ACT Government

LOWLAND NATIVE GRASSLAND ECOSYSTEM CONDITION MONITORING PLAN

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Conservation Effectiveness Monitoring Program: ACT Lowland Native Grasslands Ecosystem Condition Monitoring Plan

Environment Division

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LIST OF ACRONYMS

ACT	Australian Capital Territory
AIC	Akaike Information Criterion
ANOSIM	Analysis of similarities
CEMP	Conservation Effectiveness Monitoring Program
CNP	Canberra Nature Park
CR	Conservation Research
EGK	Eastern Grey Kangaroo
EPBC	Environmental Protection and Biodiversity Conservation
FC	Fractional cover
GAMM	Generalised additive mixed model
GED	Grassland Earless Dragon
GSM	Golden Sun Moth
LMU	Land management unit
MNES	Matters of national environmental significance
MTA	Majura Training Area
MRC	Murrumbidgee river corridor
NR	Nature reserve
NRM	Natural Resource Management
NSR	Native plant species richness
NSW	New South Wales
NTG	Natural Temperate Grassland
PCS	Parks and Conservation Service
PTWL	Pink-tailed Worm-Lizard
SLL	Striped Legless Lizard
TFI	Tolerable fire interval
TSF	Time since fire
UC	University of Canberra

SUMMARY

The Conservation Effectiveness Monitoring Program (CEMP) produces ecosystem condition monitoring plans for eight identified ecosystem units within the ACT reserve system. This document forms the first plan for the lowland native grasslands ecosystem unit.

The CEMP identifies three major components that enable the assessment of ecosystem condition: ecological values (environmental characteristics identified as a priority for conservation), ecological stressors (threatening processes suspected to illicit change in ecological values) and reserve management programs (which aim to enhance values and decrease the impact of stressors). CEMP assess ecosystem through selecting suitable indicators from identified ecological values and stressors within the ecosystem (Brawata et al., 2017).

Within the lowland native grasslands ecosystem, identified ecological values that are used as ecosystem condition indicators include native flora and fauna (including threatened species) and the endangered Natural Temperate Grassland (NTG) ecological community. Ecological stressors that are used in condition assessments include invasive weeds, inappropriate grazing regimes, introduced herbivores and predators and inappropriate fire regimes. Management programs designed to reduce stressors (e.g. grazing management, weed control, vertebrate pest management, fire management) and enhancement programs designed to increase ecological values (e.g. habitat restoration) are conducted throughout native grassland ecosystems in the ACT. The effectiveness of these current management programs in reducing ecological stressors and maintaining/enhancing ecological values is included in the ecosystem condition assessment.

The CEMP uses monitoring data to assess the current condition of ecosystem indicators against three condition measures: the baseline, reference and target conditions. The baseline condition refers to the initial condition from which changes in condition over time can be measured. The reference condition refers to the ideal condition of the metric, often defined as condition pre-European settlement or taken from sites identified as being in 'reference' condition. The reference condition enables a true contextual assessment of the indicator against what its likely condition was prior to any degradation from post-European settlement activities; however, restoration to reference condition may be unachievable. The target condition offers a practical alternative for management to strive for when the reference condition is either unattainable or unknown. The target condition is defined as the condition that management is striving for. The target condition is set by managers with intimate knowledge of the ecosystem; it can change over time with improved condition, knowledge and methods (Brawata et al., 2017).

In addition to using monitoring data, CEMP draws on expert opinion during selection of the indicators, setting of target conditions and data interpretation. Indicator condition is graded into four categories; 'good', 'good with concerns', 'moderate' and 'poor'. Trend in indicator condition over time is also assessed where possible and confidence in the data used for indicator condition assessment is graded as either low, moderate or high. The symbology used for each of these attributes of indicator condition is given in Figure 3 (see section 1.8 of this document).

Within the lowland native grasslands ecosystem, most indicators used for ecological condition assessment were graded as in 'poor 'condition against reference condition, but indicator condition was assessed as either in 'moderate' or 'good with some concerns' against target condition. Indicators assessed to be in 'poor' condition against reference condition had threatened status under ACT or Commonwealth legislation (including threatened flora, fauna and the threatened ecological community of Natural Temperate Grassland) and thus have been significantly reduced in either numbers or extent since European settlement. In comparison, the assessment for most indicators against target condition as either 'moderate' or 'good condition with some concerns' reflects that, overall, management within lowland native grasslands ecosystems is achieving conservation goals in protecting and enhancing ecosystem values (Table 1).

Stressor states in the ecosystem were graded as 'poor' against reference condition if they represented an uncontrolled introduced species (foxes and feral cats) or were insufficiently managed (fire regimes). When assessed against target condition, the condition of stressor states showed that the effectiveness of management programs at minimising stressors in this ecosystem was more mixed. Similar to the findings again reference condition, rating against the target condition was 'poor' for the key stressor representing appropriateness of fire regimes (Table 1).

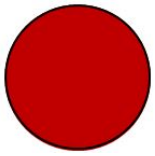
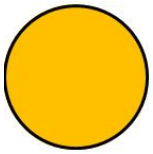
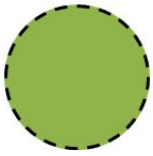
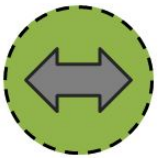
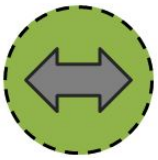
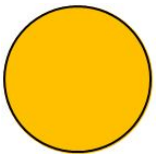
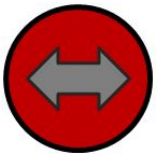
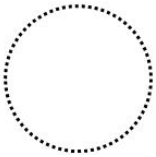
Where analysis of trend was possible, most indicators and stressors were assessed as increasing or stable, indicating that broadly the ecosystem condition is stable overall. Two ecosystem stressors which were rated 'poor' and 'moderate' against target condition showed increasing trends; namely fire regimes and invasive weeds (Table 1). This shows that, while the effectiveness of management programs at minimising these stressors currently within the ecosystem was not optimal, improvements were already being made, with stressor impacts being reduced over time.

While there is a significant amount of monitoring and research currently conducted in ACT lowland native grasslands, the outcomes of this plan indicate that some clear gaps in knowledge remain and some change in management actions are required. Key recommendations include an increase in the use of ecological burns in grasslands, more detailed mapping of grassland communities, research into cost effective restoration techniques, improved recording of conservation grazing actions, monitoring of introduced predators in grasslands and a commitment to standardised long-term monitoring of ecologically representative indicators such as key functional invertebrates and reptile communities.

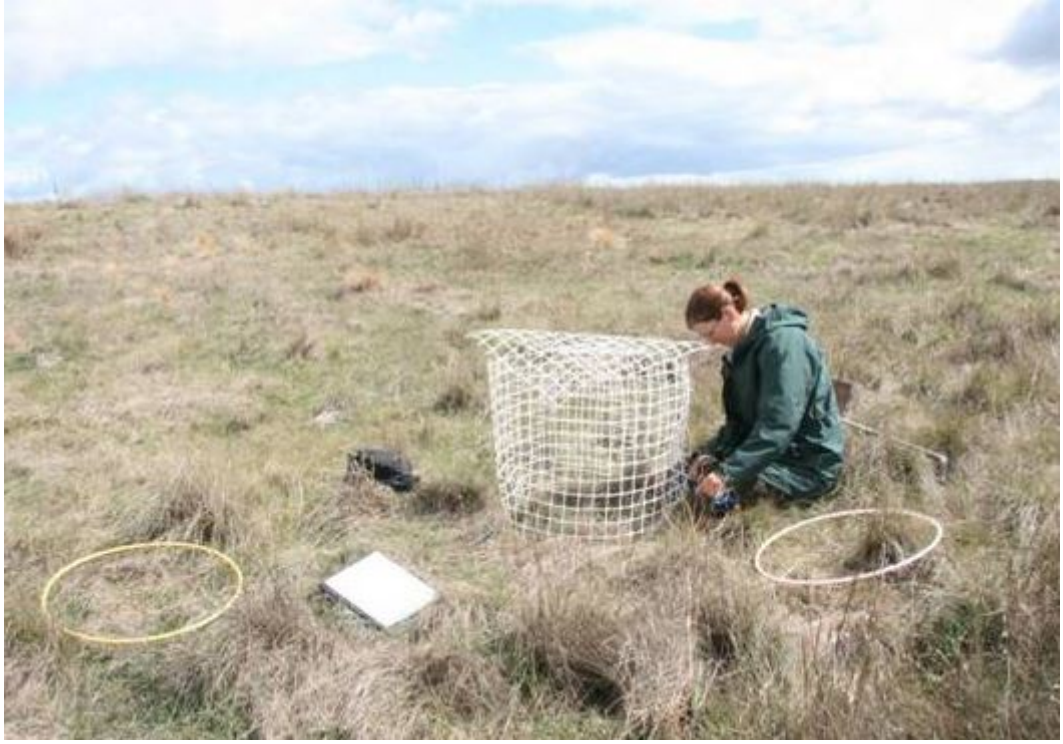
Another area for improvement is better maintenance of monitoring data. The consolidation of aligned datasets across the Environment Division, in addition to ensuring consistency in field methods, is an important step in improving data validity, information flow and accessibility. General improvements in survey design, data collection methods and data storage will make long term monitoring programs more robust to statistical analysis for a range of programs and end users.

