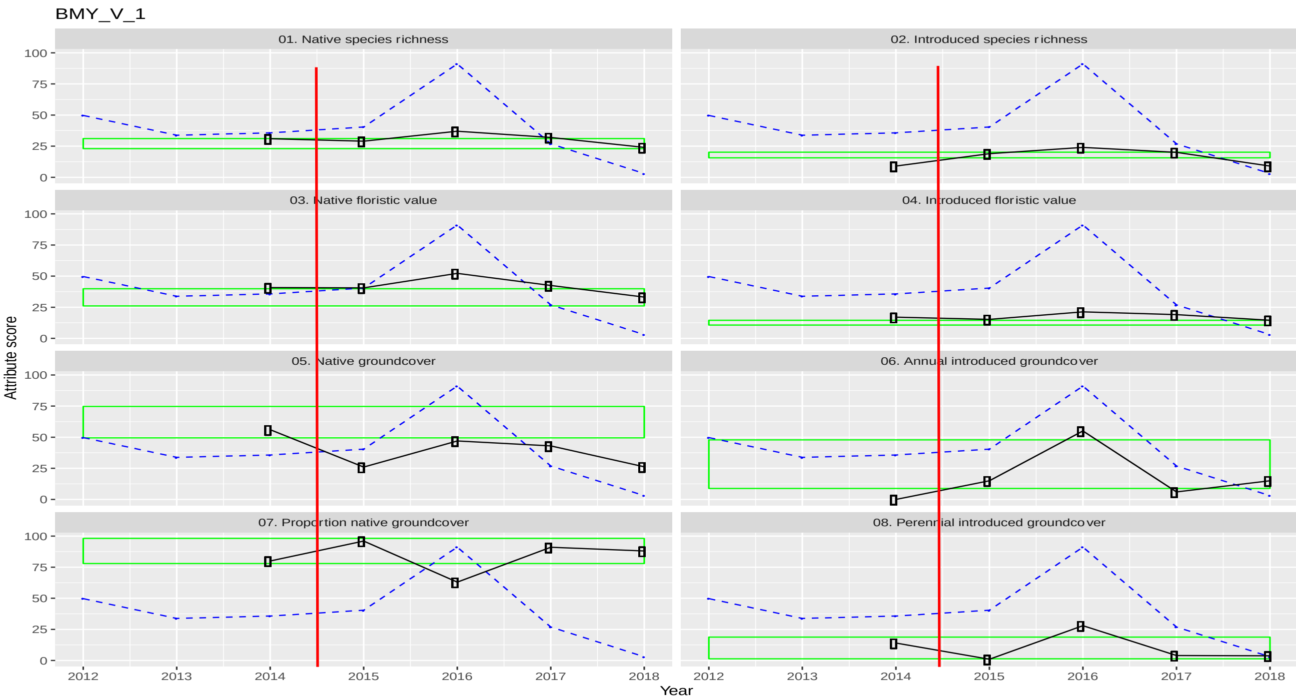
Bullan Mura Yarralumla 2014–2018 BMY_1

Monitoring undertaken by Sarah Sharp
Location: Block 2, Section 128 in Yarralumla, between Alexandrina Drive and Forster Crescent and adjoining Stirling Ridge. The plot is more or less parallel and north of the powerlines.
Land use: open space (City Services)
Vegetation Type Yellow Box – Blakely's Red Gum Grassy Woodland (CEEC) **Vegetation structure** Grassy Woodland
Management Woody weed control autumn 2014.
Aim: to monitor change in vegetation and habitat condition following woody weed control.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑↓	Changes reflect soil moisture availability post woody weed control. Button Wrinklewort *Rutidosis leptorhynchoides* count of 62 in 2014, 140 plants in 2016; increase may be because plants were not as visible in 2014 or because of reduced competition for resources.
Native species richness	↑↓	Increase following control corresponds to available soil moisture
Native floristic value	↑↓	Increase following control corresponds to available soil moisture
Native groundcover	↑↓	Decreased in the first year following woody weed control, then increased
Proportion native groundcover	↑↓	Decrease n 2016 corresponds to increase in Intr. perennial groundcover
Introduced species richness	←→	Fluctuation corresponds to soil moisture availability
Introduced floristic value	←→	Fluctuation corresponds to soil moisture availability
Introduced annual groundcover	←→	Very strong increase in 2016 corresponds to soil moisture availability
Intr. perennial groundcover	←→	Fluctuation corresponds to soil moisture availability
Benchmark condition score	63%	High woody weed content reduced condition.
Habitat diversity score	73%	Some loss of habitat due to clearance of woody weed habitat; more open post weed control.

16/2/15

31/10/18



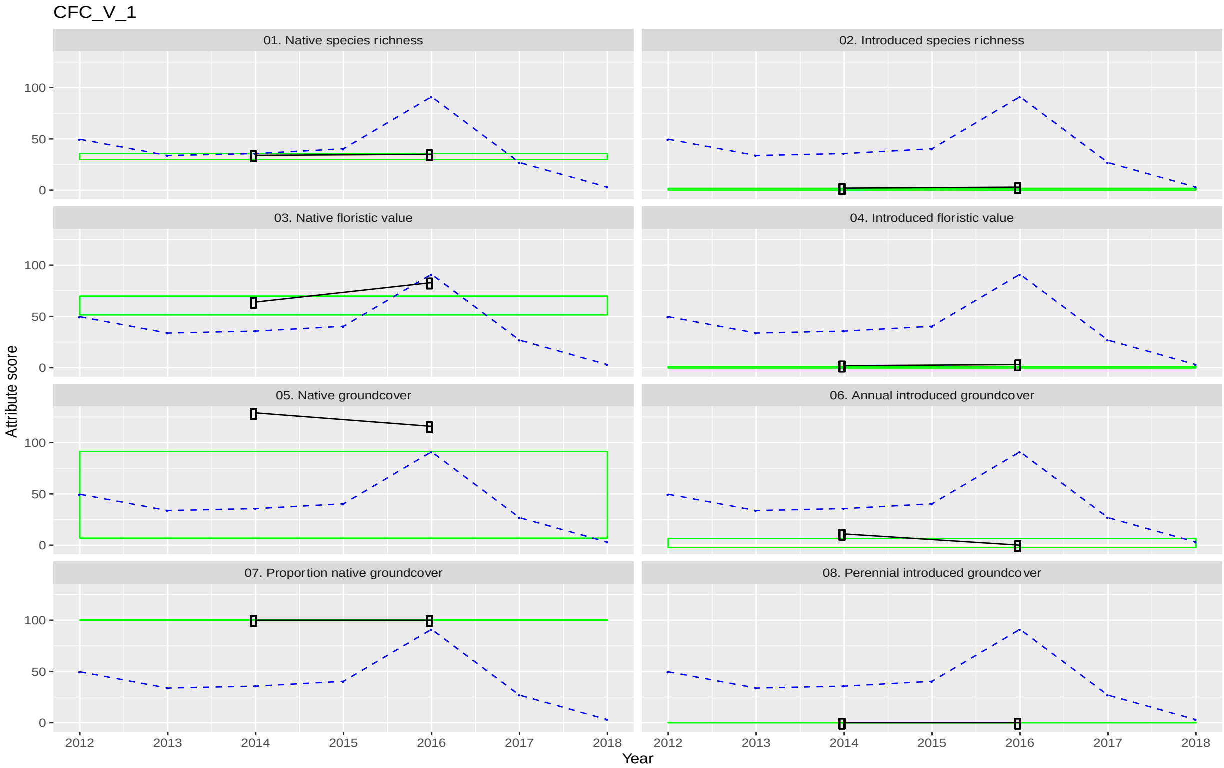
Captains Flat Cemetery 2014, 2016 CFC_1

Monitoring 2014, 2016, undertaken by Captains Flat Landcare Group
Location: in the south-western corner of the cemetery, near the sign for the Presbyterian section of the cemetery.
Vegetation Type Snow Gum – Candlebark tall woodland **Vegetation structure** Shrubby forest
Management no active management. The site has been cleared of trees sometime in the past – there are no mature trees and it is dense with regenerating trees and shrubs.
Aims: to monitor change in vegetation and habitat condition and to use the results to contribute to the management plan.

Condition indicators	Condition, trend	Interpretation
Overall condition	↔	*Eucalyptus aggregata*, listed as vulnerable in NSW, is present on the site. Changes in vegetation indicators did not reflect variations in soil moisture availability.
Native species richness	↔	
Native floristic value	↑	
Native groundcover	↓	
Proportion native groundcover	↔	
Introduced species richness	↔	Sweet Vernal Grass *Anthosanthum odoratum* is common
Introduced floristic value	↔	
Introduced annual groundcover	↑	Decrease in annual introduced cover in 2016
Intr. perennial groundcover	↔	
Benchmark condition score	74%	The lack of mature and hollow-bearing trees reduces the benchmark condition score
Habitat diversity score	79%	The lack of mature and hollow-bearing trees reduces the habitat diversity score

(no photo available from 2016)

5/12/14

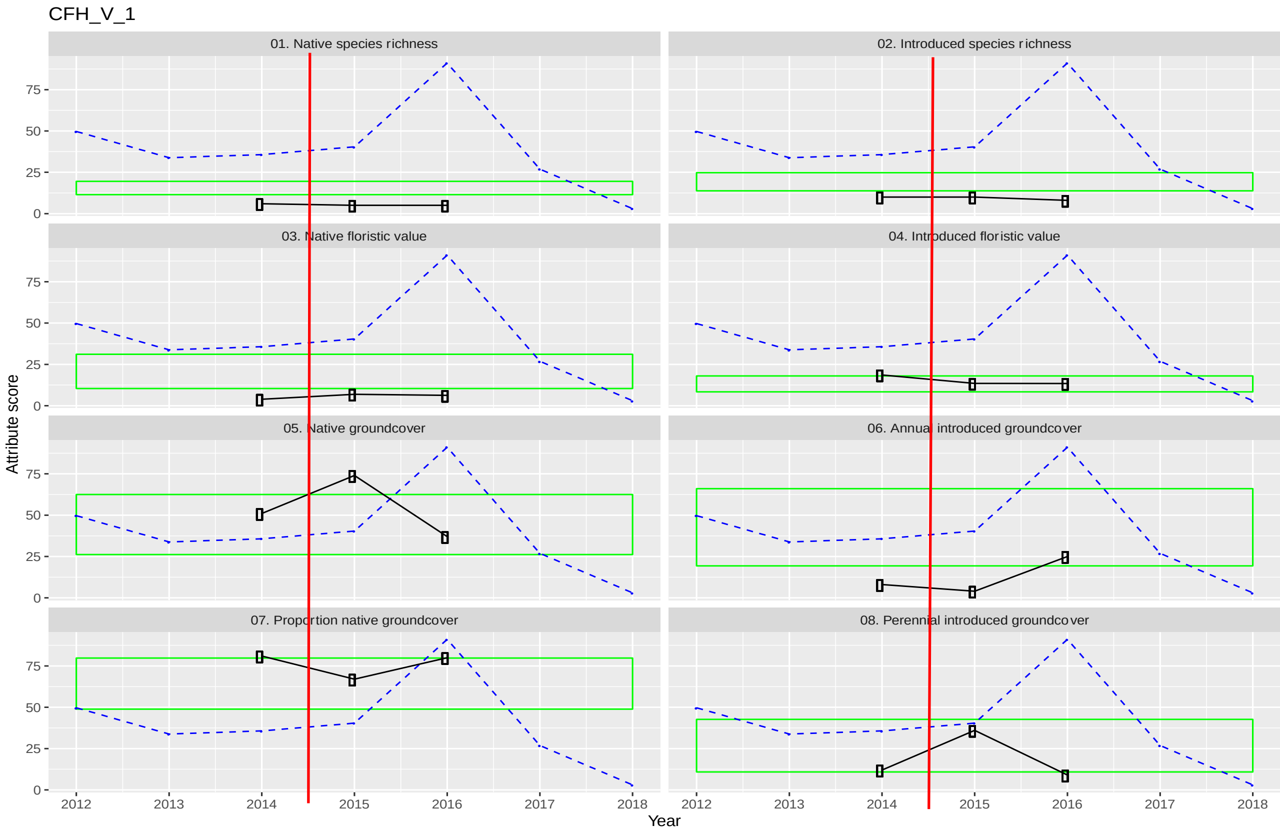


Captains Flat Property 2014–2016 CFH_1

Monitoring undertaken by Captains Flat Landcare Group
Location: property located on the Molonglo River, 5 km north of Captains Flat
Vegetation Type: native grassland (pasture), origin unknown **Vegetation structure**: grassland
Management: Blackberry and Broom were sprayed in January 2015
Aim: To monitor change in vegetation and habitat condition after spraying Blackberry and Broom

Condition indicators	Condition, trend	Interpretation
Overall condition	←→	Following spraying in January 2015 there was a significant reduction in the cover of Montpellier Broom (*Genista monspessulana*), and Blackberry evident in summer 2015, but recovery of Broom and some Blackberry was evident in 2016. Cover of introduced annual species, litter and bare earth were much higher in 2016 than in previous years, corresponding to variations in fluctuations in soil moisture availability. Reduction in native groundcover in 2016 may be due in part to lack of visibility due to the higher annual groundcover.
Native species richness	←→	Very low, no change following woody weed control
Native floristic value	←→	Very low, no change following woody weed control
Native groundcover	↑↓	Fluctuating increase following woody weed control, then decrease
Proportion native groundcover	←→	Fluctuating, decrease following woody weed control, then increase
Introduced species richness	←→	Low, stable
Introduced floristic value	←→	Low, slight decrease
Introduced annual groundcover	↓	Increase may reflect clearing or soil moisture availability
Intr. perennial groundcover	↑↓	Increase following woody weed control then decrease
Benchmark condition score	54%	
Habitat diversity score	51%	

No photos available



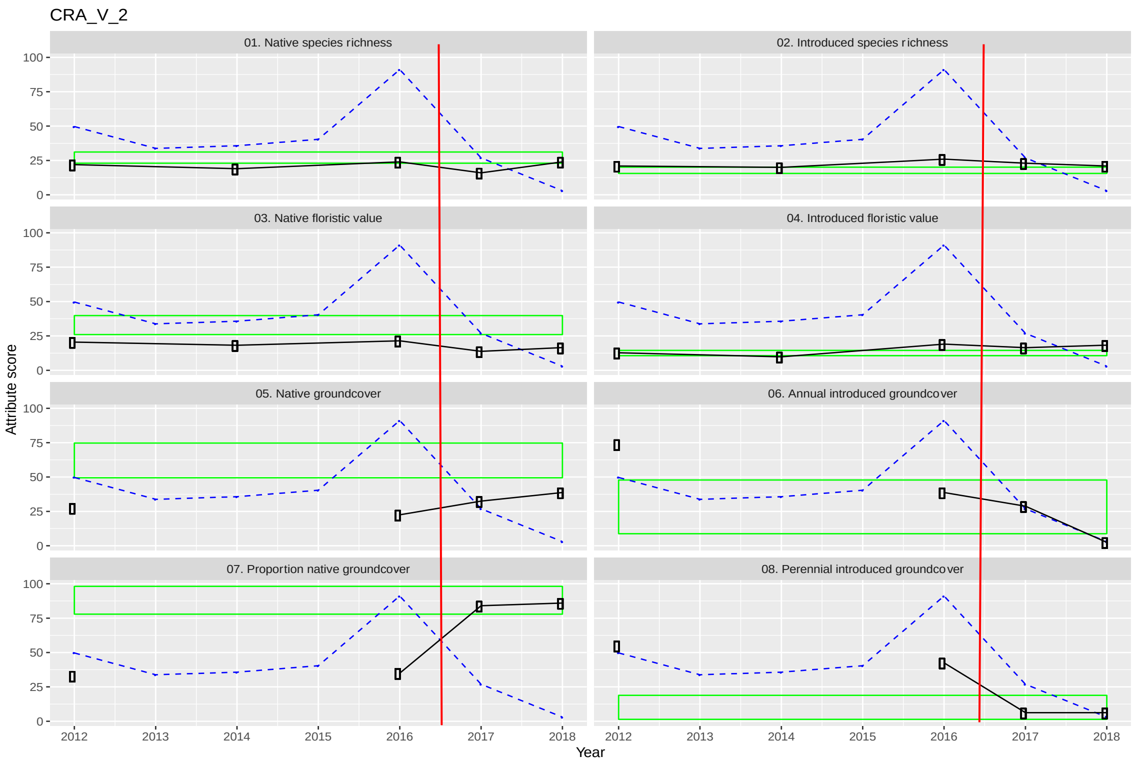
Cooleman Ridge Nature Reserve 2011–2018 CRA_1