More streamlined and robust data collection through the use of mobile data capture devises would also increase opportunities for community involvement in monitoring. Finally, there are some metrics incorporated into this ecosystem condition plan for which no or limited data were available and it is recommended to include these metrics in future monitoring to improve ecosystem condition assessment in future.

Table 1. The condition of indicators (C1-C5) and state of stressors (S1-S4) assessed in the Lowland Native Grassland Ecosystem Condition Monitoring Plan. Condition/state is given against both reference condition and target condition. A key to the rating symbology is provided in Figure 3.

Indicator or Stressor	Rating against Reference condition	Rating against Target condition
C1. Natural Temperate Grassland		
C2. Native Flora general		
C3. Threatened Flora		
C4. Native Fauna general		
C5. Threatened Fauna		
S1. Herbivore pressure		
S2. Fire regimes		
S3. Invasive weeds		
S4. Introduced predators		

PART ONE: CONDITION MONITORING PLAN FOR THE LOWLAND NATIVE GRASSLANDS ECOSYSTEM



Sampling at off-take cages, Mulanggari NR – Photo credit Don Fletcher

LOWLAND NATIVE GRASSLANDS ECOSYSTEMS UNIT

1.1 LOWLAND NATIVE GRASSLANDS OVERVIEW

The lowland native grasslands ecosystems unit encompasses those areas contained within the ACT identified as Natural Temperate Grassland (NTG), native grassland or degraded native grassland under the Draft ACT Native Grassland Conservation Strategy and Action Plans (ACT Government, 2017a) below an elevation of 625 m. These grasslands are primarily dominated by native perennial grasses, and areas in good condition also contain a diversity of other native plant species. They are naturally treeless, with less than 10% projective foliage cover of trees, shrubs and sedges. Large tracts of lowland native grasslands were once found across the lower elevation areas of the Molonglo, Jerrabomberra, Majura and Tuggeranong valleys, and the Belconnen and Gungahlin Plains (Benson, 1994).

European land use such as grazing, pasture improvement, introduction of exotic species and changes to burning regimes have dramatically reduced the extent and condition of lowland native grasslands. Urban development associated with the expansion of Canberra has contributed to further loss of this community throughout the region. The ecological community referred to as 'Natural Temperate Grassland', now covering an estimated 6% of its former extent in the ACT, is listed as a critically endangered ecological community under Commonwealth legislation (*EPBC Act 1999*). The ACT contains some of the best quality lowland native grasslands remaining in Australia, a significant extent of which is protected within ACT nature reserves.

The lowland native grasslands ecosystem unit comprises of the following ACT grassland communities:

- *Poa labillardierei – Themeda triandra – Juncus sp.* wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion (r2)
- *Rytidosperma sp. - Themeda triandra – Juncus sp*. tussock grasslands of occasionally wet sites of the South Eastern Highlands bioregion (r3)
- *Rytidosperma sp. – Austrostipa bigeniculata – Chrysocephalum apiculatum* tussock grassland of the South Eastern Highlands bioregion (r5)
- Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion (r6)
- *Themeda australis – Rytidosperma sp. – Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion (r7)
- *Themeda australis – Lomandra filiformis – Aristida ramosa* dry tussock grassland of the South Eastern Highlands bioregion (r8)

(Office of Environment and Heritage, 2011)

1.2 ECOSYSTEM GOALS AND ASSOCIATED RESERVES AND ENVIRONMENTAL OFFSET AREAS

This Lowland Native Grasslands Ecosystem Condition Monitoring Plan evaluates ecosystem condtion, monitoring and conservation effectiveness in lowland native grassland ecosystems within ACT nature reserves. Knowledge derived from this plan is likely to be relevant beyond the reserve estate and may be useful for nil tenure conservation planning and assessment. As a consequence, this plan aims to align with environmental offsets and matters of national environmental significance (MNES) monitoring, in addition to recommendations and priorities identified in the Draft ACT Lowland Native Grassland Conservation Strategy and Action Plans (ACT Government, 2017a) as per the following:

Ecosystem protection goals

- Protect all remaining areas of native grassland in the ACT that are in moderate to high ecological condition;
- Protect all viable wild populations of native grassland flora and fauna species in the ACT;
- Support local, regional and national efforts to conserve these species.

Ecosystem management goals

- Maintain and improve grassland structure, function and diversity;
- Reduce the impacts of threats;
- Conserve grassland biodiversity;
- Manage habitat to conserve species.

Monitoring plan objectives

1. Identify ecosystem drivers, values, stressors and management programs that occur in lowland native grassland reserves.
2. Define indicators of ecological values and stressors and corresponding metrics that are to be used to assess ecosystem condition.
3. Through assessing ecosystem condition, determine the effectiveness of management programs at protecting ecological values in this ecosystem.
4. Identify requirements for reporting information collected under this monitoring plan, so that it best serves to inform management actions.

The plan applies to lowland native grassland areas contained in the following nature reserves:

- Mulanggari NR
- Gungaderra NR
- Crace NR
- Jerrabomberra East NR
- Jerrabomberra West NR
- Dunlop NR
- Molonglo River Corridor
- Jarramlee NR
- Kama NR
- West Majura Grasslands
- Googong Foreshores

This list includes reserves containing native grasslands in addition to Googong Foreshores which contains secondary grassland managed as grassland.

The monitoring plan also applies to any lowland grassland sites managed currently by the environmental offsets team within PCS. As of August 2017, these include:

- Kenny
- Jarramlee
- Throsby
- Mulanggari extension
- Gungaderra extension
- Kinleyside
- Bonshaw
- Molonglo
- Bonner 4 East
- Eastern Broadacre (Jerrabomberra East, Amtech, Woolshed Creek and Majura Grasslands)

1.3 ECOSYSTEM PRIMARY DRIVERS FOR LOWLAND NATIVE GRASSLANDS

Climate and climate change

Total rainfall and seasonal variability are important drivers of annual cover, biomass, flowering and composition in lowland native grasslands (Morgan and Williams, 2015). Lowland native grasslands in the ACT require a moderate annual rainfall of 500-800mm (ACT Government, 2017a). Drought years often fall well below these rainfall totals and may have a temporary negative impact on grassland condition. Seasonality and extremes of temperature including intense frosts in winter or heat waves in summer may periodically change local species composition and distribution.

The occurrence of extreme climatic conditions is likely to change with global warming predictions and may impact on grassland biodiversity in the long term. While climate change is an emerging threat on the ecosystem, there is no direct management lever on the threat itself, therefore for the purpose of CEMP climate change is considered a primary driver. Management actions can, however, attempt to mitigate the impacts from changing climate through future 'climate proofing' of habitats (e.g. planting more climate-tolerant plant species) and creating climate refugia in identified biodiversity hotspots.

Landscape position

The type and distribution of grassland ecosystems in the ACT is thought to be heavily determined by landscape position. Cold air drainage, water drainage, water logging, soil temperature, aspect and windfetch together influence distribution, patch size and diversity of grasslands (ACT Government, 2017a; Sharp, 1997).

Past landuse

ACT lowland native grassland communities have been extensively cleared or substantially modified with exotic species for pasture improvement, cropping or other agricultural development. ACT lowland native grassland communities have also been degraded, fragmented, altered or removed for the development of urban infrastructure in the ACT.