Monitoring undertaken by Cooleman Ridge ParkCare
Location: eastern slope of Mt Arawang.
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC in 2018)
Vegetation structure: grassy woodland
Management Serrated Tussock control in 2011; control burn in autumn 2017 for wildfire mitigation.
Aim: To monitor change in vegetation and habitat condition after control of Serrated Tussock and implementation of a control burn.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑	Changes in introduced species cover reflects both improved changes post burn, and soil moisture availability. Serrated Tussock was recorded annually, but after 2014, at lower abundance.
Native species richness	↔	Slight reduction post burn, increased again after 18 months
Native floristic value	↔	Reduction post burn
Native groundcover	↑	Increase post burn, despite reduced soil moisture availability
Proportion native groundcover	↑	Increase post burn, despite reduced soil moisture availability
Introduced species richness	↔	No change
Introduced floristic value	↓	Slight increase in weeds (decrease in condition)
Introduced annual groundcover	↑	Significant decrease post burn, also reflecting soil moisture availability (increase in condition)
Intr. perennial groundcover	↑	Significant decrease post burn, also reflecting soil moisture availability (increase in condition)
Benchmark condition score	69%	
Habitat diversity score	70%	

6/12/16

27/11/18



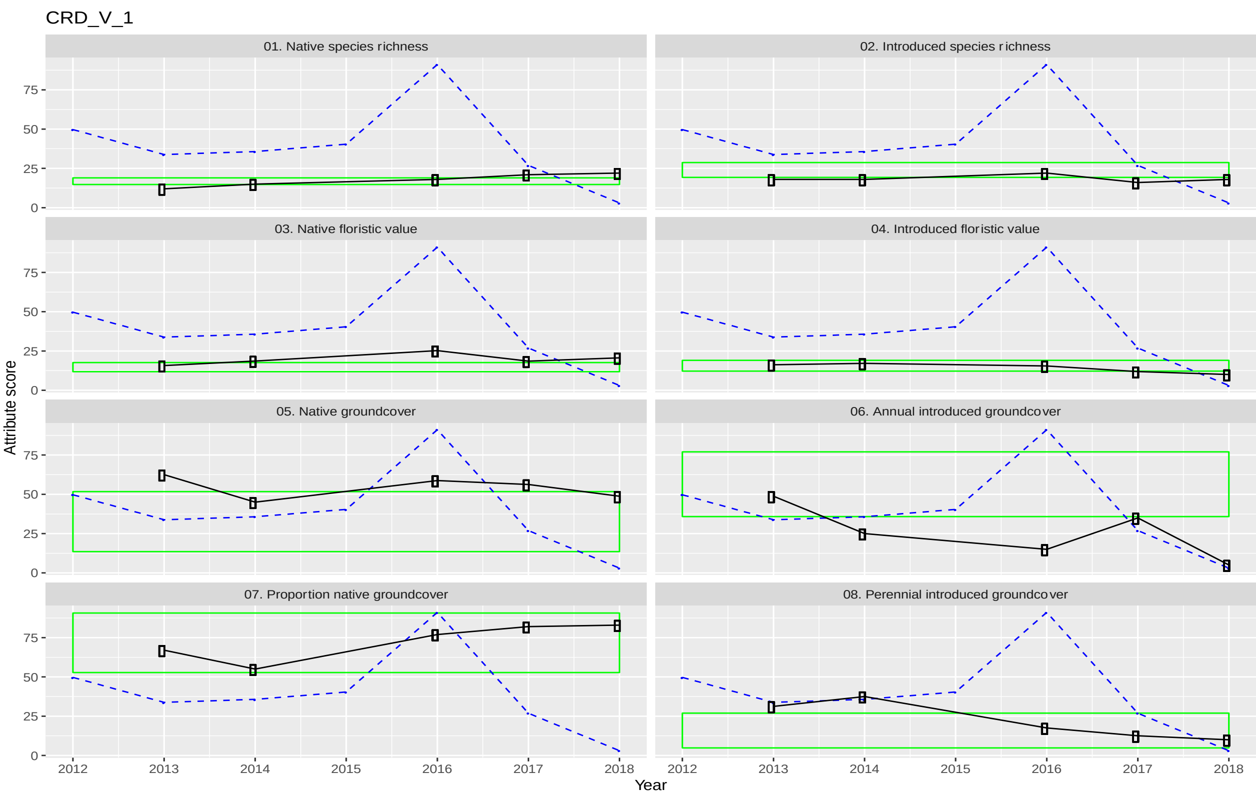
Cooleman Ridge Nature Reserve, 2013–2018 CRD_1

Monitoring undertaken by Cooleman Ridge ParkCare
Location: south facing slope south from Darrell Place, Chapman.
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland CEEC (2017)
Vegetation structure Derived grassland
Management general weeding. Possible treatment of St John's Wort in 2018.
Aim: To monitor change in vegetation and habitat condition, particularly change in native and introduced species cover and richness.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑	The cover of St John's Wort has reduced. Changes in condition do not reflect soil moisture availability, with possible exception of reduced introduced annual cover in 2018.
Native species richness	↑	Gradual increase in species richness
Native floristic value	↑	Slightly higher in 2016, year of higher soil moisture
Native groundcover	↔	Moderately stable
Proportion native groundcover	↑	
Introduced species richness	↔	
Introduced floristic value	↔	
Introduced annual groundcover	↑	Decrease over time, perhaps reflecting lower soil moisture in 2018 (an increase in condition)
Intr. perennial groundcover	↑	Decrease over time (an increase in condition)
Benchmark condition score	39%	Low, reflecting lack of tree cover and fallen timber
Habitat diversity score	49%	Low, reflecting lack of habitat features

18/11/14

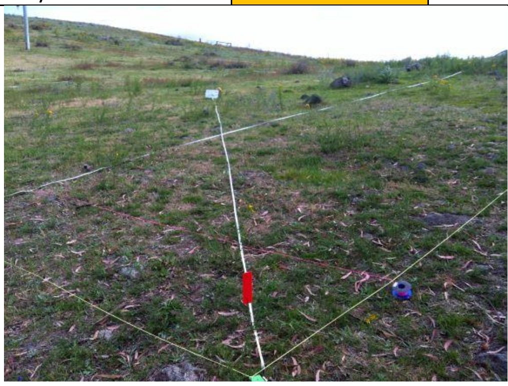
12/11/18



Isaacs Ridge Nature Reserve, 2012–2016 ISR_1

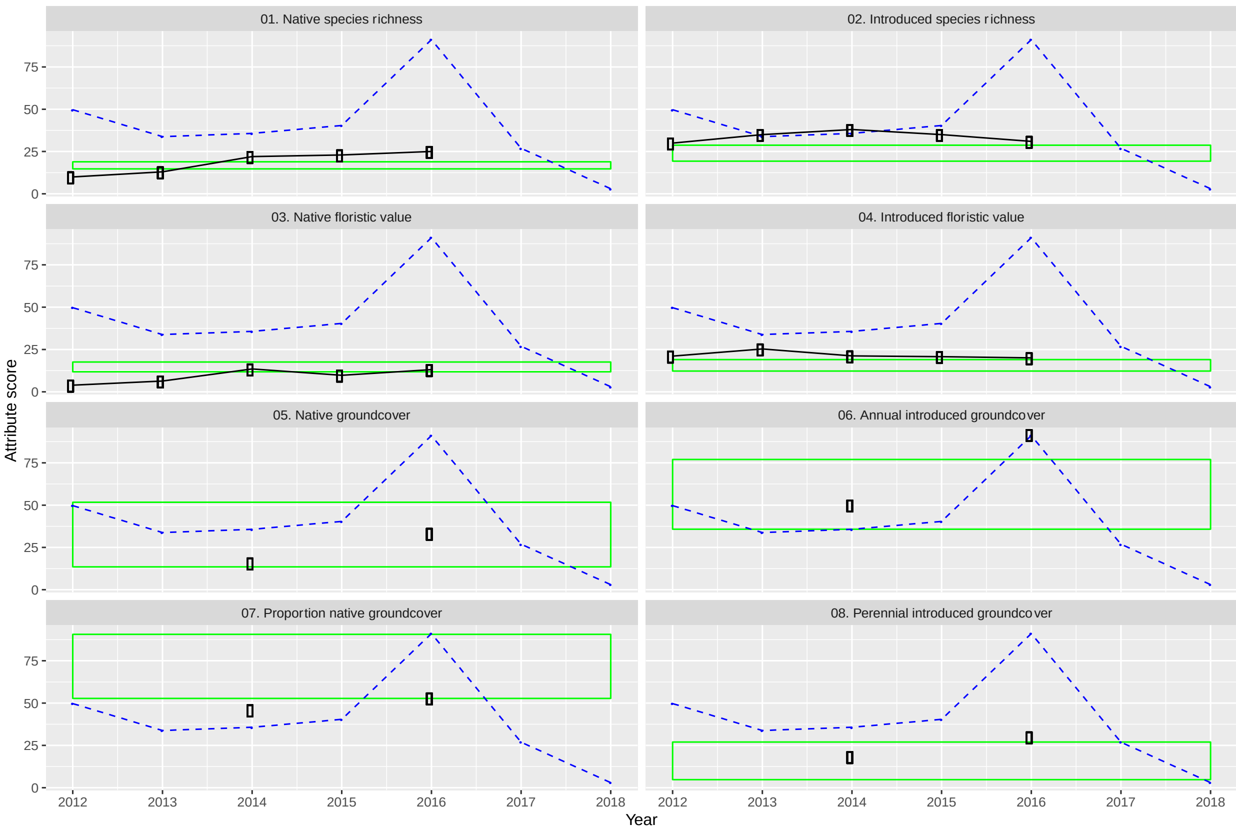
Monitoring undertaken by Isaacs Ridge ParkCare
Location: ridgetop on the easternmost border of Isaacs Ridge, adjacent to the boundary track
Vegetation Type: Native grassland, possibly derived from Yellow Box +/- Apple Box tall grassy woodland?
Vegetation structure: derived grassland
Management: cleared of pine trees in 2007.
Aim: To monitor change in vegetation and habitat condition following removal of the pines and regular weeding.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑	High increase in introduced annual cover in 2016 corresponding to high soil moisture availability
Native species richness	↑	Gradual increase over time
Native floristic value	↑	Gradual increase over time
Native groundcover	↑?	Increase, measured only twice
Proportion native groundcover	↑?	Increase, measured only twice
Introduced species richness	↔	Stable
Introduced floristic value	↔	Stable
Introduced annual groundcover	↓?	Increase, measured only twice (decrease in condition)
Intr. perennial groundcover	↓?	Increase, measured only twice (decrease in condition)
Benchmark condition score	52%	
Habitat diversity score	54%	


25/11/2013


28/11/2016 (photos taken from different angles)

ISR_V_1



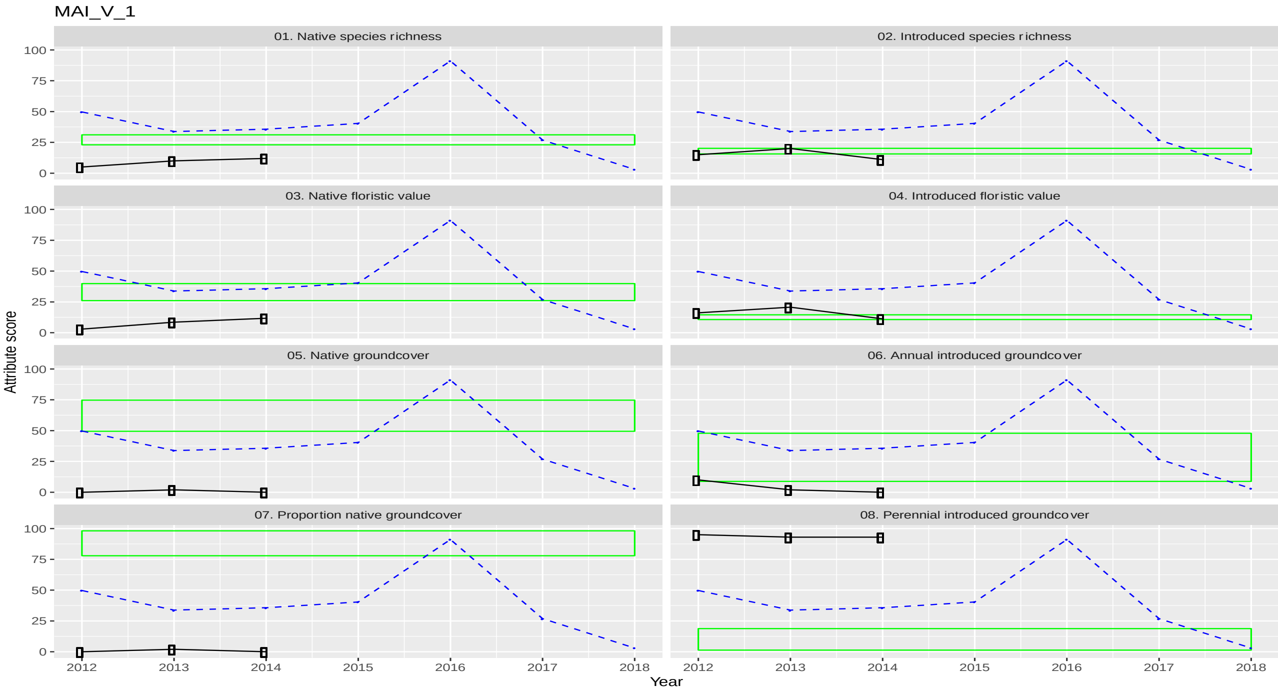
Mt Ainslie Nature Reserve, 2012–2014 MAI_1, 2

Monitoring undertaken by Mt Ainslie Weeders
Location: at the end of the tip track, accessed from Phillip Ave gate, MAI_1 in the northern end of the tip revegetation plot, MAI_2 south towards the powerlines.
Vegetation Type Environmental revegetation, native, formerly Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland
Vegetation structure Shrubby woodland
Management: the area was used as a tip until the 1990s. Following that, the site was covered with soil and revegetated with trees and shrubs, mainly Acacias.
Aim: To monitor change in vegetation and habitat condition following revegetation with native trees and shrubs.

Condition and trend	MAI_1, 2 condition, trend	Interpretation
Overall condition	↑	Higher cover of planted trees and shrubs in MAI_1 than MAI_2. The monitoring ceased prior to the period of lower soil moisture availability so no data are available to assess changes in species cover or richness to soil moisture.
Native species richness	↑	Trees planted mainly Yellow Box and Blakely's Red Gum. Some native forbs surviving in low numbers, higher richness in MAI_2.
Native floristic value	↑	
Native groundcover	←→	
Proportion native groundcover	←→	Very low proportion of understorey is native.
Introduced species richness	←→	
Introduced floristic value	←→	
Introduced annual groundcover	↑	Decrease in IAC, increase in condition
Intr. perennial groundcover	←→	Paterson's Curse, Cape Weed and St John's Wort
Benchmark condition score	26%	
Habitat diversity score	46%	

MAI_1, 24/10/12

MAI_2, 12/10/14



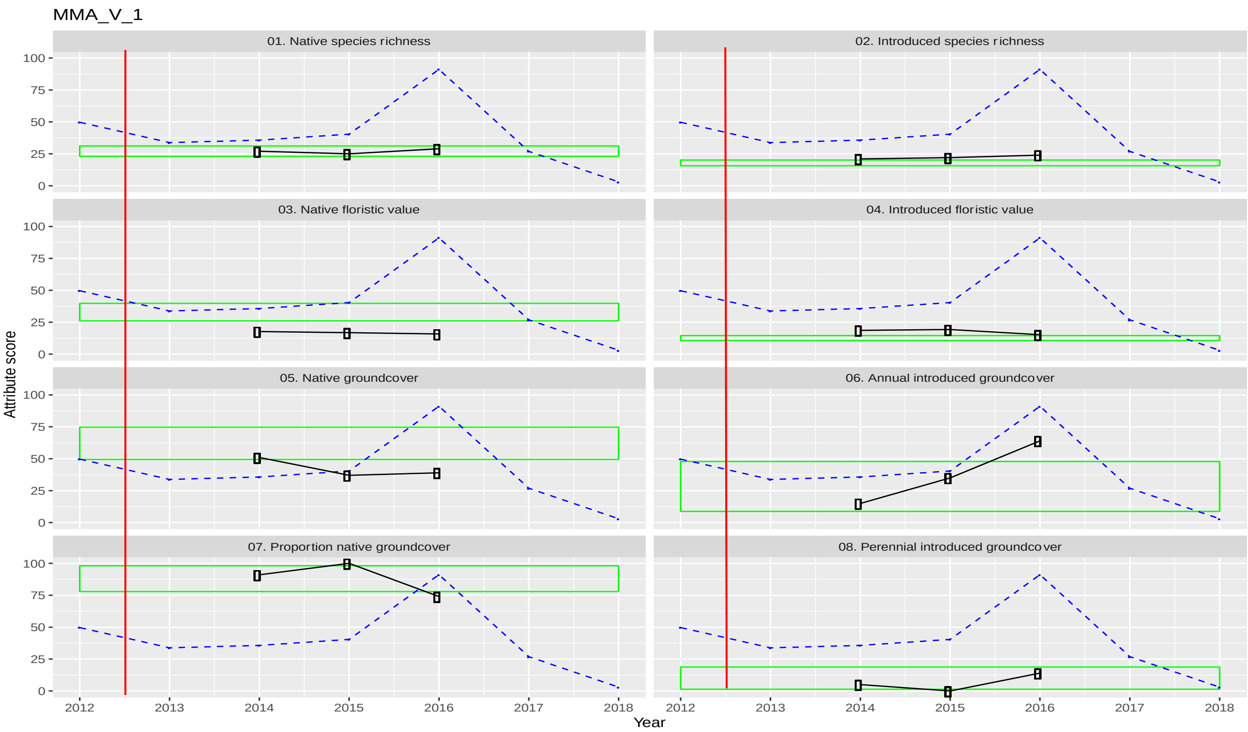
Mt Majura Nature Reserve, 2014–2016 MMA_1

Monitoring undertaken by Friends of Mt Majura
Location: Northern edge of Mt Majura Nature Reserve on Antill Street, Majura, south of The Fair housing development.
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC)
Vegetation structure Derived grassland
Management: revegetation of shrubs, trees and herbaceous species in 2013.
Aim: To monitor change in vegetation and habitat condition following revegetation of a variety of trees, shrubs and forbs.

Condition indicators	Condition, trend	Interpretation
Overall condition	↔	The significant increase in cover, particularly of the annual introduced species, corresponds with the very high soil moisture in 2016.
Native species richness	↔	
Native floristic value	↔	
Native groundcover	↓	
Proportion native groundcover	↓	
Introduced species richness	↔	
Introduced floristic value	↔	
Introduced annual groundcover	↓	High increase corresponds to high soil moisture availability, decrease in condition
Intr. perennial groundcover	↔	
Benchmark condition score	57%	
Habitat diversity score	61%	Increased habitat diversity due to growth of shrub revegetation

28/11/2014

25/11/2016



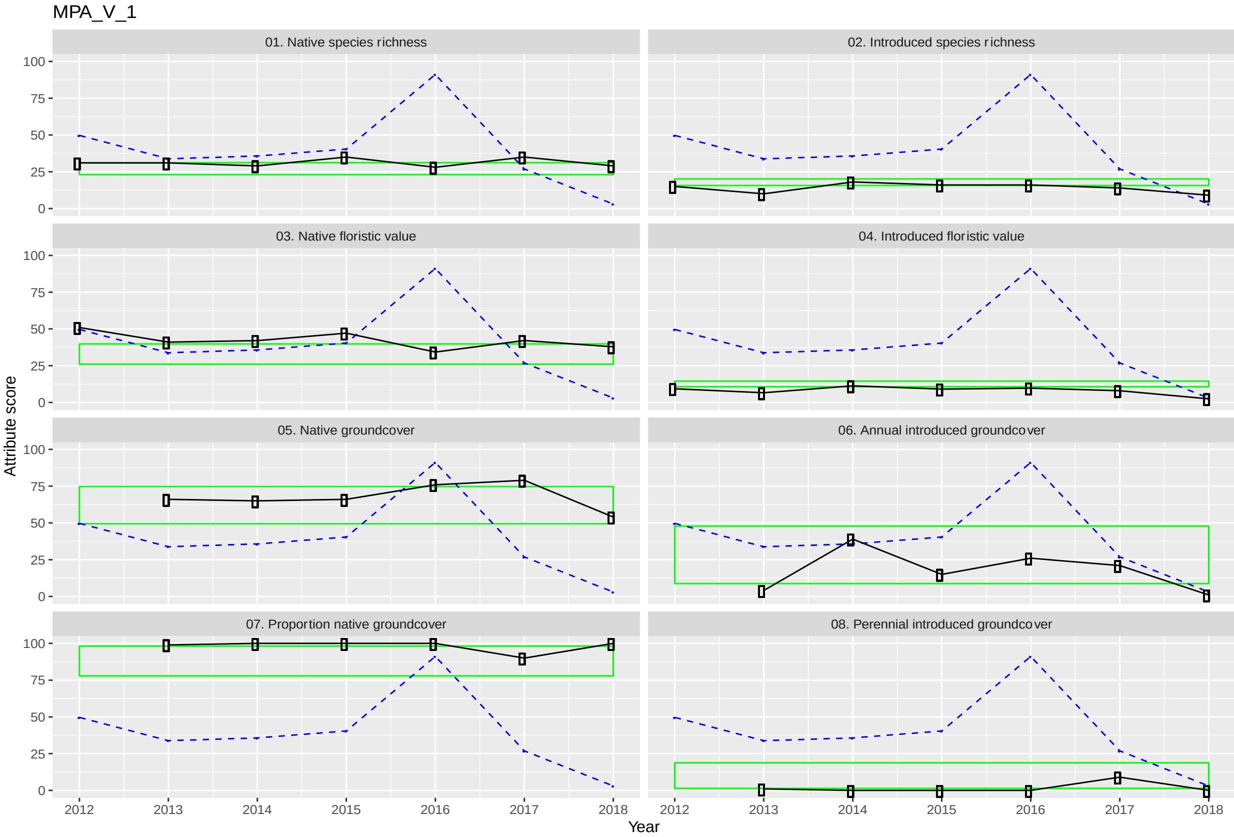
Mt Painter Nature Reserve, 2012–2018 — MPA_1

Monitoring undertaken by Friends of Mt Painter
Location: on the north-facing slope of Mt Painter above Skinner St in Cook
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC)
Vegetation structure Derived grassland
Management: weed management including Mullein and St John's Wort.
Aim: To monitor change in vegetation and habitat condition in a high condition location.

Condition indicators	Condition, trend	Interpretation
Overall condition	←→	Increase in introduce annual groundcover in 2016 is probably a result of increase in soil moisture availability
Native species richness	←→	Variable but stable
Native floristic value	←→	Variable but stable
Native groundcover	←→	Variable but stable
Proportion native groundcover	←→	Variable but stable
Introduced species richness	←→	Variable but stable
Introduced floristic value	←→	Variable but stable
Introduced annual groundcover	↑↓	Increase in 2014, otherwise stable
Intr. perennial groundcover	←→	Stable, very low, condition good; no significantly invasive plants present
Benchmark condition score	62%	Lack of mature trees
Habitat diversity score	65%	Plot lacks diversity in tree and shrub cover

23/10/2012

4/11/18



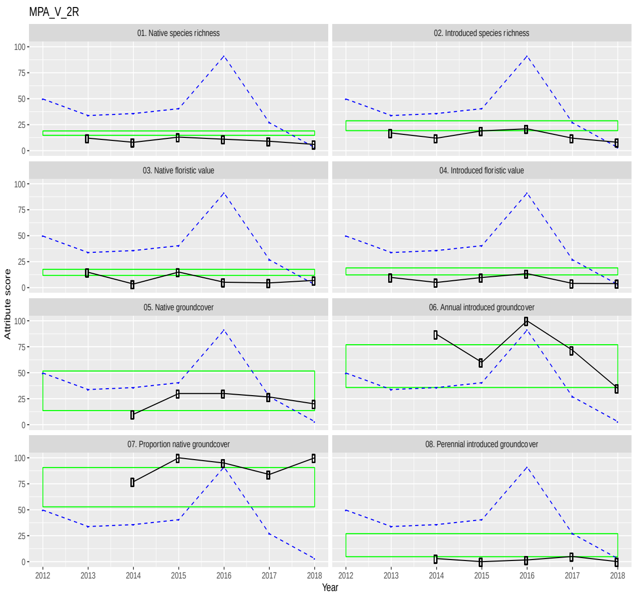
Mt Painter Nature Reserve, 2013–2018 — MPA_2R, 2C

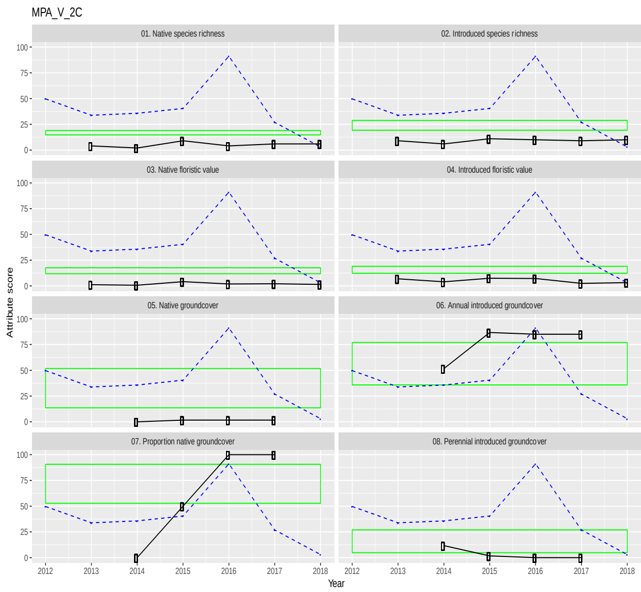
Monitoring undertaken by Friends of Mt Painter
Location: north-facing slope on the western side of the summit path
Vegetation Type Native grassland, formerly Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland
Vegetation structure Derived grassland
Management revegetation of herbaceous species in 2011. Weed, kangaroo and rabbit control. Plot MPA2C was established as a control for comparison, in which no revegetation occurred.
Aim: To monitor change in vegetation and habitat condition following native forb revegetation in Plot MP_2R. Plots are smaller than the standard, being 6 x 15 m (0.01 ha), to fit with the size of the revegetated area.

Condition indicators	2R	2C	Interpretation
Overall condition	←→	←→	Introduced annual species cover coincided with variations in soil moisture availability. Reduction in species richness reflected the senescence of herbaceous revegetation.
Native species richness	←→	←→	Higher in MPA_2R; increase then decrease
Native floristic value	↓	←→	Increase in2015, then decrease
Native groundcover	↑	←→	Increase in cover compared to control plot
Proportion native groundcover	↑	↑	
Introduced species richness	↑↓	←→	
Introduced floristic value	←→	←→	
Introduced annual groundcover	↓↑	↓	Increase in annual groundcover equates to decrease in condition. Very high cover of the annual Wild Oats *Avena* sp. in 2016
Intr. perennial groundcover	←→	↑	Slight decrease in cover equates to increase in condition
Benchmark condition score	41%	28%	Very poor condition
Habitat diversity score	66%	54%	Moderate to good habitat diversity (rocks, some trees and shrubs)
Revegetation	2016: 42%		54 plants of four species were planted in MP2R (revegetation plot) in 2011; Yellow Buttons *Chrysocephalum apiculatum*, Chocolate Lily *Arthropodium fimbriatum*, Bulbine Lily *Bulbine bulbosa,* and False Sarsparilla *Hardenbergia violacea*.

MPA_2R 11/10/12

MPA_2R 4/11/18



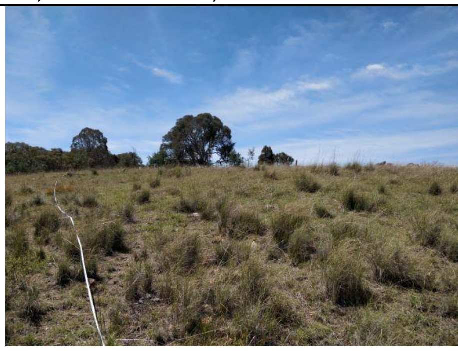


Mt Painter Nature Reserve, 2013–2018 MPA_3

Monitoring undertaken by Friends of Mt Painter
Location: within the Wildflower Triangle, accessed from Wybalena Grove
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland
Vegetation structure: derived grassland
Management: Control burn in autumn 2014. Weed priorities for control are St John’s Wort, Flax-leaved Fleabane (*Conyza bonariensis*) and Twiggy Mullein (*Verbascum virgatum*).
Aim: To monitor change in vegetation and habitat condition after a control burn undertaken in 2014.

Condition indicators	Condition, trend	Interpretation
Overall condition	↑	Introduced annual and perennial species cover reflects the variability in soil moisture availability in 2017 and 2018.
Native species richness	↓	Slight decrease in condition after the burn, regeneration of Silver Wattle.
Native floristic value	↓	Slight decrease in condition after the burn
Native groundcover	↑	Increase in native groundcover after the burn, including an increase post burn in native forb cover, from 0% in 2013 to of 16% in 2017
Proportion native groundcover	↔	Stable, high proportion of native groundcover
Introduced species richness	↑	Decrease after the burn, greater decrease in 2018. Equates to increase in condition
Introduced floristic value	↑	Decrease after the burn. Equates to increase in condition
Introduced annual groundcover	↓↑	High increase following the burn, reduction with fluctuation
Intr. perennial groundcover	↓↑	Stable, increase in 2017
Benchmark condition score	65%	Reduced by the lack of woody overstorey and litter
Habitat diversity score	54%	Lacks trees, shrubs and rocks, but there was