Nutrient cycling

Nutrient levels, water availability and soil type together influence grassland community composition and structure. In the ACT region, the wet *Themeda community* and *Poa* dominated grasslands occur in heavy clay soils while, *Rhytidosperma, Austrostipa* and dry *Themeda* communities occur in well-drained loamy or skeletal soils. Native grassland in Australia is generally low in phosphorus on a global scale (Morgan and Williams, 2015), however the addition of fertilisers used for grazing pasture improvement has increased phosphorus levels to the detriment of many native species, particularly forb species (Prober et al., 2002) which are now absent from many native grasslands.

Fire regimes

Fire regimes may influence the structure and composition of native grasslands through directly altering biomass and altering the abundance of species with different functional traits (Lunt et al., 2012). Studies have shown that regular fire can increase diversity in highly productive *Themeda* grasslands (Morgan, 1999b), and reduce diversity in *Poa* dominated grasslands (Prober et al., 2007). It is thought that lowland native grasslands in the ACT are adapted to a fire regime derived from Aboriginal burning of patchy, low intensity, mosaic burning in autumn or spring with occasional high intensity wildfires in summer (Lunt et al., 2012).

Herbivory

Lowland native grasslands have evolved under grazing from native herbivores such as kangaroos, wallabies, bettongs, wombats and insects (Fletcher, 2006). Populations of herbivores were largely determined by seasonal abundance of grassland flora, and these herbivore populations in turn influenced plant diversity through grazing pressure. Many native herbivores are no longer present in lowland native grasslands (Morgan and Williams, 2015); however Eastern Grey Kangaroo (*Macropus giganteus*) populations have persisted and in some areas grown significantly due to abundant food and low predation pressure (Fletcher, 2006).

Insects are also major herbivores of grasslands but very little is known of their ecology (Antos and Williams, 2015; Morgan and Williams, 2015). Despite this lack of knowledge of specific ecological interactions they are undoubtedly involved in the herbivory and pollination of many grassland plants.

1.4 ECOLOGICAL VALUES WITHIN LOWLAND NATIVE GRASSLANDS

Natural Temperate Grassland endangered ecological community

Natural Temperate Grassland (NTG) is listed as an endangered ecological community under commonwealth legislation (*Environment Protection and Biodiversity Conservation (EPBC) Act 1999)* and under ACT legislation through the *Nature Conservation Act (2014)*. Many areas within lowland grassland reserves meet the criteria for NTG status and these reserves are managed with the aim of maintaining and improving extent and connectivity of the Natural Temperate Grassland community. Other areas of grassland that are more degraded (often referred to as 'native pasture') may also support moderate diversity of native species and contain important habitat for threatened fauna or perform other functional roles such as buffers to the higher quality areas.

In this plan, the condition of Natural Temperate Grassland is assessed through condition indicator C1: Natural Temperate Grassland which contains the metrics of C1.1: Extent of native vs. exotic grassland within reserves and C1.2: Extent of NTG within reserves.

Native flora

Lowland native grasslands are structurally dominated by perennial tussock grasses of genera *Themeda*, *Austrostipa*, *Poa* and *Rhytidosperma.* In an intact condition these grasslands also contain a high diversity of native forbs; at some sites lilies, daisies, gentians, orchids, peas, rushes and sedges may comprise of up to 70% of all species present. Many of these native forb species disappear from grasslands as disturbance patterns change from their historical patterns.

Conservation of the threatened species Button Wrinklewort (*Rutidosis leptorrhynchoides*) and Ginninderra Peppercress (*Lepidium ginninderrense*) are listed as conservation objectives in the Draft ACT Lowland Native Grassland Conservation Strategy and Action Plans (ACT Government, 2017a). Additionally, there are many rare plants that are not listed, but contribute to grassland flora diversity and are also important indicators of overall grassland condition.

In this plan, the condition of native flora is assessed through condition indicators C2: Native Flora general and C3: Threatened Flora. The condition indicator C2: Native Flora, general, contains the metrics of C2.1: Native plant species richness; C2.2: Ground cover and C2.3: Indicator 2 species richness. The condition indicator C3: Threatened Flora contains the metrics of C3.1: Button Wrinklewort and C3.2: Ginninderra Peppercress.

Native fauna

Grassland fauna are an intrinsic component of lowland native grassland ecosystems and contribute to ecosystem function. Fauna provide essential pollination, dispersal, biomass turnover and nutrient cycling functions, in addition to other likely functions that remain unknown. Native fauna distribution and diversity is correlated with the availability of suitable habitat. ACT grasslands are home to many invertebrates, birds, mammals, reptiles and amphibians.

The decline of fauna species in lowland native grassland ecosystems is likely associated with habitat removal and fragmentation resulting from urban expansion and agricultural improvements, in addition to increased predation from exotic species. Grasslands provide habitat required by many

species, some of which are restricted to grassland ecosystems. The number of threatened species in this ecosystem is in part a result of the severe reduction and fragmentation of native grasslands in south-eastern Australia. Habitat removal or alteration has resulted in significant impacts to populations and remaining grassland habitat is important to ensure the long-term survival of grassland fauna, including threatened species.

In this plan, the condition of native fauna is assessed through condition indicators C4: Native Fauna general and C5: Threatened Fauna. The condition indicator C4: Native Fauna general contains the metrics of C4.1: Reptiles, general and C4.2: Invertebrates, general. The condition indicator C5: Threatened Fauna contains the metrics of C5.1: Grassland Earless Dragon; C5.2: Striped Legless Lizard; C5.3: Golden Sun Moth and C5.4 Pink-tailed Worm-lizard.

1.5 THREATS AND STRESSORS TO LOWLAND NATIVE GRASSLANDS

Inappropriate grazing regime

Both excessive grazing pressure and total exclusion of grazing can negatively impact on grassland flora diversity (Lunt, 2005). The natural relationship between native herbivores and grassland flora has been significantly altered since European settlement (Lunt, 2005; Lunt et al., 2012). The removal of fire and native herbivores from much of the landscape and their replacement with cattle or sheep grazing has significantly altered natural processes of reproduction, germination and succession of grassland flora and fauna. Additionally, surrounding land uses compete with ecological grazing requirements and contribute to the complexity of achieving an appropriate balanced grazing regime. Overabundant native herbivores, introduced herbivores (rabbit, pig and deer) and selective grazing by stock are the leading causes of inappropriate grazing regimes in lowland native grasslands (ACT Government, 2017a, b).

Overgrazing in grassland may lead to a loss of structural diversity, selective grazing of some flora species, an increase in nutrients to the soil (unfavourable to native flora, but favourable for many exotic plants) and increased soil disturbance. Undergrazing may result in biomass accumulation that suppresses some native plants by reducing available light and the amount of bare ground between tussocks for native flora regeneration. Biomass accumulation also impacts on fauna by altering habitat structure and availability of appropriate micro habitats.

In this plan, the state of inappropriate grazing regimes is assessed through stressor indicator S1: Herbivore Pressure, which contains the metrics S1.1: Eastern Grey Kangaroo; S1.2: Rabbit and S1.3: Domestic Stock.

Inappropriate fire regime

A fire regime characterises the spatial and temporal patterns and ecosystem impacts of fire on the landscape (Bradstock et al., 2012). A fire regime refers to the frequency, intensity, season and extent of fire in an area (Gill, 1975). A fire regime with intervals that are too short or too long, lacks appropriate mosaic across the landscape or are too hot or cool or occur in the wrong season may have adverse impacts on lowland native grassland ecosystems. Fires intervals that are too short may

not allow enough time for some species to regenerate and reproduce; fire intervals that are too long may result in biomass accumulation that suppresses some species by reducing available light and the amount of bare ground between tussocks for native flora regeneration. Biomass accumulation also impacts on fauna by altering habitat structure and availability of appropriate micro habitats.

Inappropriate fire regimes may result from wildfire frequency, size or intensity; fuel management procedures, wildfire suppression or seasonality of burning. Adjacent land use and inappropriate fire regimes are linked whereby adjacent landuse may require fuel management that is not consistent with the ecological requirements. Climate change may also impact on fire regimes in grassland reserves in the future by increasing frequency and intensity of wildfires (and possibly changing seasonality), and a possible need for fuel management activities.