4/12/2013



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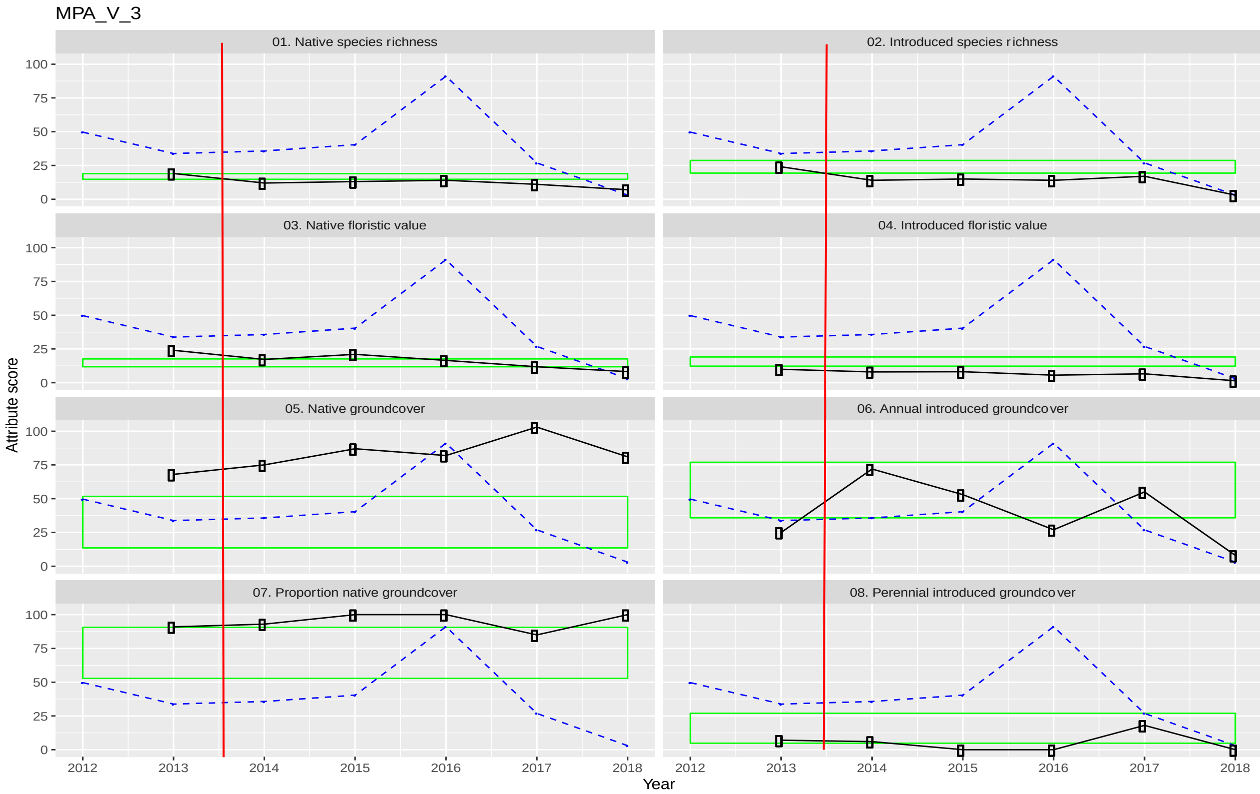
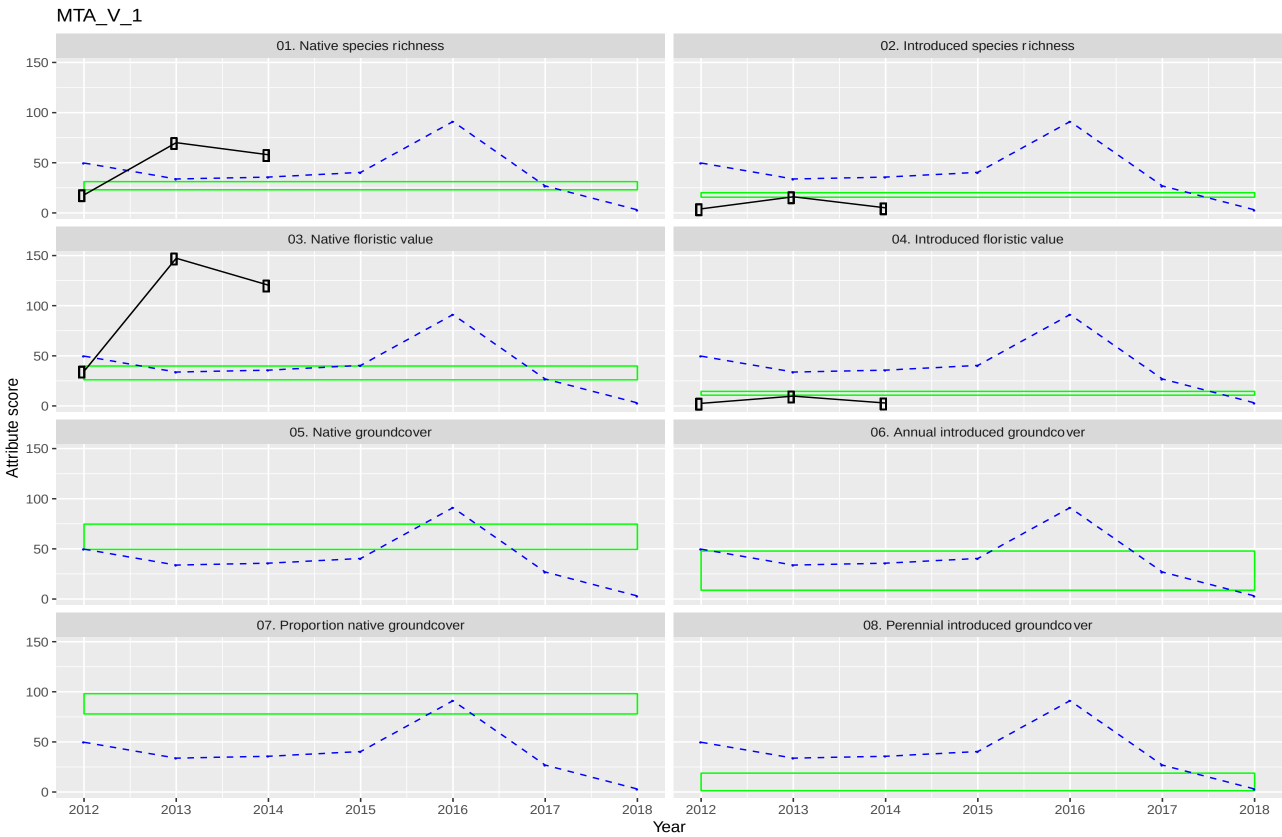


Mt Taylor Nature Reserve, 2013 - 2018 MTA_1

Monitoring undertaken by Mt Taylor ParkCare group
Location: south-western part of the reserve, adjacent to the powerline track and adjacent to the creekline containing the endangered Small Purple Pea *Swainsona recta*
Vegetation Type Mealy Bundy - Broad-leaved Peppermint shrubby mid-high open forest
Vegetation structure: shrubby woodland
Management: high intensity wildfire in 2003 resulted in very dense shrub regeneration.
Aim: To monitor change in vegetation and habitat condition after the 2003 wildfire.

Condition indicators	Condition, trend	Interpretation
Overall condition	?	Unclear if condition is improving; errors in species identification likely
Native species richness	↑	Very high increase is thought to be reflecting errors in species identification
Native floristic value	↑	
Native groundcover	not measured	
Proportion native groundcover	not measured	
Introduced species richness	↔	
Introduced floristic value	↔	
Introduced annual groundcover	not measured	
Intr. perennial groundcover	not measured	
Benchmark condition score	not measured	
Habitat diversity score	not measured	

No photos available

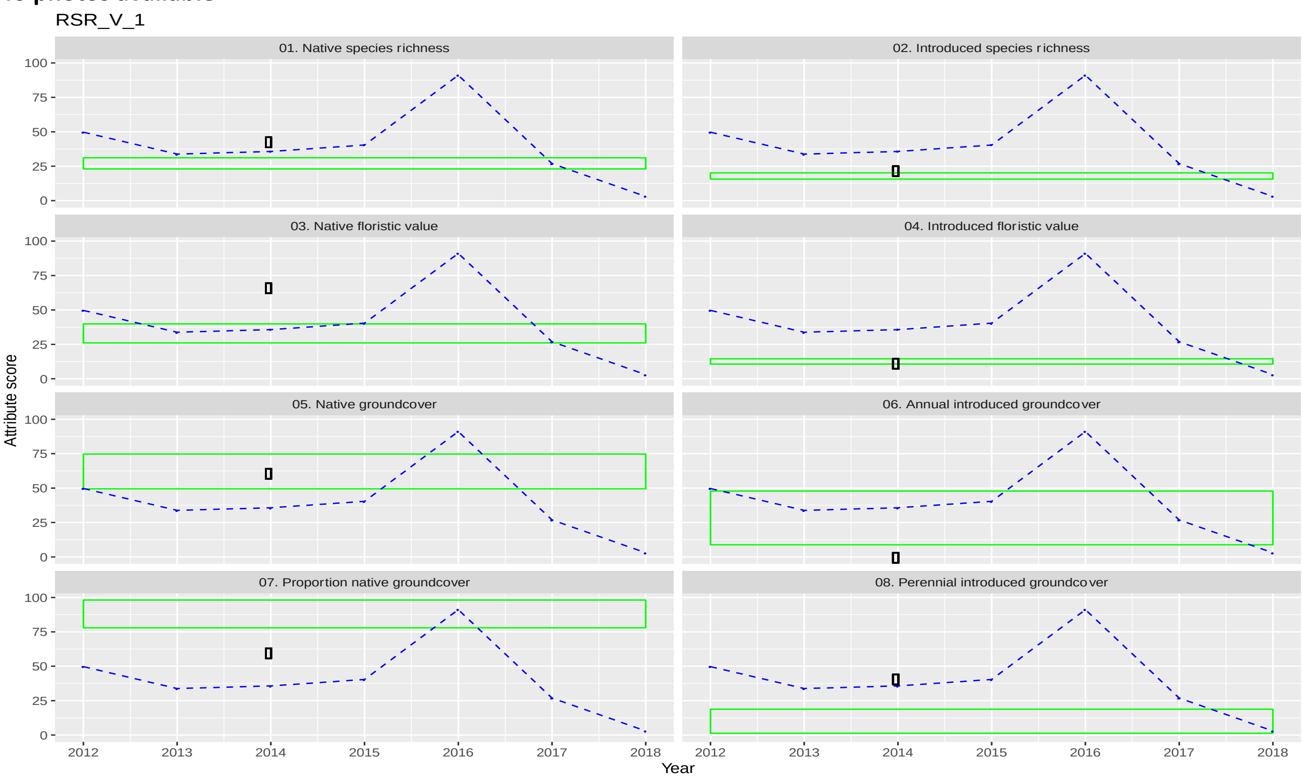


Royalla Swainsona Reserve, 2014 RSR_1

Monitoring undertaken by Royalla Landcare Group
Location: on Royalla Drive on the eastern side of the railway crossing.
Vegetation Type: Mealy Bundy - Broad-leaved Peppermint shrubby mid-high open forest
Vegetation structure: shrubby woodland
Management: forb revegetation.
Aim: To monitor change in vegetation and habitat condition following revegetation with native forbs.
The plot was monitored once, in 2014

Condition indicators	Condition	Interpretation
Overall condition		Interpretation was limited by only one survey. This plot has the highest native species richness of all the Vegwatch monitored plots
Native species richness		There are 29 non-grass species and 24 species that are disturbance sensitive, including two species threatened in NSW.
Native floristic value		Very high native floristic value score
Native groundcover		
Proportion native groundcover		Lower due to relatively high introduced perennial groundcover
Introduced species richness		
Introduced floristic value		
Introduced annual groundcover		Very few annual species present
Intr. perennial groundcover		Composition reflects grazing history
Benchmark condition score	68%	
Habitat diversity score	not measured	

No photos available



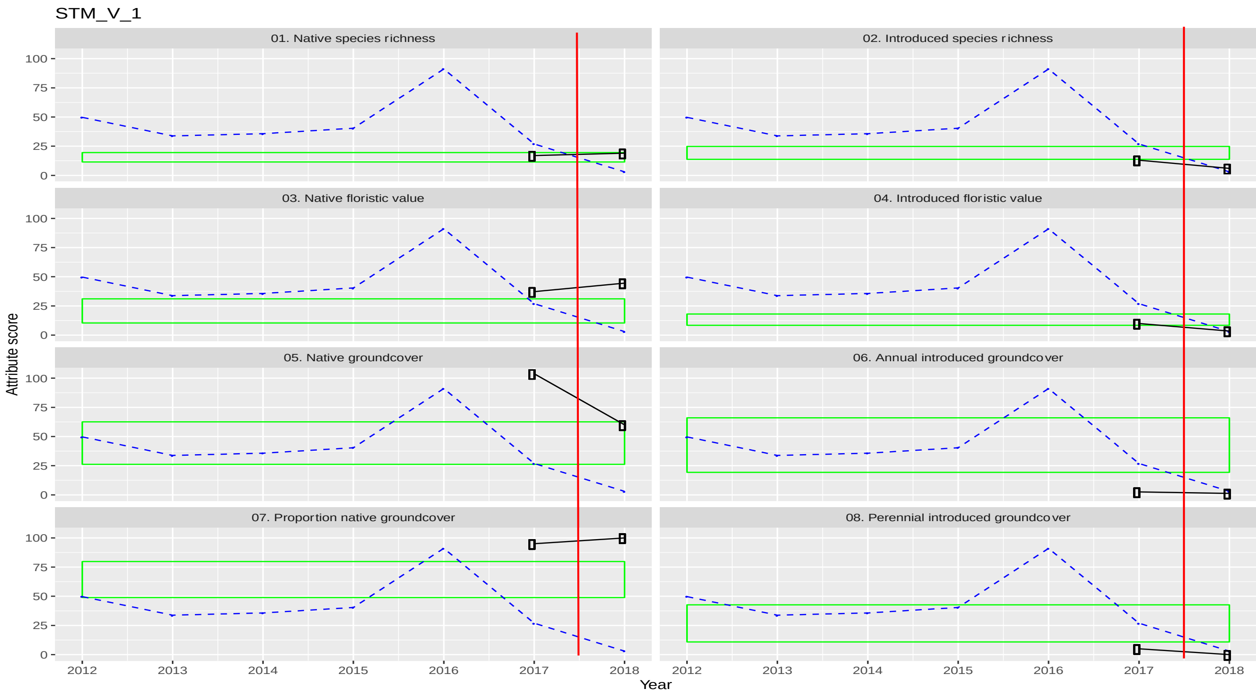
St Marks Grassland, 2017–2018 STM_1

Monitoring undertaken by Sarah Sharp
Location: on St Marks Theological College, Barton, located at the Charles Sturt University campus of St Marks, between Blackall St and Bowen Drive
Vegetation Type: Natural Temperate Grassland (CEEC) **Vegetation structure**: grassland
Management: burnt in 2014? and in 2018.
Aims: To monitor change in vegetation and habitat condition in a site subject to regular ecological burning; To monitor changes in population abundance of Button Wrinklewort and To measure the broader impacts of management of the grassland in accordance with the site's Conservation Management Plan

Condition indicators	Condition, trend	Interpretation
Overall condition	←→?	Interpretation was limited by the short period of monitoring. Changes in native species richness and cover may also correspond to soil moisture levels, although with only two years data any significance cannot be inferred. BWW population count: 42 in 2017, stable
Native species richness	←→	No change after the burn, despite increase in bare ground.
Native floristic value	←→	Slight increase after the burn
Native groundcover	↓	High biomass in 2017, mostly native grasses (Kangaroo Grass) which was burnt; decrease in biomass opened out spaces for other species
Proportion native groundcover	←→	Very slight increase after the burn
Introduced species richness	←→	Little response six months after the burn
Introduced floristic value	←→	
Introduced annual groundcover	←→	
Intr. perennial groundcover	←→	
Benchmark condition score	80%	
Habitat diversity score	40%	Low score due to homogeneity of site


9/11/17


1/11/18



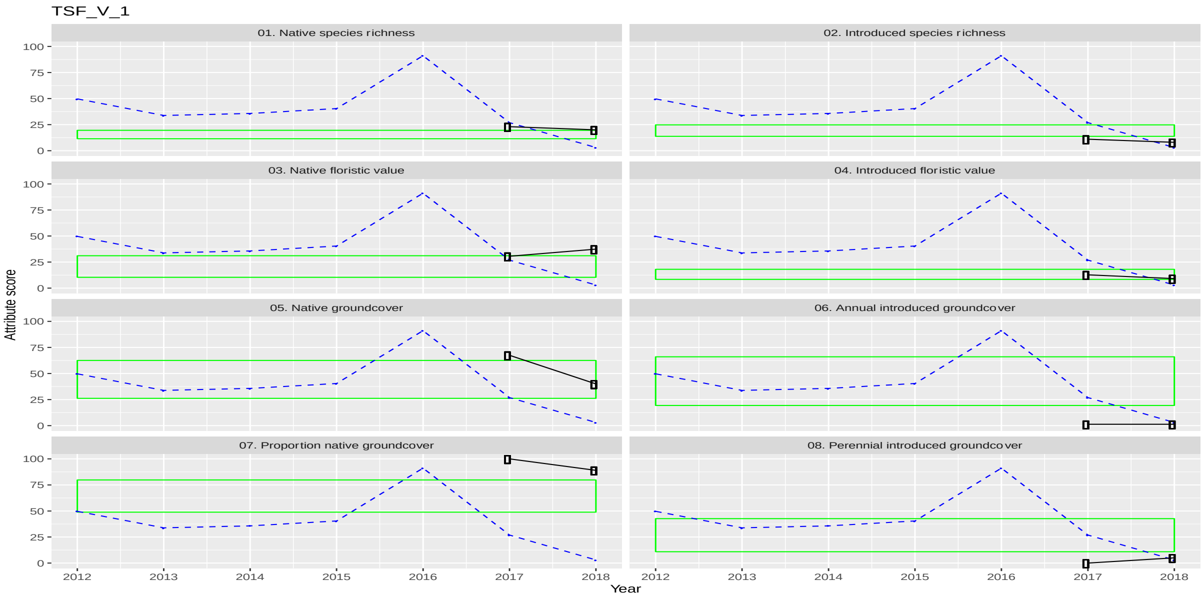
Tennant St Grassland 2017–2018 TSF_1

Monitoring undertaken by Molonglo Conservation Group
Location: on open space between Molonglo River and Tennant St Fyshwick, within an area containing a (mostly) fenced population of Button Wrinklewort *Rutidosis leptorhynchoides*
Vegetation Type Natural Temperate Grassland (CEEC) **Vegetation structure**: Grassland
Management: The area is currently grazed (agisted) for bushfire protection but most of the area containing the Button Wrinklewort is fenced off; cattle walk through the fenced area when being moved. Kangaroo grazing pressure appears to be high.
Aims: To monitor change in vegetation and habitat condition and to monitor the plot as a condition benchmark of high quality NTG

Condition indicators	Condition, trend	Interpretation
Overall condition	←→?	Interpretation was limited by the short period of monitoring. Plot has very shallow soil; past erosion is evident in rilling of soils, although cryptogams are present and may be stabilising the soil to some extent. There are more than 1000 Button Wrinklewort plants, which have spread beyond the enclosure fence.
Native species richness	←→	
Native floristic value	←→	
Native groundcover	↓	
Proportion native groundcover	↓	Native groundcover reduced considerably in 2018, corresponding to the very low soil moisture.
Introduced species richness	←→	Very low ISR
Introduced floristic value	←→	
Introduced annual groundcover	←→	Very low introduced groundcover
Intr. perennial groundcover	←→	
Benchmark condition score	81%	
Habitat diversity score	74%	Rocky site, with surface and buried rocks, cryptogams

3/1/18

15/10/18



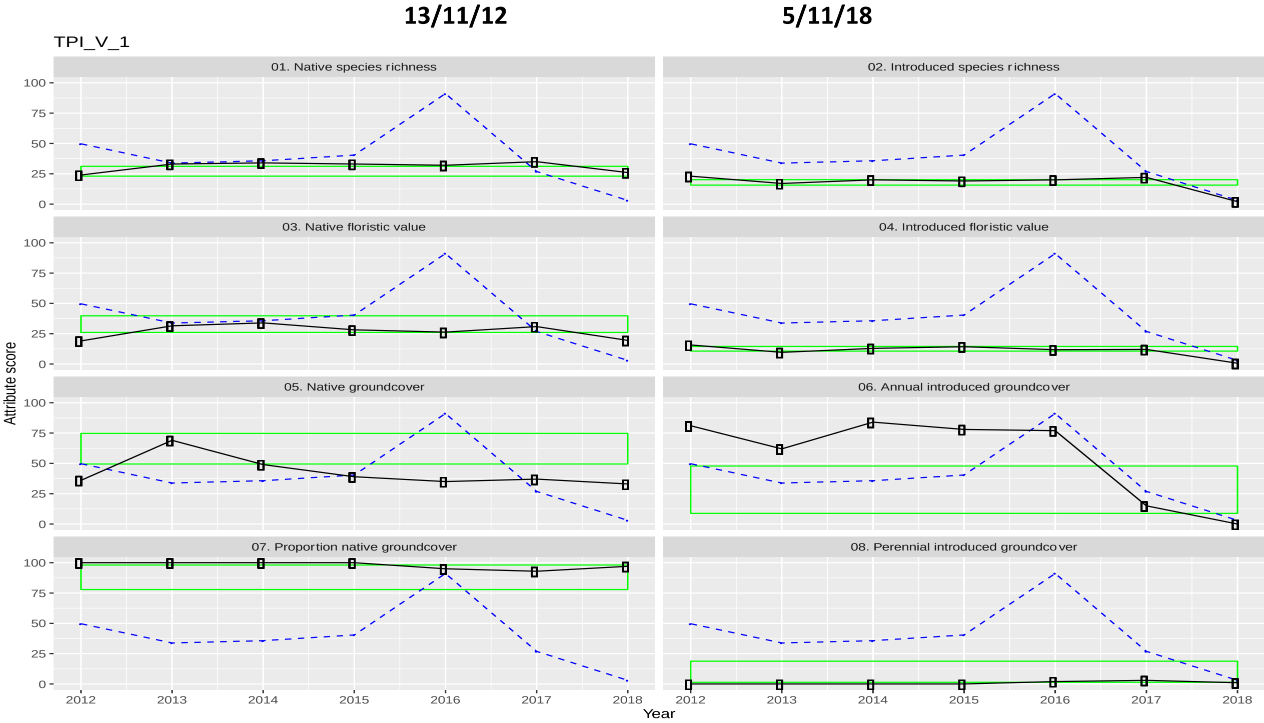
The Pinnacle Nature Reserve 2012–2018 TPI_1

Monitoring undertaken by Friends of The Pinnacle
Location: ‘Kama Paddock’, in the north of the reserve, south of Marrakai St, Hawker
Vegetation Type: environmental revegetation, native, formerly Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland
Vegetation structure shrubby woodland
Management: revegetation of trees in the 1980s, mostly Red Box with some Red Stringybark and Acacia species; revegetation of shrubs and understorey species in spring 2011; regular weeding undertaken.
Aims: To monitor change in vegetation and habitat condition and structural diversity following revegetation with shrubs and forbs; and to monitor herbaceous revegetation success

Condition indicators	Condition, trend	Interpretation
Overall condition	↔	Reduction in introduced annual groundcover corresponded with the low and extremely low soil moisture in 2017, 2018.
Native species richness	↔	Stable, slight increase over time
Native floristic value	↔	Stable, slight increase over time
Native groundcover	↑↓	Increase then decrease gradually
Proportion native groundcover	↔	Very high
Introduced species richness	↔	stable
Introduced floristic value	↔	Slight decrease in 2018
Introduced annual groundcover	↑	High, steep decrease in 2017, corresponding to an increase in condition
Intr. perennial groundcover	↔	Very low; significant reduction in St John’s Wort, Paterson’s Curse, Verbascum
Benchmark condition score	62%	
Habitat diversity score	68%	
Revegetation success	2019: 66%	See separate study

13/11/12

5/11/18



Revegetation success

213 seedlings were planted in 2011, of which 75 were forbs, the remainder shrubs and trees. 94% were alive after several months. After 8 years 140 were still alive (66%) and 38 plants had recruited. Survival varied from 0% (*Hardenbergia violacea*) to 91% (*Callitris endlicheri*)

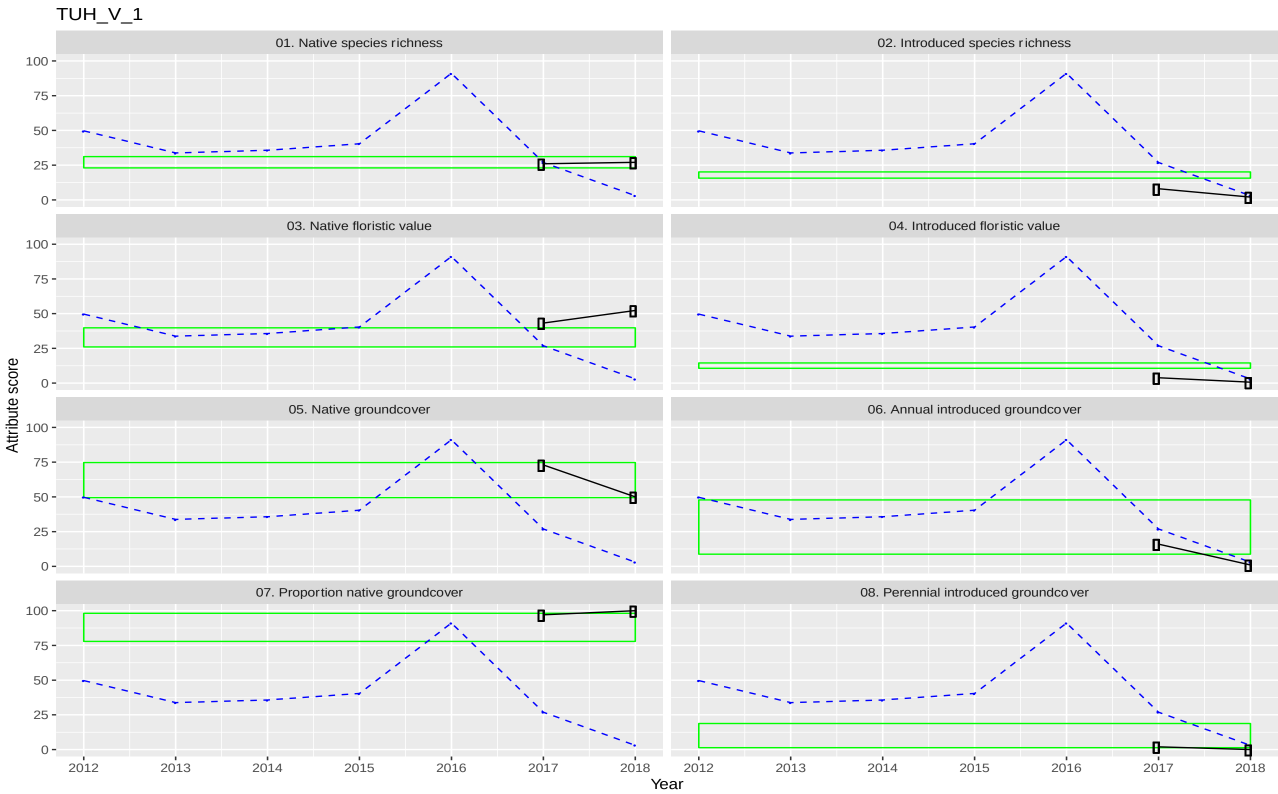
Species	Common Name	Planted	2012	2019	% alive after 8 years	Recruitment, 2019
Acacia rubida	Red-stemmed Wattle	11	11	6	55%	9
Allocasuarina verticillata	Drooping She-oak	14	13	11	85%	
Bursaria spinosa	Australian Blackthorn	30	30	17	57%	
Callitris endlicheri	Black Cypress Pine	11	11	10	91%	
Cassinia quin/long.	Cassinias	22	22	19	86%	
Dodonaea viscosa	Narrow-leaved Hopbush	17	17	15	88%	
Hardenbergia violacea	False Sarsparilla	3	3	0	0%	
Indigofera adesmiifolia	Leafless Indigo	9	9	3	33%	1
I. australis	Austral Indigo	22	21	13	59%	17
Chrysocephalum apiculatum	Yellow Buttons	16	16	6	38%	
C. semipapposum	Clustered Everlasting	59	48	40	68%	11
Total		213	201	140		38
Percentage survival			94%	66%		74%

Tuggeranong Hills Nature Reserve 2017–2018 TUH_1

Monitoring undertaken by Friends of Tuggeranong Hills
Location: on Tuggeranong Hills Nature Reserve, accessed from Christmas St in Theodore, north of the Grinding Grooves
Vegetation Type: Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC)
Vegetation structure: grassy woodland
Management: no active management
Aim: To monitor change in vegetation and habitat condition while existing very low-level management is undertaken.

Condition indicators	Condition, trend	Interpretation
Overall condition	↔	Interpretation was limited by the short period of monitoring. Reduction in native groundcover corresponds with the reduced soil moisture levels in 2018.
Native species richness	↔	
Native floristic value	↑	
Native groundcover	↓	
Proportion native groundcover	↔	
Introduced species richness	↔	No significant environmental weeds present in the plot
Introduced floristic value	↔	
Introduced annual groundcover	↑	
Intr. perennial groundcover	↔	
Benchmark condition score	69%	Low tree cover, few old-growth trees and no fallen timber in plot
Habitat diversity score	75%	

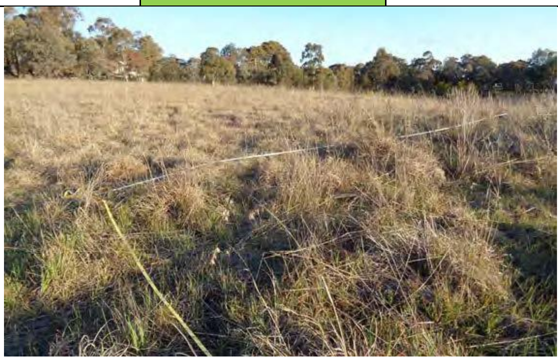
No photos are available



Umbagong Grassland 2015–2018 UMG_1

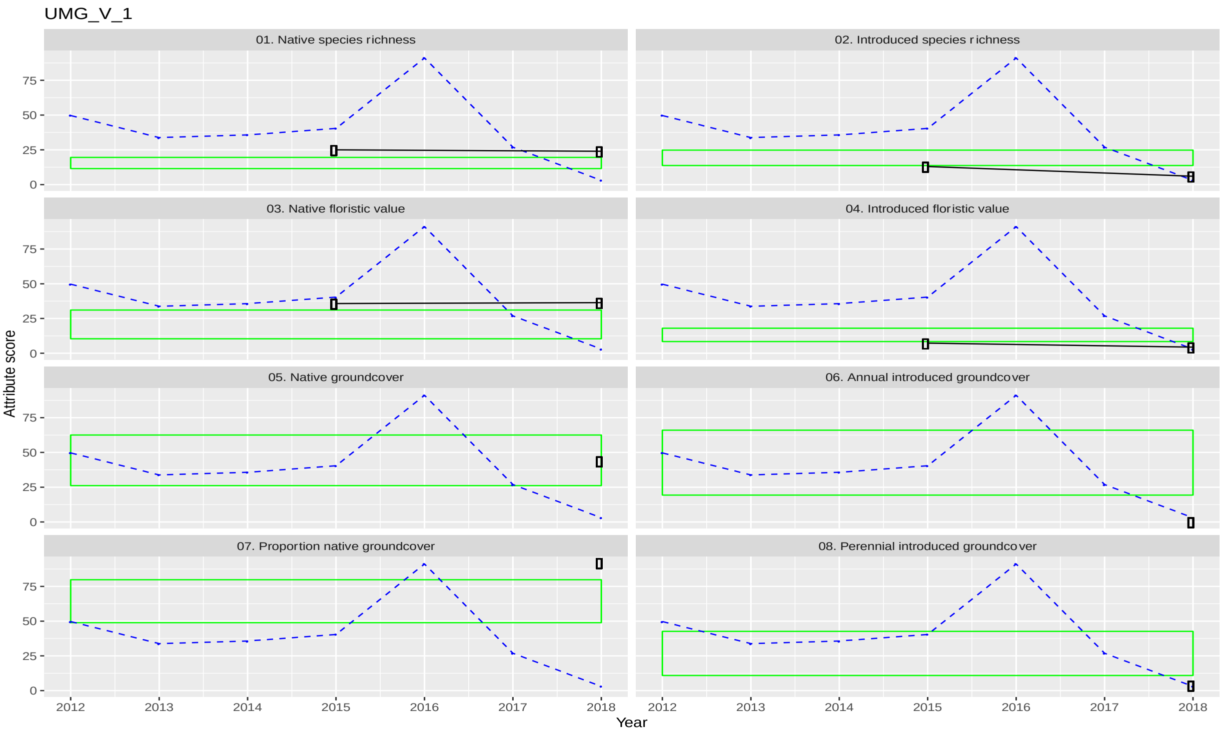
Monitoring undertaken by Friends of Grasslands
Location: on east of Ginninderra Creek on the southern end of Umbagong Reserve
Vegetation Type: Natural Temperate Grassland (CEEC)
Vegetation structure: grassland
Management: regular ecological burns; last burnt 2018.
Aims: To monitor change in vegetation and habitat condition with the implementation of regular ecological burns; and to monitor the plot as a condition benchmark of high quality NTG

Condition indicators	Condition, trend	Interpretation
Overall condition	←→	Interpretation was limited by the short period of monitoring. The low native groundcover reflects the biomass removed by the burn.
Native species richness	←→	
Native floristic value	←→	
Native groundcover		Cover values only measured in 2018.
Proportion native groundcover		
Introduced species richness	←→	
Introduced floristic value	←→	
Introduced annual groundcover		Cover values only measured in 2018.
Intr. perennial groundcover		Cover values only measured in 2018.
Benchmark condition score	81%	
Habitat diversity score	68%	



23/11/15

22/10/18



Yarramundi Grassland 2012–2018 YAG_1, YAG_2

Monitoring undertaken by Friends of Grasslands (FOG)
Location: below the Burringiri Aboriginal and Torres Strait Islander Cultural Centre off Lady Denman Drive; YAG_1 directly to the south-east of the buildings, YAG_2 the southern side of the creek.
Vegetation Type Natural Temperate Grassland (YAG_2: CEEC)
Vegetation structure: grassland
Management: ecological burns have occurred in 2012 and 2017 (YAG_1) and 2011 and 2017 (YAG_2). Both areas are weeded regularly by FOG, particularly for St John's Wort and Chilean Needlegrass. YAG_1 was revegetated with forbs following disturbance in 2012.
Aims:

- To measure change in vegetation and habitat condition with the implementation of management by FOG and National Capital Authority.
- To measure change in vegetation and habitat condition in an area of high native diversity natural temperate grassland to provide a benchmark of change against seasonal conditions.