In this plan, the state of inappropriate fire regimes is assessed through stressor indicator S2: Fire Regimes, which contains the metrics S2.1: Fire frequency within ecological thresholds and S2.2: Fire season as recommended in ecological guidelines.

Weed invasion

Many lowland native grasslands are under significant pressure from invasive weeds due to their small size and high perimeter to area ratio, elevated fertility, surrounding land use and land use history (Williams and Morgan, 2015). Despite this many lowland native grasslands retain significant native plant cover, especially perennial native grasses. Some of the highest condition grasslands have a high exotic species richness component but also retain high native species diversity. The most problematic weeds are perennial tussock weeds that have potential to shift structural dominance. In the ACT these include African Lovegrass (*Eragrostis curvula*), Serrated Tussock (*Nassella trichotoma*) and Chilean Needlegrass (*Nassella neesiana*). St John's Wort (*Hypericum perforatum*) is a perennial rhizomatous plant that is also a major threat to grasslands. These invasive weeds are particularly favoured by soil disturbance, nutrient enrichment and presence of bare ground. Weed species compete with native flora species and may alter grassland structure and reduced native cover and diversity.

In this plan, the state of invasive weeds is assessed through stressor indicator S3: Invasive Weeds, which contains the metrics S3.1: Changes in the distribution and abundance of priority weeds and S3.2: Invasive weeds – new incursions.

Adjacent land use

Grassland reserves in the ACT are isolated remnants surrounded by agricultural and urban areas. Activities undertaken in surrounding areas will impact on grassland functionality. Urban and agricultural areas are sources of weed propagules, increased recreation and run-off containing nutrients, chemicals and heavy metals. Urban infrastructure development also increases habitat loss, fragmentation and resulting edge effects. Urban and agricultural expansion has fragmented many fauna populations and restricted their distribution and genetic dispersal. Additionally, domestic pets living adjacent to grassland reserves may prey on grassland fauna species.

Introduced predators

Foxes and feral /stray cats are likely present in all lowland grassland reserves and surrounding urban and agricultural areas. Both predators are known to prey on grassland fauna, particularly reptiles

and birds, and are therefore a threat to grassland fauna diversity and distribution (ACT Government, 2017a).

In this plan, the state of introduced predators is assessed through stressor indicator S4: Introduced Predators, which contains the metrics S4.1: European Fox and S4.2: Feral Cat.

1.6 RESERVE MANAGEMENT PROGRAMS IN LOWLAND NATIVE GRASSLANDS

Community education

Community education programs that focus on building awareness of the value of lowland native grasslands of the ACT are currently undertaken within the Environment Division. Signage provides interpretation at visitor sites, while ranger guided tours, engagement with community volunteer groups, presentations and ranger patrols provide direct interactions with community members.

Land use planning and management

Grasslands in Canberra Nature Park (CNP) are managed under the guidance of the Canberra Nature Park Management Plan (ACT Government, 1999) and the Draft ACT Lowland Native Grassland Conservation Strategy and Action Plans (ACT Government, 2017a). These two plans identify and provide clear direction for protection and management of grassland reserve ecological values.

Grassland reserves have featured prominently in planning processes. For example, Gungahlin Town Centre was relocated at the planning stage to protect patches of Natural Temperate Grasslands that supported threatened species.

Legislation provides PCS with the authority to manage native grassland reserves. Important legislation that applies to grassland reserves include the *Nature Conservation Act (2014), Water Resources Act (2007), Environmental Protection Act (1997), Pest Plants and Animals Act (2005)* and *Trespass on Territory Land Act (1932)*.

Enhancement programs

Enhancement programs are conducted to improve extent, connectivity and condition of lowland grassland reserves. There have been several threatened species translocation programs and trials are underway to determine the effectiveness of different management options for enhancing fauna habitat.

Fire management program

An annual Bushfire Operations Plan (BOP) is implemented to help protect people, built and natural assets from fire. As part of this program ecological burns are conducted in grassland areas to promote and maintain a mosaic of native species cover and diversity in areas that are nearing or have exceeded maximum inter-fire intervals, or where a particular threatened species may require fire to promote germination. Ecological guidelines have been developed which identify fire interval thresholds to guide management of grassland reserves to guide the management of fire so as to be consistent with the protection of ecological values.

Grazing management

An adaptive grazing management program is implemented in select nature reserves. Grazing management aims to achieve suitable herbivore off take in order to promote native flora diversity and maintain desirable habitat condition. Grazing management includes kangaroo population management, livestock rotation and vertebrate pest control.

In some reserves livestock grazing may be used to reduce biomass; however this has different impacts on grassland structure and composition to biomass control methods such as burning and kangaroo grazing. Livestock grazing is only used in ACT reserves where a reduction of biomass is required and prescribed burning, kangaroo grazing or slashing are not successful or viable methods for achieving desired grassland structure. Additionally, livestock grazing is used for fuel management if reserve condition is already low and livestock grazing is unlikely to impact on ecological values.

Research has demonstrated that kangaroos can impact on grassland flora diversity and fauna abundance in the ACT (Snape et al., in review). Kangaroos are managed within some ACT reserves to reduce the impacts of overabundant kangaroo populations on other native fauna and threatened vegetation communities (ACT Government, 2017b).

Invasive weeds control

An Invasive Weed Operational Plan (IWOP) is implemented annually to reduce the impact of environmental weeds on reserve values and to control the spread of noxious weeds. Weeds are treated using a variety of methods including herbicide, physical removal or mechanical control. Additionally, integrated management of grasslands through grazing and fire may also help reduce weeds.

Vertebrate pest management

A vertebrate pest management program exists for lowland native grasslands. Current control programs are undertaken to manage rabbits in some lowland native grassland areas within reserves, however there are no current control programs targeting foxes, cats or deer in lowland native grassland reserves, although some opportunistic control may be undertaken at times.

Health Checks

'Health checks' refer to a program which outlines regular monitoring activities for rangers and/or community groups to perform within ACT reserves. The health check program will be trialled in 2017-2018, and aims to enable a quick seasonal 'snapshot' of reserve condition, while collecting valuable information on critical management levers such as biomass, thatch depth, rabbit activity and response of weeds to control. Data collected during health checks will fill data gaps as well as increase the involvement of rangers and community groups in the monitoring of grasslands.

1.7 LOWLAND NATIVE GRASSLAND CONCEPTUAL MODELS AND METRICS

Ecosystem conceptual model

To establish a conceptual understanding of how primary drivers, ecological values and threats interact within the lowland native grasslands ecosystem, and how management actions may interact with these elements, a conceptual model of the lowland native grassland ecosystem was constructed (Figure 1). This conceptual model, in conjunction with an expert panel discussion, was used to select indicators and corresponding metrics for the lowland native grassland ecosystem condition assessment contained within this plan.

Ecological values recognised in the ecosystem model include the Natural Temperate Grassland (NTG) endangered ecological community, soils, native flora and native fauna. Stressors include introduced pests (predators and herbivores), weeds, inappropriate grazing and fire regimes, over abundant native herbivores (kangaroos) and adjacent land use (see sections 1.4 and 1.5 of this chapter). Threatening processes included predation, competition from weeds and introduced herbivores, altered or reduced habitat and soil disturbance/erosion (Figure 1).

A number of management programs, aimed at reducing the impact of stressors and enhancing ecological values, are already undertaken within the ecosystem (see sections 1.6 of this chapter). These include some vertebrate pest management (sporadic fox and rabbit control), over abundant native herbivore management (control of kangaroo populations), livestock grazing management, extensive invasive weed control, fire management programs, land use planning and ecosystem enhancement programs (Figure 1).

Ecosystem function model

A healthy, functioning grassland ecosystem contains both a high diversity of flora and fauna at different trophic levels and heterogeneity of structure that promotes habitat diversity. High diversity enables resilience and an intrinsic ability to respond to change under pressures such as climate change and invasion by exotic species (Holling, 1973).