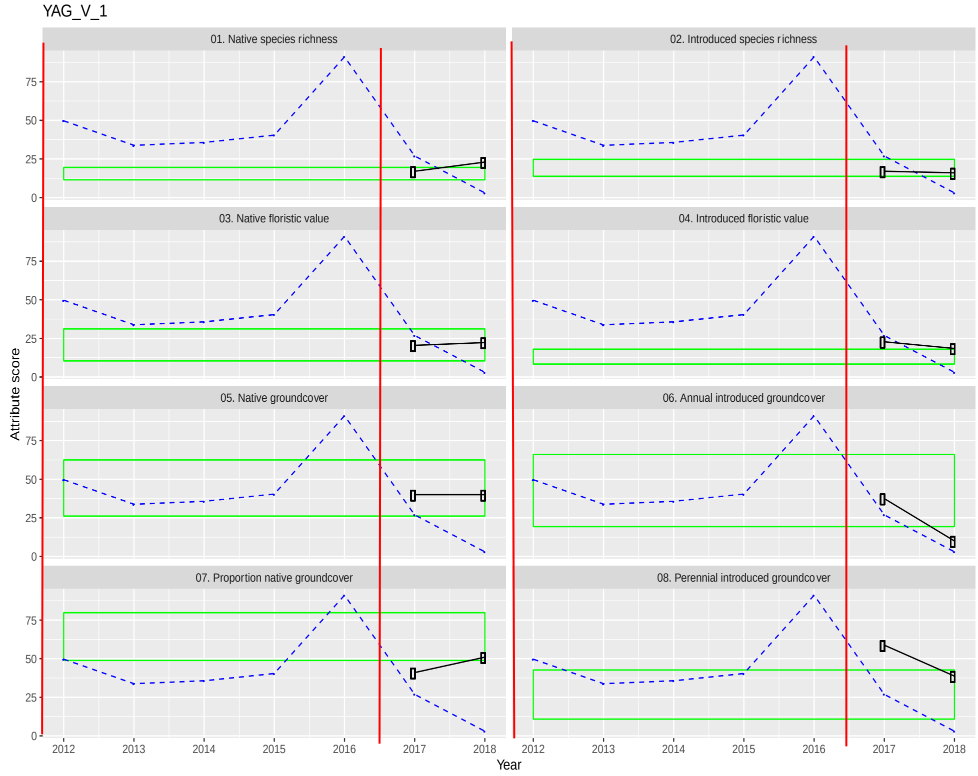
Condition indicators	YAG_1	YAG_2	Interpretation
Overall condition	↔	↔	Interpretation was limited by the short period of monitoring. Decrease in cover of introduced annual and perennial groundcover may reflect lower soil moisture availability in 2018.
Native species richness	↔	↔	
Native floristic value	↔	↔	
Native groundcover	↔	↓	Small reduction in groundcover in YAG_2
Proportion native groundcover	↑	↔	
Introduced species richness	↔	↔	
Introduced floristic value	↔	↔	
Introduced annual groundcover	↑	↔	Decrease in cover corresponds to increase in condition
Intr. perennial groundcover	↑	↔	Decrease in cover corresponds to increase in condition
Benchmark condition score	52%	78%	
Habitat diversity score	43%	54%	

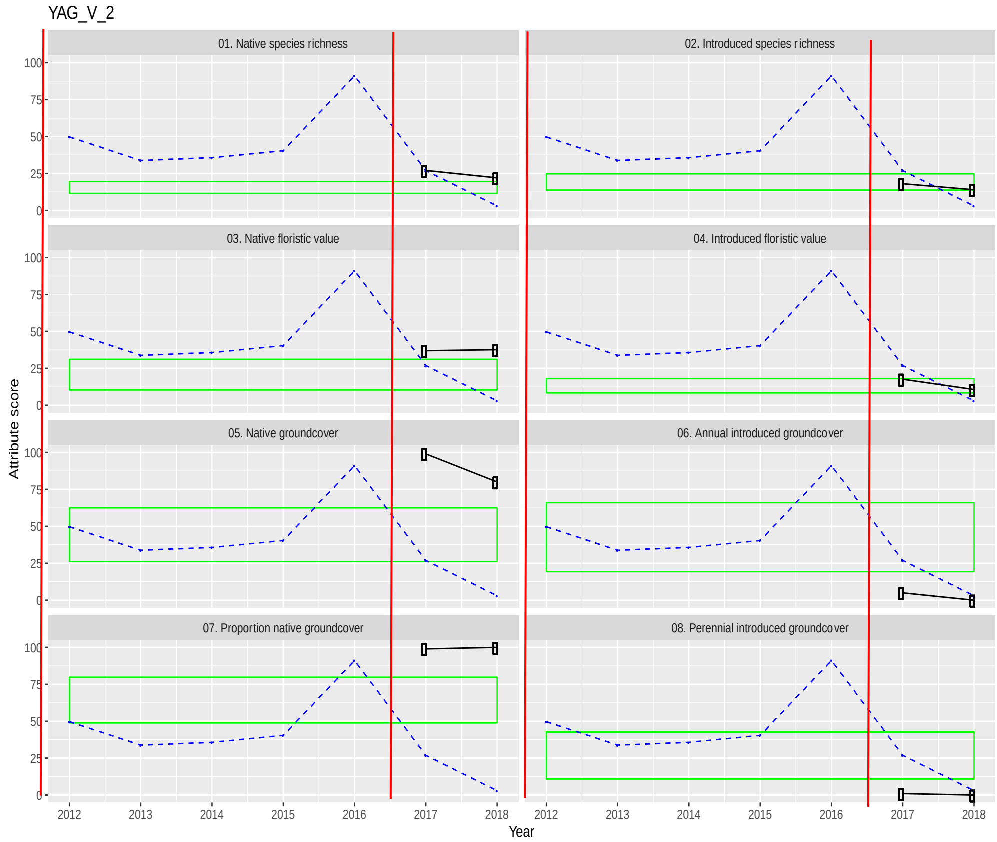
YAG_1 2017

YAG_1 8/12/18

YAG_2 2017, indicated by arrow

YAG_2 8/12/18


YAG_V_1
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year


YAG_V_2
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year

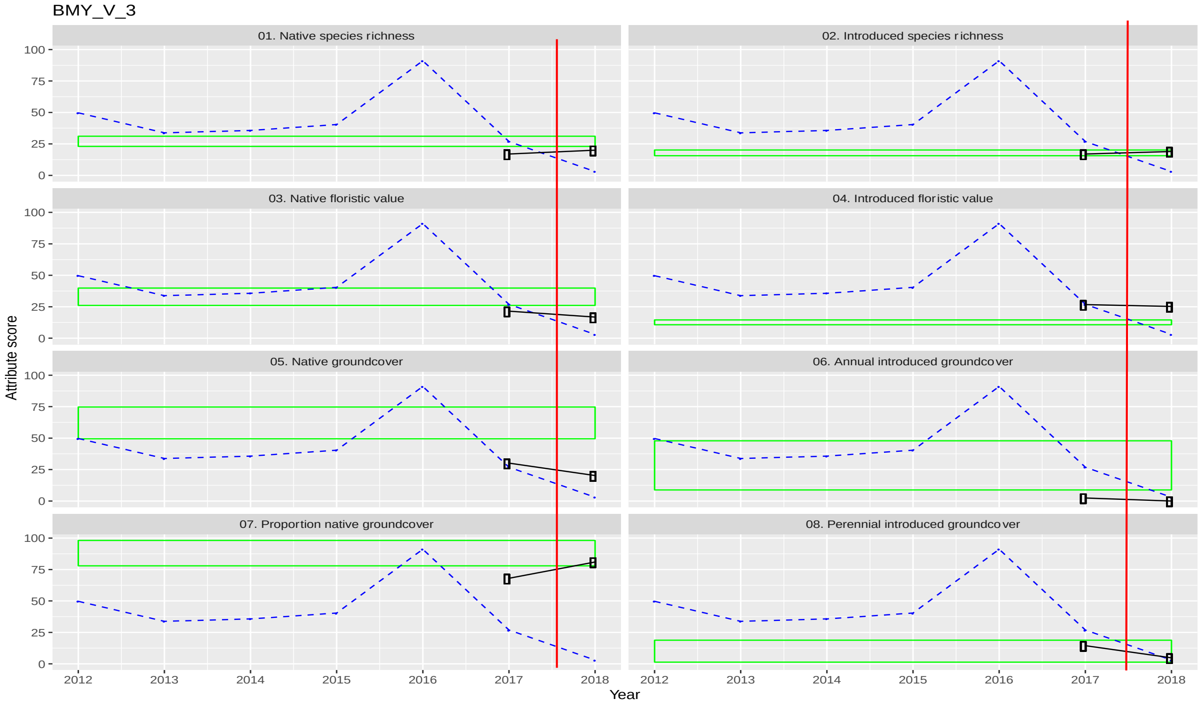
Bullan Mura Autumn 2018–Spring 2018 BMY_3

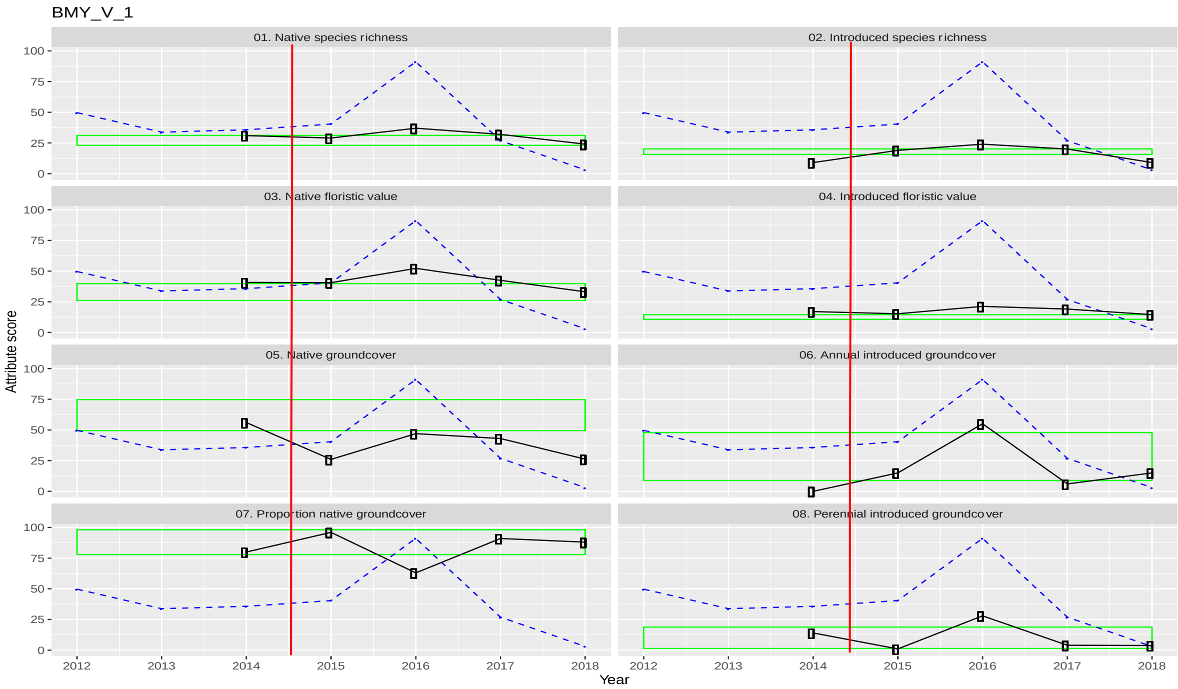
Monitoring undertaken by Sarah Sharp for MCG project
Location: in the south-eastern corner of Bullan Mura Woodland adjacent to the Chinese Embassy on Forster Crescent
Vegetation Type: Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC in 2018)
Vegetation structure: grassy woodland
Management: BMY_3 is one of four plots in four sites subject to a cultural cool burn in autumn 2018.
Aim: To monitor change in vegetation composition and structure and condition following a cultural burn.
Data from BMY_1 in the years 2017, 2018 was used to compared to BMY_3, as a control.

Condition indicators	BMY_3 burnt	BMY_1 control (2017, 2018 data only)	Interpretation
Overall condition	↑	↔	Interpretation was limited by the short period of monitoring. There was a large increase in bare ground cover after the burn. There was a small decrease in introduced perennial groundcover and native groundcover, which correspond both with the burn and with the low soil moisture conditions. In 2018 the plot met the criteria as the critically endangered ecological community.
Native species richness	↑	↔	Very slight increase is apparent, but within the range of the confidence intervals
Native floristic value	↔	↔	
Native groundcover	↓	↓	Poor scores in both plots likely to reflect in part variability in seasonal conditions
Proportion native groundcover	↑	↔	Increase in native groundcover after the burn
Introduced species richness	↔	↑	
Introduced floristic value	↔	↔	
Introduced annual groundcover	↔	↔	
Intr. perennial groundcover	↔	↔	
Benchmark condition score	58%	63%	
Habitat diversity score	55%	73%	


February 2018


October 2018





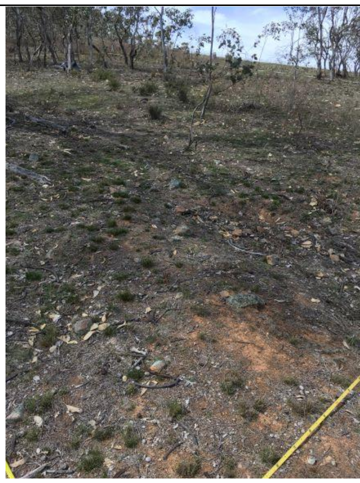
(management applied in BMY_V_1 was woody weed control)

Icon Water Williamsdale Autumn 2018–Spring 2018 IWW_1B, IWW_2C

Monitoring undertaken by Sarah Sharp for MCG project
Location: on Icon Water Woodland Biodiversity Offset site, Williamsdale, to the south of the electricity sub-station
Vegetation Type: Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland (CEEC)
Vegetation structure: grassy woodland
Management: IWW_1B is one of four plots in four sites subject to a cultural cool burn in autumn 2018. IWW_2C was not burnt (a control). St John's Wort was treated in March 2018.
Aim: To monitor change in vegetation composition and structure and condition following a cultural burn.

Condition indicators	IWW_1B Burnt	IWW_2C Control	Interpretation
Overall condition	↔	↔	Interpretation is limited by the short period of monitoring. The burn in plot 1B was very light – seedlings were burnt but are regenerating. There are few other visible signs of the burn. It was difficult in spring to identify where the burn occurred in the plot; no changes in indicators is attributable to the burn. The decrease in cover of native groundcover and proportion of native groundcover in both plots reflect changes in soil moisture availability.
Native species richness	↔	↔	
Native floristic value	↔	↓	
Native groundcover	↓	↓	Decrease in native groundcover in both plots
Proportion native groundcover	↔	↓	Decrease in proportion of native species in the control plot.
Introduced species richness	↔	↔	
Introduced floristic value	↔	↔	
Introduced annual groundcover	↔	↔	
Intr. perennial groundcover	↔	↔	
Benchmark condition score	54%	57%	
Habitat diversity score	76%	80%	

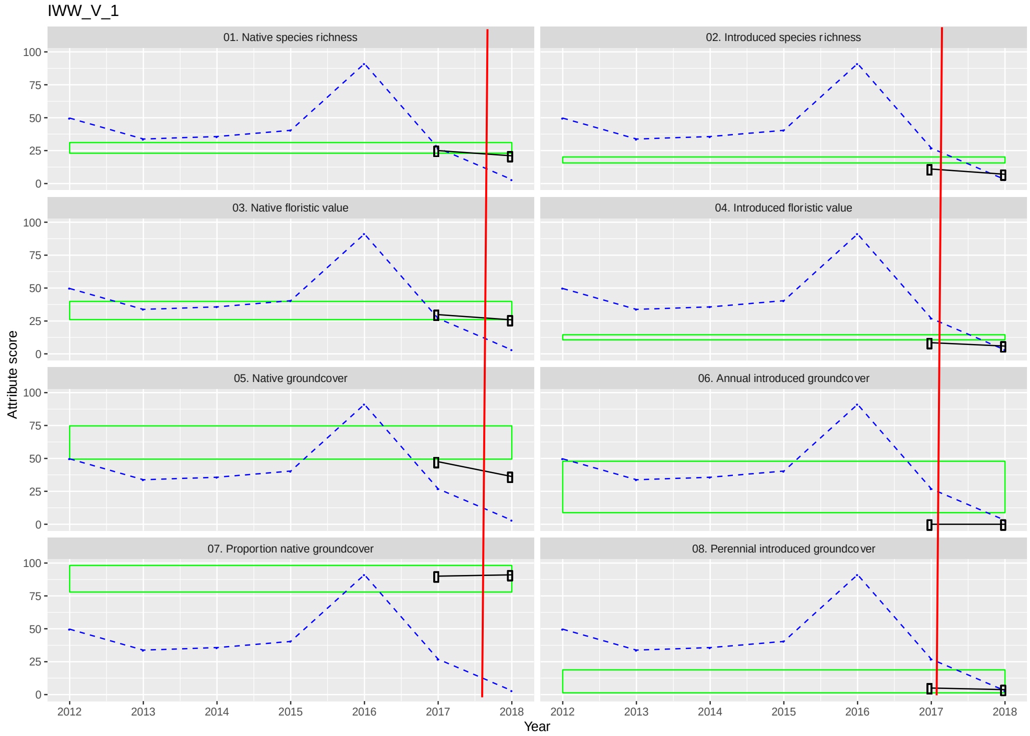
Icon_1B, 4/4/18

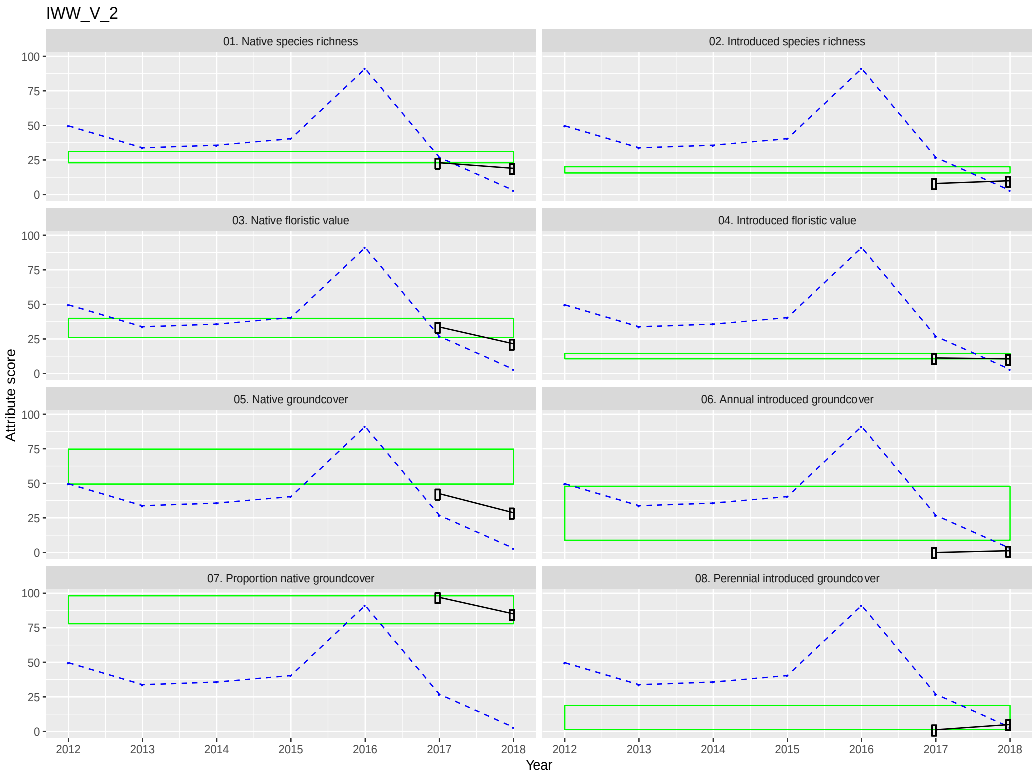


Icon_1B 23/10/18

Icon_2C, 4/4/2018

Icon_2C 23/10/18


IWW_V_1
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year
0
25
50
75
100
2012
2013
2014
2015
2016
2017
2018


IWW_V_2
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year
0
25
50
75
100
2012
2013
2014
2015
2016
2017
2018

Millpost Bungendore Autumn 2018–Spring 2018 MLP_1B, MLP_2C

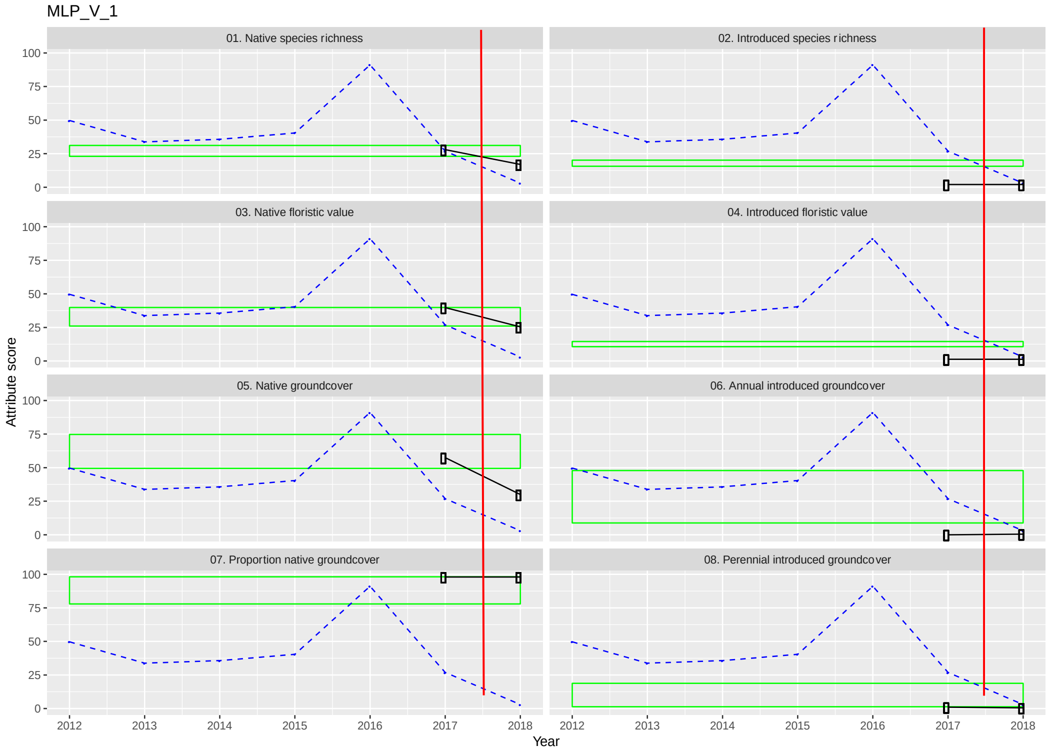
Monitoring undertaken by Sarah Sharp for MCG project
Location: on in the hills south-west of Bungendore, on Millpost property, to the east of the homestead
Vegetation Type: Brittle Gum - Scribbly Gum shrubby tall dry open forest
Vegetation structure: shrubby woodland
Management: MLP_1B is one of four plots in four sites subject to a cultural cool burn in autumn 2018. MLP_2C was not burnt as a control but was only monitored in 2018.
Aim: To monitor change in vegetation composition and structure and condition following a cultural burn.

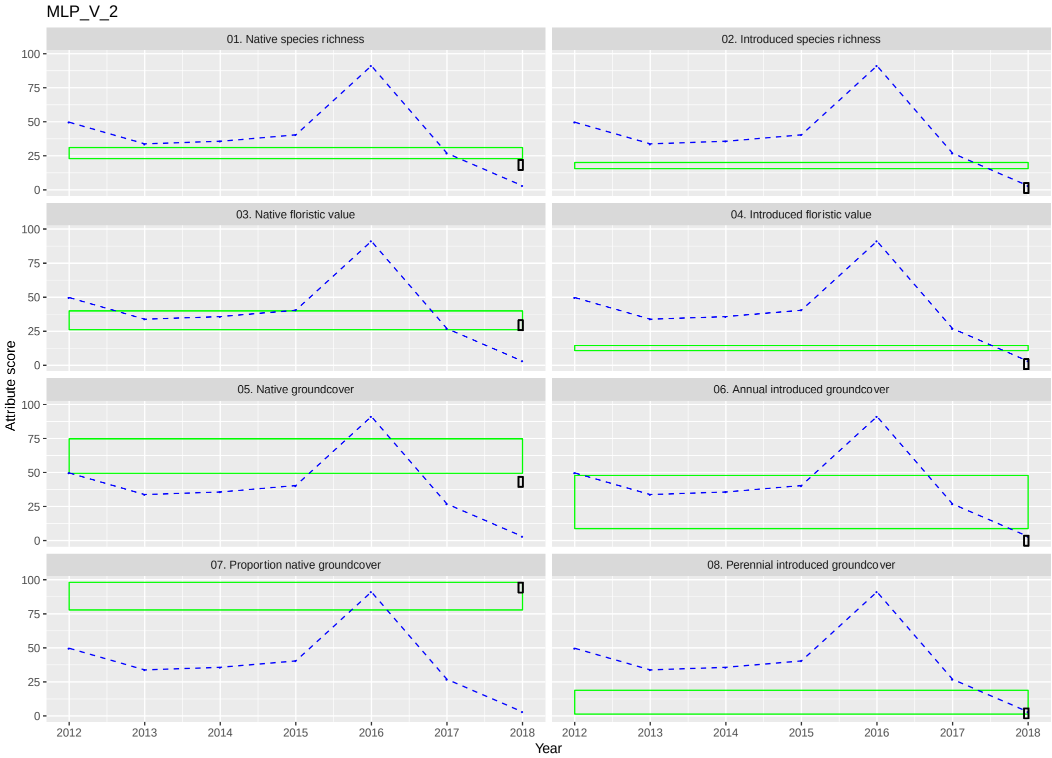
Condition indicators	MLP_1 Burnt	MLP_2 Control	Interpretation
Overall condition	←→		Interpretation is limited by the short period of monitoring. Native floristic condition was high, due to the occurrence of many significant sub-shrub species but was lower following the burn –many of the sub-shrubs were burnt to the ground, although nearly all are regenerating. There was a decrease in native grass cover and litter cover corresponding to the burn and to reduction in soil moisture. MLP_2 not surveyed in 2017; also in poor condition overall in 2018.
Native species richness	↓		
Native floristic value	↓		
Native groundcover	↓		
Proportion native groundcover	←→		
Introduced species richness	←→		Extremely low: only two introduced species were recorded
Introduced floristic value	←→		
Introduced annual groundcover	←→		
Intr. perennial groundcover	←→		
Benchmark condition score	53%	53%	
Habitat diversity score	75%	55%	Plots lack old growth trees

MLP_1B March 2018

MLP_1B October 2018

MLP_2C October 2018

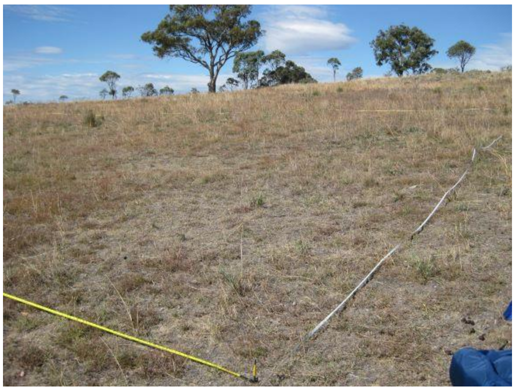

MLP_V_1
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year
0
25
50
75
100
2012
2013
2014
2015
2016
2017
2018


MLP_V_2
01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
Year
0
25
50
75
100
2012
2013
2014
2015
2016
2017
2018

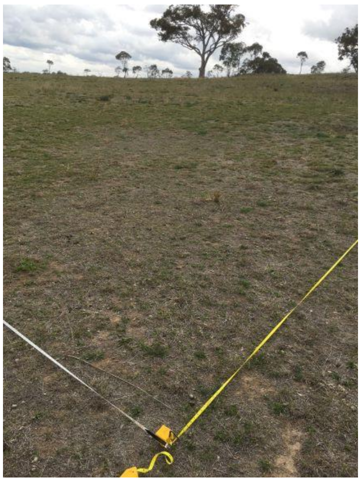
Wandiyali Conservation Reserve Autumn 2018–Spring 2018 WAG_1B, WAG_2C

Monitoring undertaken by Sarah Sharp for MCG
Location: on the western side of Old Cooma Road near Googong on the property 'Wandiyali'.
Vegetation Type Blakely's Red Gum - Yellow Box +/– White Box tall grassy woodland
Vegetation structure derived grassland
Management: WAN_1B is one of four plots in four sites subject to a cultural cool burn in autumn 2018. WAN_2C was not burnt (a control).
Aim: To monitor change in vegetation composition and structure and condition following a cultural burn.

Condition and trend	WAN_1 Burnt	WAN_2 Control	Interpretation
Overall condition	↑	↔	Interpretation is limited by the short period of monitoring. After the burn there was an increase in native species richness and introduced perennial groundcover in the burnt plot. There was a small decrease in the native forb cover, but other changes occurred in both plots. Plot WAN_1B met the criteria as the critically endangered YBRG woodland in 2018 after the burn.
Native species richness	↑	↔	Slight increase in NSR after the burn
Native floristic value	↑	↔	Slight increase in NFS after the burn
Native groundcover	↓	↓	Similar decrease similar in both plots
Proportion native groundcover	↓	↓	Similar decrease similar in both plots
Introduced species richness	↔	↔	
Introduced floristic value	↔	↔	
Introduced annual groundcover	↔	↔	
Intr. perennial groundcover	↑	↔	
Benchmark condition score	69%	59%	
Habitat diversity score	57%	54%	