In an intact grassland ecosystem in the ACT region, plants comprise the lower trophic level of primary autotrophs and soils and rocks form abiotic habitat for flora and fauna. Primary herbivores include grainivorous birds, mammalian herbivores (including native and introduced species) and invertebrates while secondary consumers include both birds and a variety of reptile species. Avian, reptilian and mammalian predators make up the highest trophic level (Figure 2). A further primary and secondary consumer not in this diagram is small native mammal species. Likely naturally occurring at low densities in the lowland native grasslands, small native mammals have all but disappeared from this ecosystem and small mammalian fauna is now primarily represented by a very small number of introduced species.

In the context of this plan, ideally each trophic level should be represented in monitoring of condition of the ecosystem. All trophic levels have been included in this plan with the exception of abiotic factors (soil and rocks). The reasoning behind this exclusion is discussed in the additional metrics chapter of this document.

Figure 1 Conceptual model of the lowland native grassland ecosystem unit in the ACT.

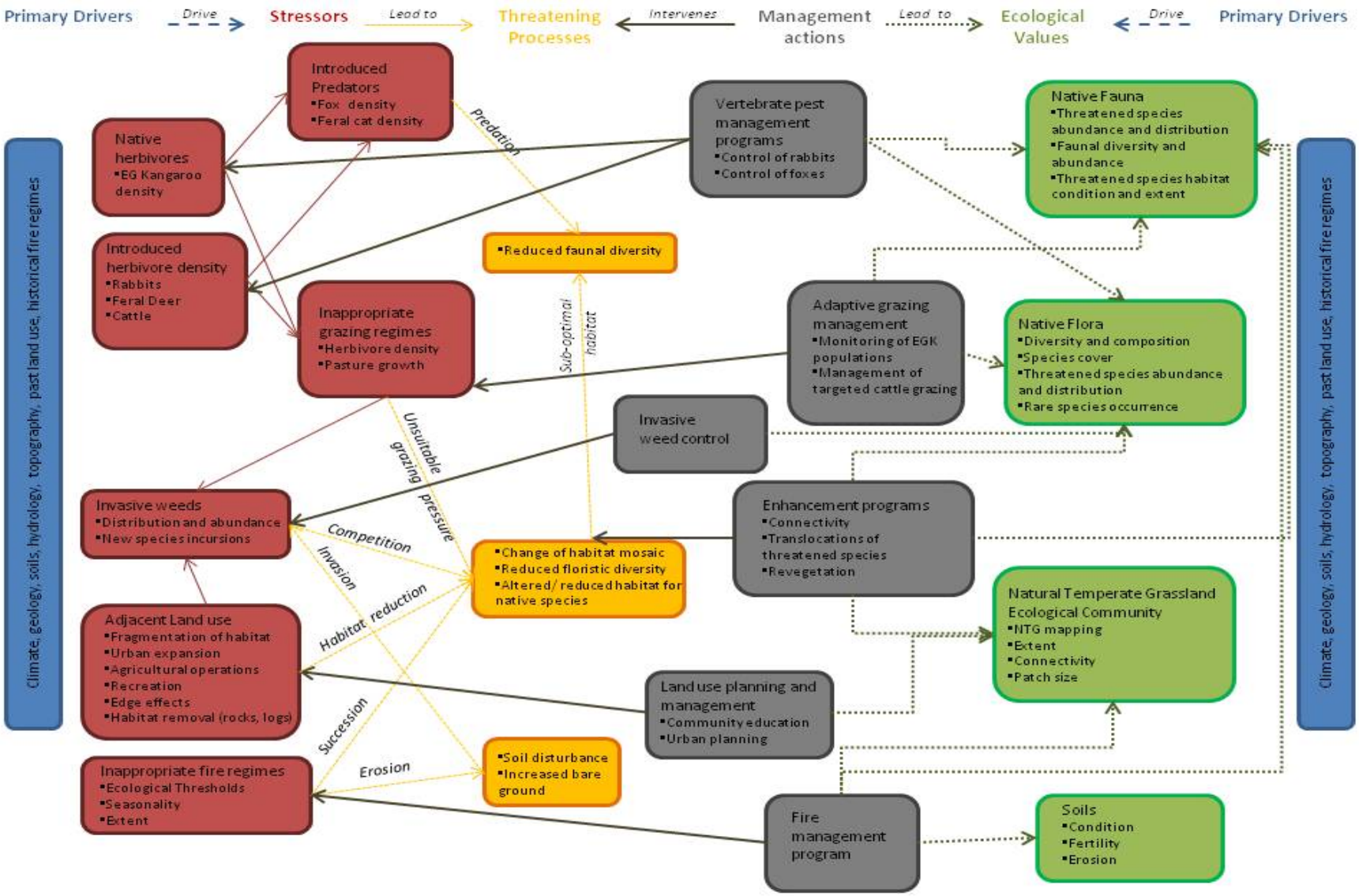
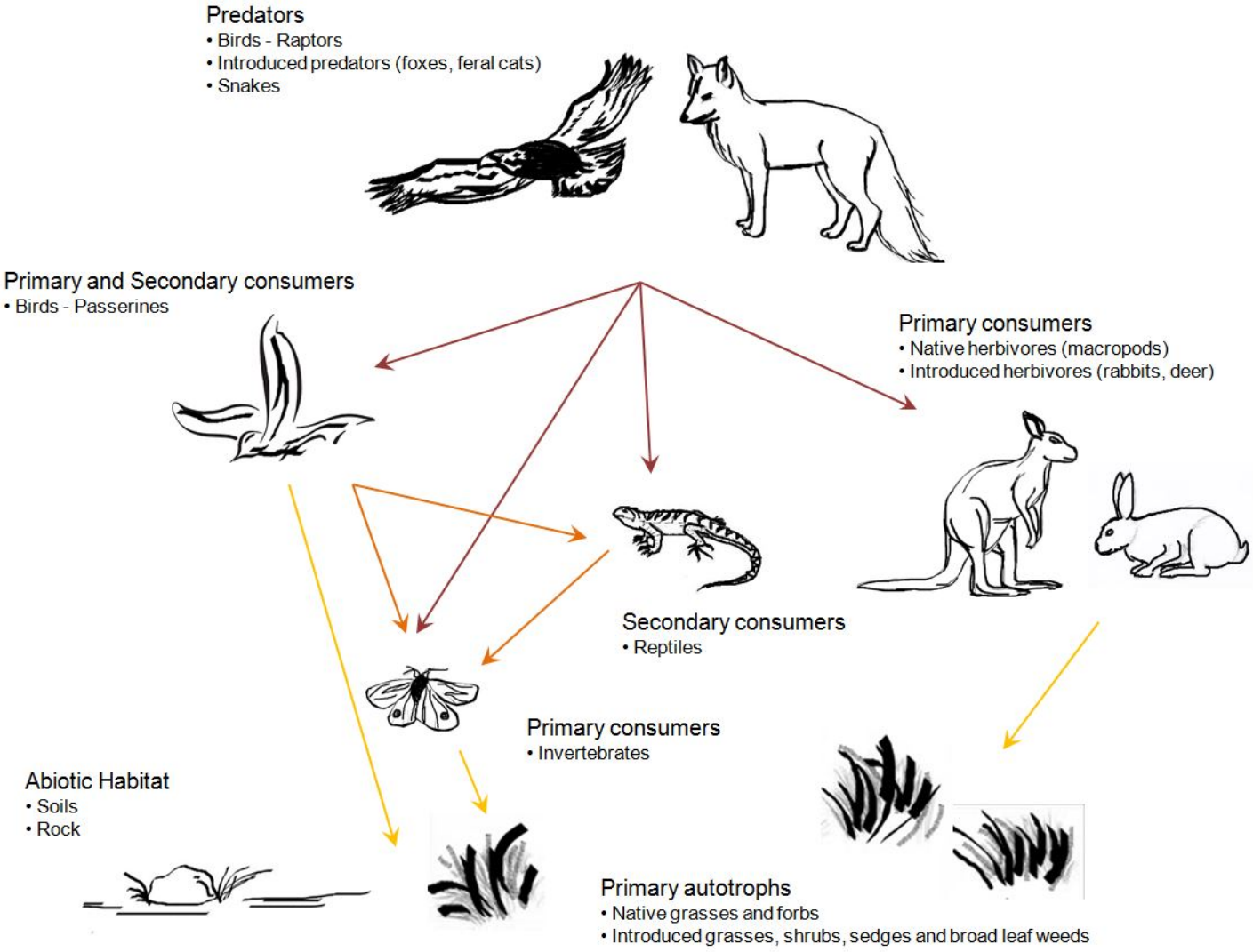


Figure 2. Trophic level flow diagram or food web of an ACT lowland native grassland ecosystem.



1.8 THE CEMP FRAMEWORK

The CEMP framework uses **indicators** and corresponding **metrics** to capture current knowledge and to provide a measurement of ecosystem condition. Two types of indicators are used in the CEMP monitoring plans; **ecosystem condition indicators** and **ecosystem stressors**. Ecosystem condition indicators report on the state of ecological values within an ecosystem; ecological values are the biological and physical environmental characteristics contained within ACT nature reserves that the ACT Government identifies as core values for conservation and key for healthy ecosystem function. Ecosystem stressor indicators identify threatening processes in the ecosystem that are suspected to elicit change in the condition of the ecological values of the ecosystem. The combined use of these two types of indicators enables assessment of effectiveness of management actions aimed at reducing threatening processes and maintaining or enhancing ecosystem condition. Metrics, or measurable attributes of the indicator, are used to capture quantitative data that is used to assess indicator condition. There may be more than one metric contributing to each indicator.

Key attributes of each metric that enable measurement of indicator condition are the **baseline**, **reference condition** and **target condition**. The baseline refers to the initial condition of the metric from which any change in condition, including an increasing, stable or declining trend, can be measured. For many metrics the results from the first survey are used as a baseline, or alternatively the first data contributing to CEMP are used. For research projects with a robust experimental design, data from control plots are used as a baseline.

The reference condition is defined as the ideal condition of the metric reflecting a relatively intact ecosystem. This may be the estimated abundance or distribution prior to European settlement or a site (or a number of sites) thought to be in intact condition, data from which may then be used as a reference for comparison. In many cases restoration to reference condition is not attainable, and therefore may not be the ultimate goal for management. The target condition is established for metrics where the reference condition is, in all practical terms, beyond the ability of management to achieve, and represents medium-term goals for management to work towards. The target condition for metrics are established with extensive consultation with managers, and can be adjusted over time as increased knowledge of the ecosystem is available and better adaptive management outcomes are obtained.

Three elements of condition are assessed to determine the overall condition rating for each metric (Figure 3). **Condition/State** (where the term 'condition' is used for ecosystem condition indicators and 'state' is used for ecosystem stressors) refers to the current condition of the metric relative to the prescribed reference condition or target condition; **condition trend** is a measure of the trend in movement of the current condition away from the baseline condition (i.e. whether condition is improving, stable or declining over time) and **data confidence** refers to how confident we are in the accuracy of the data informing ecosystem condition assessments. The data confidence rating may be one of four ratings: high, moderate, low or unavailable.

Using outcomes from data analysis, combined with expert input for correct data interpretation, the condition or state of each metric is graded as one of four categories; 'good',' good with some concerns', 'moderate' and 'poor'. Metrics in 'good' condition are close to or above the reference condition, or in the case of an ecosystem stressor, the negative impacts of threatening processes are limited or successfully controlled by management actions. Metrics that are rated 'good with some

concerns' are in overall good condition, but there are some sites or attributes that need improvement or do not meet the 'good' condition criteria and condition is therefore below reference condition. Metrics in 'moderate' condition are showing signs of degradation and management actions need to be implemented as a priority to restore condition and to prevent further loss of condition. Metrics rated as in 'poor' condition are not being effectively managed, posing a significant threat to ecosystem values. In this case, changes to management should be of high priority.

When each contributing metric has been assessed for condition or state, the outcomes are 'rolled-up' to inform the condition or state of the relevant indicator that the metric is contributing data to. The process of 'rolling-up' of metric data to get the ranking of condition or state of the indicator follows an averaging process.

Figure 3. Levels of and corresponding symbology for condition/state, condition trend and data confidence ratings used in the CEMP framework.

Condition/State		Condition Trend		Data Confidence	
	Indicator is in good condition	⇧	Condition of the indicator is improving		Confidence in condition assessment is high
	Indicator is in good condition with some concerns	⇔	Condition of the indicator is stable		Confidence in condition assessment is moderate
	Indicator is in moderate condition with a number of concerns	⇩	Condition of the indicator is declining		Confidence in condition assessment is low
	Indicator is in poor condition with many significant concerns		(Blank) Trend in the condition of the indicator is unknown		Confidence in condition assessment is not available

More detailed information on the data and analyses behind each condition assessment is presented under individual metrics within part two of this plan. Further information on the CEMP framework, interpretation of condition assessments and symbology can be found in the Conservation Effectiveness Monitoring Program overview report (Brawata et al., 2017), which can be accessed on the EPSDD website at http://www.environment.act.gov.au/__data/assets/pdf_file/0004/1059241/Conservation-effectiveness-monitoring-program.pdf.

1.9 ECOSYSTEM CONDITION ASSESSMENT

Using data from relevant monitoring and research programs, this Lowland Native Grassland Ecosystem Condition Monitoring Plan captured current available knowledge on select condition indicators (values) and stressors (threats) that operate within ACT lowland native grassland ecosystems. In doing so this plan aims to assist management in setting priorities for research and monitoring to help better target management actions to maintain or improve grassland ecosystem condition.

From the identified values and stressors within the lowland native grassland ecosystem, condition indicators and stressor indicators have been derived and were used for assessing ecosystem condition. Ecosystem condition indicators were Natural Temperate Grassland, native flora (general), threatened flora, native fauna (general) and threatened fauna. Ecosystem stressors assessed were herbivore pressure, fire regimes, invasive weeds and introduced predators. Stressor metrics that were assessed as poor against their reference state included metrics for 1) introduced predators, for which little data were available and only ad-hoc control conducted, and 2) fire regimes, a key ecological process and management tool in lowland native grassland ecosystems (Table 3).

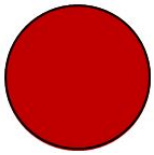
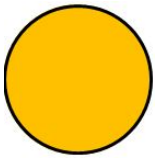
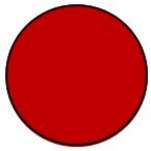
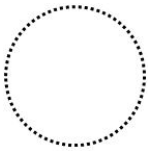
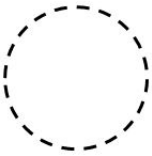
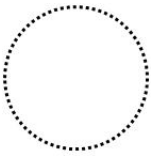
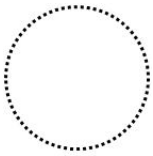
A summary of metrics contributing data to each of these indicators is shown in Table 2 (for condition metrics) and Table 3 (for stressor metrics). For each indicator and corresponding metrics, the assessed condition/state was compared to both the reference condition and target condition and given the appropriate symbol. A list of projects contributing data into the metrics can be found here or by contacting the CEMP officer.

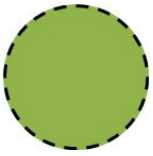
Overall, most indicators for the lowland native grasslands ecosystem rated in 'poor' condition against their reference condition, but either in 'moderate' condition or 'good condition with some concerns' against their target condition. Where indicators were assessed to be in poor condition against their reference condition, this was primarily a result of either the formal threatened status of the contributing metrics under ACT or Federal legislation, or where the extent of the contributing metrics had been significantly reduced in range compared to its former range prior to European settlement. Stressor states in the ecosystem were assessed as poor against reference condition if they represented an uncontrolled introduced species, were little known or insufficiently managed.

A large proportion of indicator metrics (Table 2) and stressor metrics (Table 3) were rated as being in 'poor' condition against their reference condition (Figure 4a, b). Indicator metrics assessed to be in poor condition against their reference condition were listed species with mandated monitoring programs, in addition to the threatened community of Natural Temperate Grassland, the extent of which has been severely reduced post European settlement (Table 2). Such assessments are unlikely to alter over time and in some cases are outside of the scope of reserve managers to address. The assessment of these indicators against reference condition does however provide an important role in that it highlights the importance of prioritising and effectively managing the remaining extent or populations of threatened ecological values.

Stressor metrics that were assessed as poor against their reference state included metrics for 1) introduced predators, for which little data were available and only ad-hoc control conducted, and 2) fire regimes, a key ecological process and management tool in lowland native grassland ecosystems (Table 3).