WAG_1B, 28/3/18

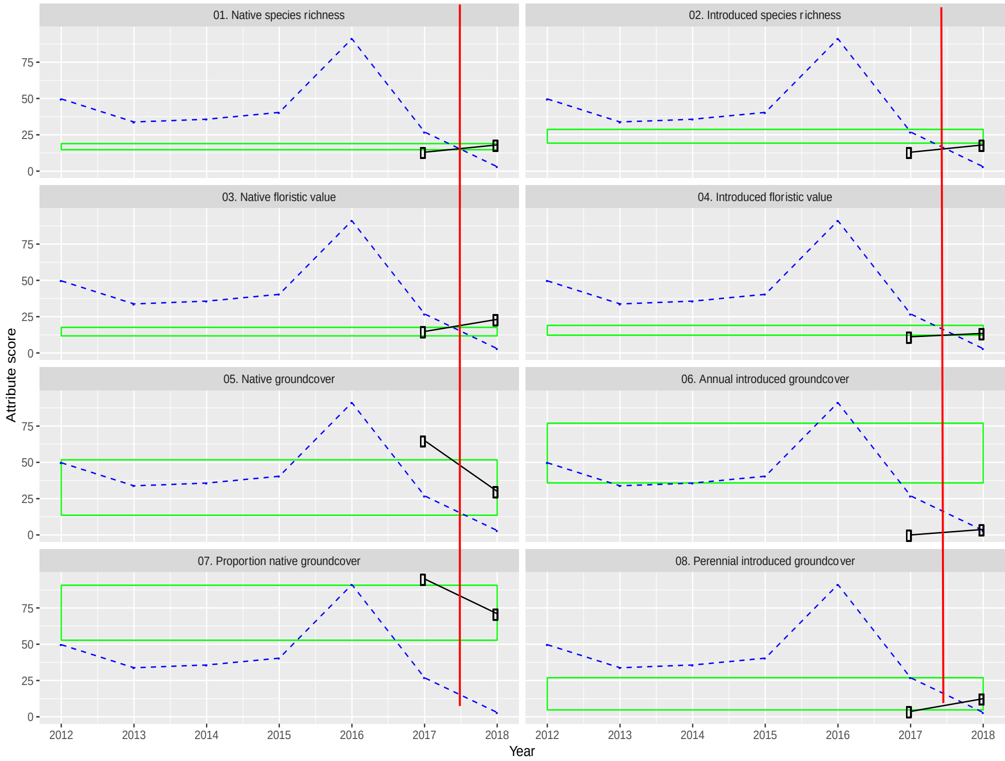


WAG_1B 18/10/18, burnt in May 2018

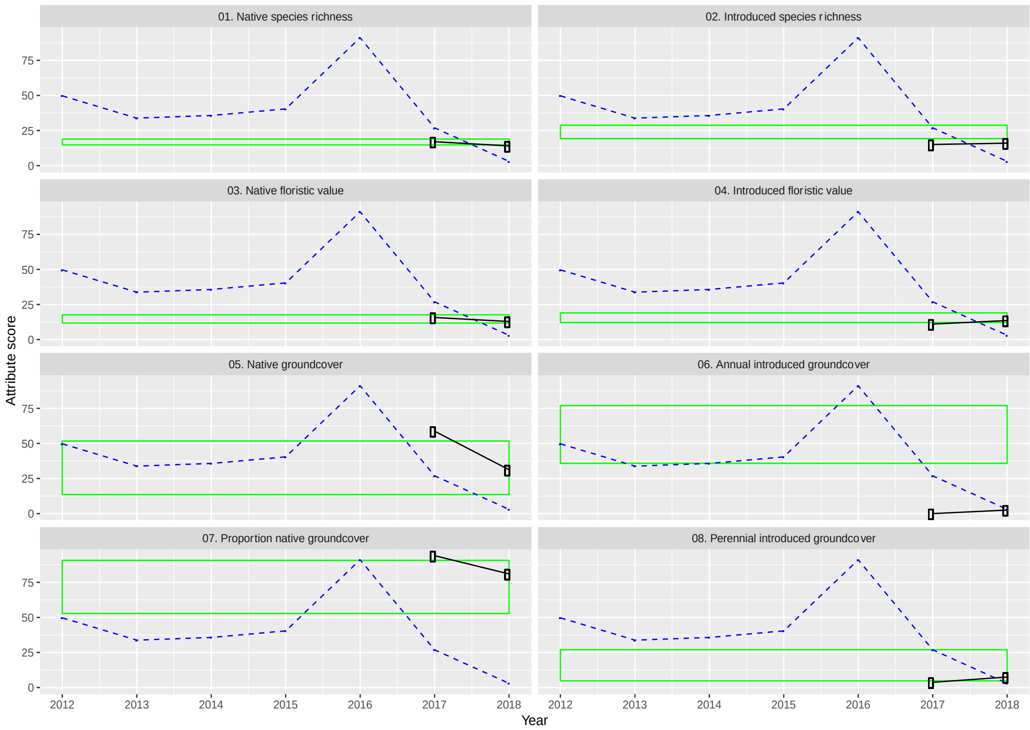
WG_2C, 28/3/18

WG_2C, 18/10/18, unburnt

WAN_V_1


01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
0
25
50
75
2012
2013
2014
2015
2016
2017
2018
Year

WAN_V_2


01. Native species richness
02. Introduced species richness
03. Native floristic value
04. Introduced floristic value
05. Native groundcover
06. Annual introduced groundcover
07. Proportion native groundcover
08. Perennial introduced groundcover
Attribute score
0
25
50
75
2012
2013
2014
2015
2016
2017
2018
Year

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APPENDIX. CALCULATING CONDITION INDICATORS

The application of condition indicators across multiple sites enables comparison of condition between sites. To be useful, the methods used to collect the data to develop the scores and the indicators need to be consistent and reliable.

The condition indicators that were developed from data collected by participants in Vegwatch are the same applied across many sites within ACT and the region.

The indicators include direct metric values that require only simple calculations: for example, the number of native or introduced species in a plot. These summary calculations are inbuilt into the database.

Two indicators require complex calculations, and integration of several types of data, as they both rely on weightings given to a range of parameters. The methods to calculate these indicators is described below.

FLORISTIC VALUE SCORE

Floristic scores developed by Rehwinkel (2015) are based on weightings that have been applied to native species that occur in natural grasslands and grassy woodlands. The weighting is related to the rarity of species based on analyses of species data from surveys undertaken on over 650 sites containing grassland or grassy woodland in the South-Eastern Highlands. The method enables a quantitative and comparative score to be developed for each plot and applied to sites.

Species ratings

This method relies on characterising species by abundance across the landscape. Each species is given a score based on its 'significance' level and additionally; this is modified by its abundance as scored in surveys (the 7 Braun-Blanquet cover/abundance scores (as described in Hnatiuk et al. 2009). The species are surveyed within a 0.04 ha plot.

Native floristic score

There are three groups, defined as follows (Rehwinkel 2015):

Indicator Level 2: species that are uncommon in the region, and where they occur, generally indicate grassland sites of high to very high value;

Indicator Level 1: species that are more common in grassland sites, relative to level 2 species; they generally occur less frequently in highly disturbed sites, though some persist with intermediate levels of disturbance; and

Common or increaser species: species that are thought to be 'disturbance-tolerant', 'disturbance responding' or 'increaser' species; increasers respond positively to various disturbances and are thus most commonly recorded in disturbed or degraded sites.

Introduced floristic value score

The scores applied to introduced species in Rehwinkel (2015) were reviewed in 2019 for this report by a panel of field ecologists and invasive species specialists, with each species allocated to a threat level based on criteria described by Hui and Richardson (2017), considering also its behaviour in the ACT region. The criteria are:

> ***Transformers***: Any invasive plant species which has established to the point that it has or is transforming the ecosystem (e.g. altering fire regime, modifying grasslands to shrublands, changing water flows) and impacting negatively upon native species or ecosystem processes. Such invasive plants can also form monocultures.
>
> ***Invasive species***: Any naturalised plant species that is actively spreading to new locations (i.e. unaided), which results in subsequent naturalisation events. These species may be widespread but current evidence does not suggest they transform ecosystems.
>
> ***Naturalised species***: Any alien plant species that establishes and reproduces, which in turn results in the establishment of additional plants at that location (i.e. unaided by deliberate cultivation). These species produce self-sustaining populations, may be widespread but do not present a risk of modification of ecosystem structure and composition.

Development of a score for each species list

The FVS is calculated as a total score, with species scored according to their level of significance and abundance (Table A.1).

Table A.1 Scores allocated to species according to their level of significance and abundance

	Abundance of 3 or less specimens and cover less than 1%	Abundance of 15 or less specimens and cover less than 1%	Abundance greater than 15 and cover less than 1%, or cover more than 1%	Abundance greater than 75%
Increaser species, Naturalised species	0.10	0.12	0.3	
Indicator Level 1, Invasive species	0.33	0.40	1.0	
Indicator Level 2, Transformer species	1.11	1.33	3.3	1
Themeda triandra, Poa labillardierei				1

A spreadsheet has been formulated by David Wong to automatically calculate the scores.

Application

The larger the native floristic score, the higher the condition; the larger the introduced floristic score, the lower the condition.

The method was designed specifically for native grasslands on the Southern Tablelands of NSW, but is appropriate for use for all grassy ecosystems, including derived grasslands formerly woodland or forest in this region (Rehwinkel 2015). However, for comparative purposes within vegetation associations the FVS has also been applied to forests and shrubby woodlands in this study. Both these systems achieve a higher score, as many of the shrubby and tree species that occur within these two associations have a high significance score.

One of the criteria to use to identify sites that contain Natural Temperate Grassland of the South-Eastern Highlands (ACT Government 2015) is whether it has a Native FVS of over 4. Indicator Level 2 species are those identified as 'Important' species of White Box - Yellow Box- Blakely's Red Gum grassy woodlands and derived native grasslands and provide one criterion to identify whether a site meets the criteria as the critically endangered ecological community (Australian Government 2005).

BENCHMARK CONDITION SCORE

The biometrics condition score was developed to identify a quantified 'reference' state for vegetation associations, to predict the condition of sites using a practical suite of variables that act as biodiversity surrogates and include values that take into account post-European settlement modification (Gibbons et al. 2008). Ten parameters were chosen as surrogates for the range of response and independent variables. Reference values for each of these parameters are developed for different regions, based on environmental variation.

The benchmark condition of each vegetation association in an area (e.g. ACT) is identified from values of the ten parameters. The values of each of the parameters (metrics) are assessed from within sites in good condition, to arrive at 'benchmark' values – i.e. representing the values found in the sites in best condition. For example, the benchmark native plant diversity within a 0.1 ha plot for Box –Gum woodland in the ACT is 35 species.

Scoring sites

The condition of a plot at the site under investigation is assessed by comparing the value of each parameter measured in the same sized plot against the benchmark value, to give a score ranging from 0 – 3, depending on the value of the parameter against the benchmark value. Each parameter is then given a weighting. A score is calculated for a site that can be between 0 and 100, i.e. calculated as a percentage of the benchmark. Thus, a grassy woodland with 35 or more native species in the plot will score 3, while if only 10 species are found it will score 1, while it will score 0 if no native species are present. Weighting is based on the difficulty of replacing that characteristic in the landscape (Phil Gibbons pers. comm., October 2017).

Nine of the ten parameters are collected from either 20m x 20m plots or 20m x 50m plots, the other is collected from the entire site. The parameters are shown in Table A.2.

Table A.2. Parameters used to score against the benchmark

Parameters	0	1	2	3	Weighting %
	Percentage of benchmark				
Native species diversity	0	>0-50	50-100	>100	25
Upper-storey (> 2 m) native cover	0–10; >200	>10–50; 150–200	>50–100; 100–150	100	10
Mid-storey (1 – 2 m) native cover	0–10; >200	>10–50; 150–200	>50–100; 100–150	100	10
ground cover grasses	0–10; >200	>10–50; 150–200	>50–100; 100–150	100	2.5
ground cover shrubs	0–10; >200	>10–50; 150–200	>50–100; 100–150	100	2.5
ground cover other	0–10; >200	>10–50; 150–200	>50–100; 100–150	100	2.5
exotic plant cover ground +mid	>66	>33–66	>5–33	0–5	12.5
No. trees with hollows	0	0–50	>50–100	100	20
Proportion overstorey regenerating	0	0–50	>50–100	100	5
Length of fallen timber	0–10	10–50	>50–100	100	10

Benchmark values used by ACT Government

As per the methodology described in Gibbons et al. (2008), benchmark values for vegetation associations identified in the ACT have been determined from extensive surveys (Table A.3). The values of the sites in best condition have been applied to provide a reference against which data from other surveys can be applied, and biometric values of sites calculated.

Difficulties lay in determining the vegetation association for plots containing modified vegetation.

Table A.3 Benchmark values for sites used in the Vegwatch program, 2011 to 2018.

	Dry Tussock Grassland NTG r	Yellow Box - Blakely's Red Gum Grassy Woodland or derived grassland (DG) u19	Snow Gum Woodland u27	Red Stringybark Forest p14	Shrubby woodland
Native species richness	30	35	22	29	30
Upper-storey native cover	0-1	11-32%	14-25	20-36%	20-40
Mid-storey native cover	0-1	0-12.5%	0-14	2-10%	1-18
Ground cover grasses	34-63%	23-63%	20-70	14-40%	18-50
Ground cover shrubs	0-3%	0-4.5%	0-20	6-22%	0-20
Ground cover other	4-17%	8-16.5%	10-33	4-15%	7-17
Exotic plant cover ground +mid	0%	0%	0	0%	0
No. large trees or trees with hollows	0	5	2	3	4
Proportion overstorey regenerating	0	100%	100	100%	100
Length of fallen timber	0	35 m	100 m	60 m	40

Table A.4. An example, Bullan Mura Woodland, Yarralumla, December 2014

	BGW benchmark values ACT	BMY_1 14	Score	Score with weighting (%)
Native species diversity	35	33	2	16.67
Upper-storey (> 2 m) native cover	11-32%	17	3	10.00
Mid-storey (1 – 2 m) native cover	0-12.5%	0	3	10.00
Ground cover grasses	23-63%	46	3	2.50
Ground cover shrubs	0-4.5%	2%	3	2.50
Ground cover other	8-16.5%	8%	3	2.50
Exotic plant cover % ground +mid	0%	16	2	8.33
No. trees with hollows	5	1	1	6.67
Proportion overstorey regenerating	100%	67	2	3.33
Length of fallen timber	35 m	0	0	0.00
Total condition score				62.50%

In this site the score indicates that its condition is 62.5% of the benchmark state.

Application to Vegwatch

The scorings used for elements of vegetation and habitat condition are those used and applied by government and scientists in ACT and NSW. Therefore, these scores are robust, tested and comparable not only with those from sites monitored in the Vegwatch Program, but also with other studies.

It is important to note that sites that are naturally treeless will achieve a minimum score of 55% based on the absence of five of the ten parameters.

TERRESTRIAL HABITAT DIVERSITY CONDITION

The characteristics that are scored in the habitat condition are in general those that provide habitat for a range of species (food, shelter, nesting). Some features are more important than others in different habitats, but there has been no attempt to weight the scores, other than not applying certain scores in non-woody ecosystems. Depending on the value of the characteristics, they receive a score between 0 and 3. The calculation of the percentage score is completed in the database.

ROOT ZONE SOIL MOISTURE

Root Zone Soil Moisture is the sum of water in the AWRA-L Upper and Lower soil layers and represents the percentage of available water content in the top 1 m of the soil profile. The maximum storage within the soil layer is calculated from the depth of the soil and the relative soil water storage capacity. The soil properties that control the storage of water are derived from the continental scale mapping within Australian Soil Resources Information System (Johnston et al. 2003). The relative available water capacity of the soil layer is derived from information in ASRIS as the available water capacity of a layer divided by its thickness. Pedotransfer functions are used to relate soil hydraulic properties to soil textural class. Soil drainage and moisture dynamics are then based on water balance considerations for each soil layer. The shallow and deep-rooted vegetation can both draw on this combined layer.

Actual soil moisture grids estimate the percentage of available water content rather than total soil water volume. Relative soil moisture grids, like the other grids, represent the long-term deciles.

The information presented on the Australian Landscape Water Balance website is produced by the Bureau of Meteorology's operational Australian Water Resources Assessment Landscape model (AWRA-L). AWRA-L is a daily 0.05° grid-based, distributed water balance model, conceptualised as a small unimpaired catchment. It simulates the flow of water through the landscape from the **rainfall** entering the grid cell through the vegetation and soil moisture stores and then out of the grid cell through **evapotranspiration**, **runoff** or **deep drainage** to the groundwater.

Each spatial unit (grid cell) in AWRA-L is divided into two hydrological response units (HRU) representing **deep rooted vegetation** (trees) and **shallow rooted vegetation** (grass). Hydrological processes are modelled separately for each HRU, then the resulting fluxes or stores are combined to give cell outputs. Hydrologically, these two HRUs differ in their aerodynamic control of evaporation and their interception capacities but the main difference is in their degree of access to different soil layers. The AWRA-L model has three soil layers (upper: 0–10 cm, lower: 10–100 cm, and deep: 1–6 m). The shallow rooted vegetation has access to subsurface soil moisture in the upper and lower soil stores only, while the deep-rooted vegetation also has access to moisture in the deep store.

The monthly root zone soil moisture data in the top 1 m at the Canberra Airport (S35.3 and E149.0) from July to November was used to calculate an average root zone soil moisture value for each year. A value of 0 represents completely dry soil and 100 represents total saturation. The values for each month between July and November were used to derive an average root zone soil moisture index for each year. The average figure was compared to Canberra average values for soil moisture, from records from the years 1911 to 2016 (BOM 2018). On that basis, 2012, 2013, 2014 and 2015 experienced average soil moisture levels, 2019 well above average soil moisture levels, 2017 below average soil moisture levels and 2018 extremely below average soil moisture levels.