Table 2. The condition of indicator metrics assessed in the Lowland Native Grassland Ecosystem Condition Monitoring Plan. Condition is given against both reference condition and target condition and rolled up to form overall assessment of indicator condition. A key to the rating symbology is provided in Figure 3.

Headline Indicator	Indicator	Metric	Rating against Reference condition	Rating against Target condition
NTG Ecological community	**C1. Natural Temperate Grassland**	C1.1 Extent of native vs. exotic grasslands within reserves		
		C1.2 Extent of NTG within reserves		
Grassland Flora	**C2. Native Flora general**	C2.1 Native plant species richness		
		C2.2 Ground cover		
		C2.3 Indicator 2 species richness		
	C3. Threatened Flora	C3.1 Button Wrinklewort		
		C3.2 Ginninderra Peppercress		
Grassland Fauna	**C4. Native Fauna general**	C4.1 Reptiles, general		
		C4.2 Invertebrates, general		

	C5. Threatened Fauna	C5.1 Grassland Earless Dragon		
		C5.2 Striped Legless Lizard		
		C5.3 Golden Sun Moth		
		C5.4 Pink-tailed Worm-lizard		

In comparison, most indicator metrics rated as either in 'moderate' or 'good condition with some concerns' against their target condition (Table 2; Figure 5a, b). This is a reflection that overall, management within lowland native grasslands ecosystems is achieving conservation goals in protecting and enhancing ecosystem values.

The effectiveness of management programs at minimising stressors in this ecosystem was more mixed, with current management regimes not meeting target conditions especially for appropriateness of fire regimes (Table 3). There has been a widespread lack of fire across much of the lowland native grasslands over the past 50 years or more, which is likely to have led reduced species diversity and ecosystem heterogeneity.

For the condition indicator 'Native Flora (general)' the assessment against reference condition and target condition were the same because both assessments were based on the same data for this plan (Table 2). To date only high quality floristic plots have been monitored in the lowland native grasslands, so data from these plots have been used to form reference conditions for floristic metrics and also for assessing the current condition of these metrics. Over time and with more representative sampling (such as expanding monitoring to include moderate and lower quality sites, in addition to high quality), the metric will be more informative and there will likely be differences in trend and condition/state between reference and target assessments as data become more representative of the ecosystem condition across the wider landscape.

Data were not available in this reporting cycle for some metrics, including metric C4.2 (Invertebrates, general) and metric S1.3 (Domestic stock). Data were also limited for metrics for which this plan forms the baseline, such as metric C1.1 (Extent of native vs. exotic grasslands within reserves) so that assessment against target conditions could not be made. For some other metrics, assessment against reference condition could not be made due to lack of substantive information about the condition/state of the metric prior to European settlement (e.g. metric S1.1 Eastern Grey Kangaroo and metric S2.2 Fire season as recommended in ecological guidelines).

Table 3: The state of stressor metrics assessed in the Lowland Native Grassland Ecosystem Condition Monitoring Plan. State is given against both reference state and target state and rolled up to form overall assessment of stressor state. A key to the rating symbology is provided in Figure 3.

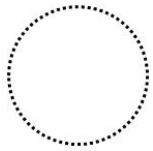
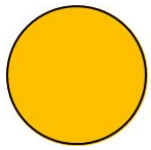
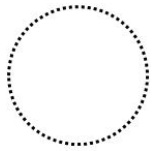
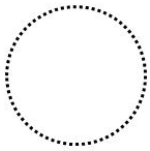
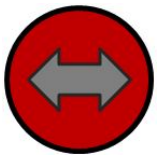
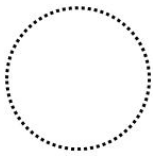
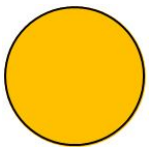
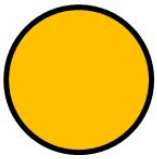
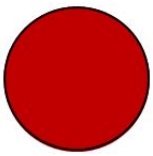
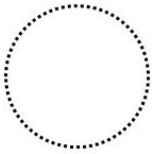
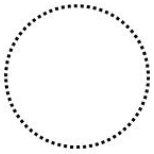
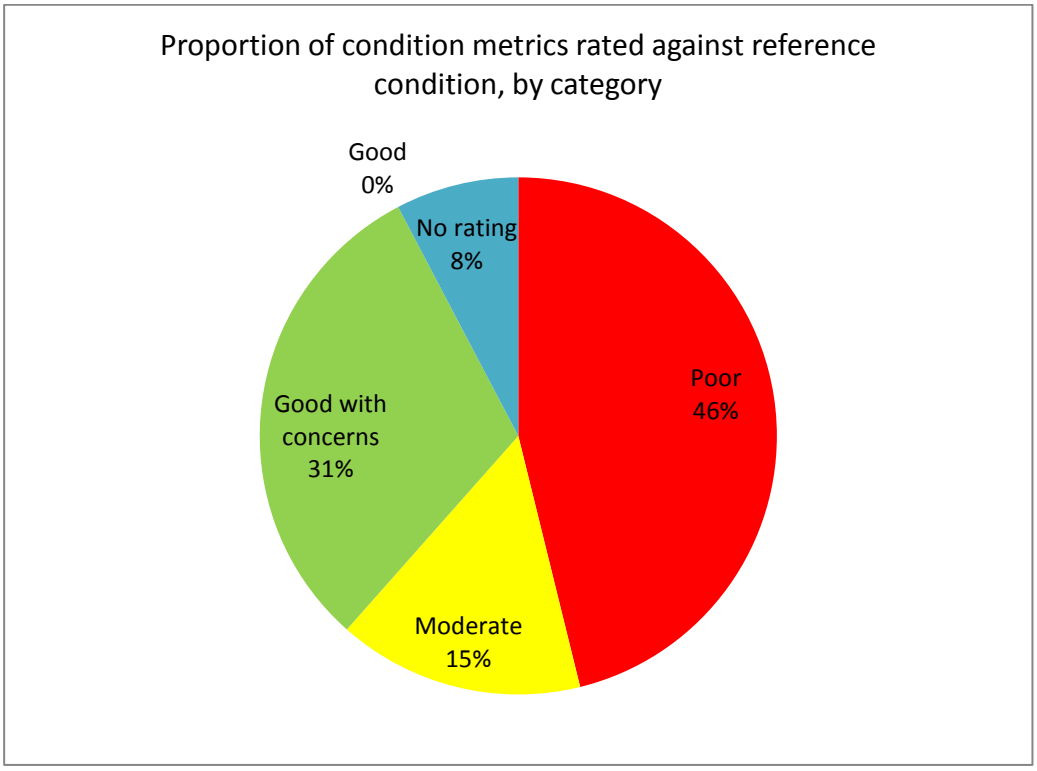
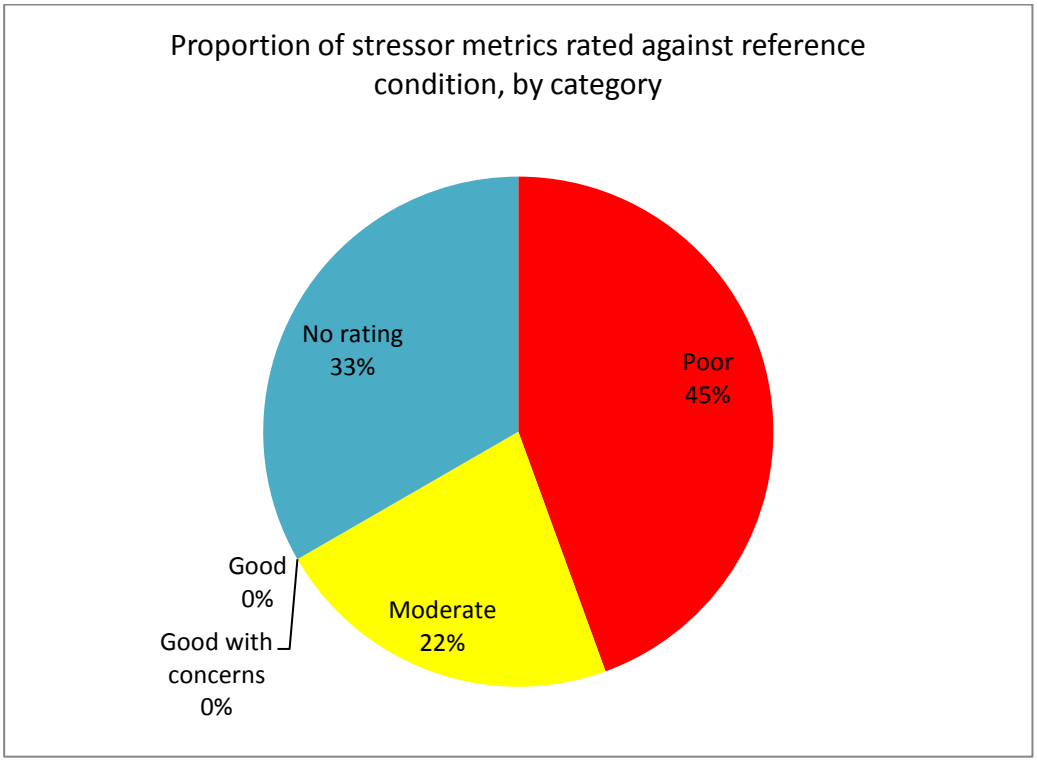
Headline Indicator	Stressor	Metric	Rating against Reference state	Rating against Target State
Inappropriate grazing regime	**S1. Herbivore pressure**	S1.1 Eastern Grey Kangaroo		
		S1.2 Rabbit		
		S1.3 Domestic stock		
Inappropriate fire regime	**S2. Fire regimes**	S2.1 Fire frequency within ecological thresholds		
		S2.2 Fire season as recommended in ecological guidelines		
Invasive weeds	**S3. Invasive weeds**	S3.1 Changes in distribution and abundance of priority weeds		
		S3.2 Invasive weeds - New incursions		
Introduced predators	**S4. Introduced predators**	S4.1 European Fox		
		S4.2 Feral Cat		

Figure 4. The proportion of condition metrics (a) and stressor metrics (b) in each category, as assessed against reference condition.

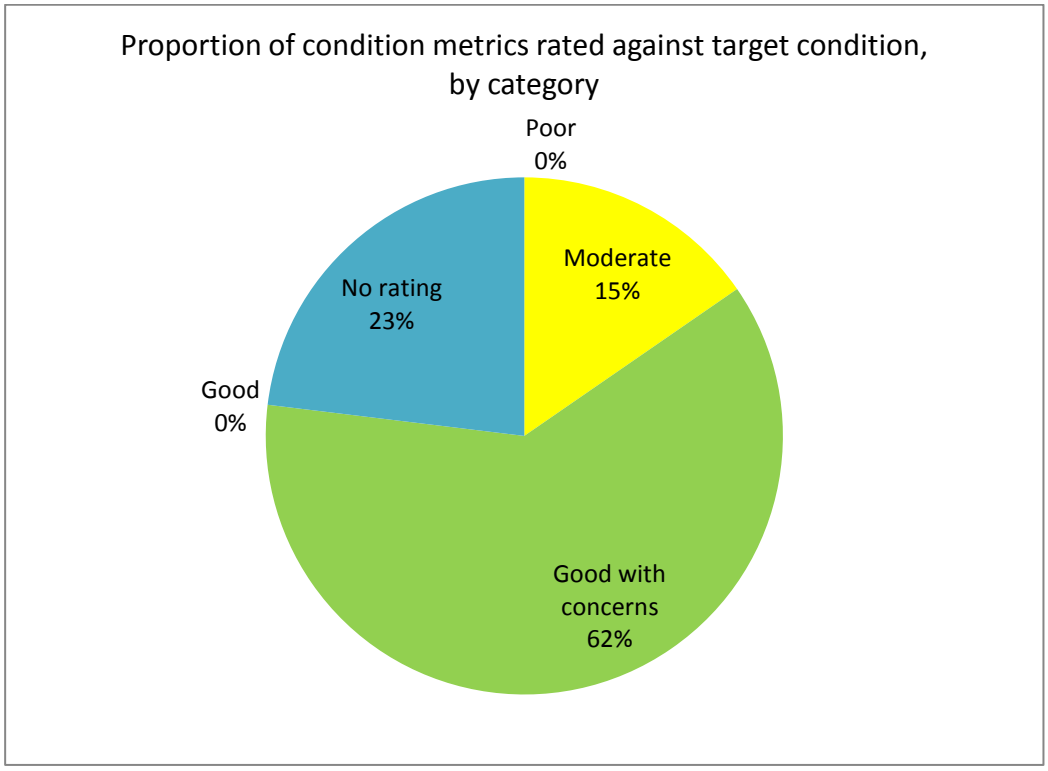


(a)

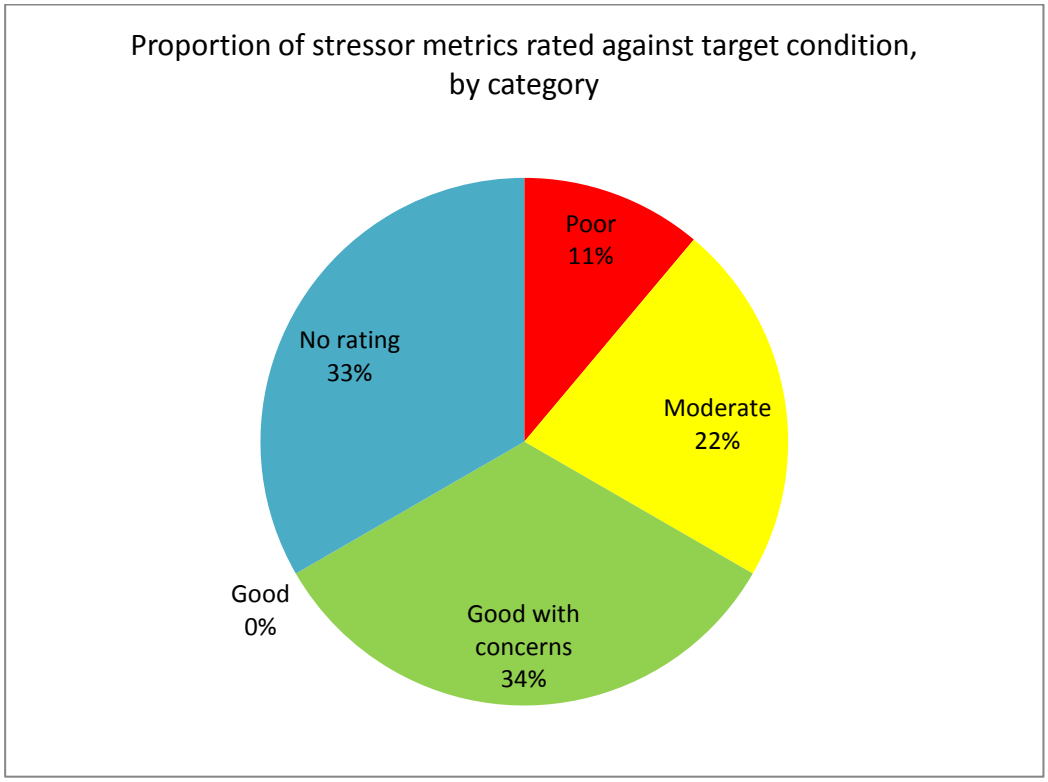


(b)

Figure 5. The proportion of condition metrics (a) and stressor metrics (b) in each category, as assessed against target condition.



(a)



(b)

Where analysis of trend was possible, most metrics were assessed as stable, with a few showing an increasing trend but none showing a decreasing trend (Tables 2 and 3). This indicates that overall, where trend information was available; the ecosystem condition is stable. For many metrics however, particularly for those where this plan formed the baseline data for subsequent plans, trend data were not yet available. For others, data assessments could not be made or data confidence remained very low due to data limitations.

1.9 KEY RECOMMENDATIONS

The overall findings from this plan suggest that while there are many monitoring programs currently undertaken in lowland native grasslands ecosystems in the ACT, some clear gaps in knowledge remain and some change in management actions are required. There is also significant room for improvement for many data sets so that they better inform management decisions. It is envisaged monitoring designs and data management will improve so that subsequent plans will benefit from enhanced data validity and availability. Identified key recommendations for improving both monitoring and management actions to enhance condition of lowland native grassland ecosystems are summarised in Table 4.

Recommendations for monitoring

In the lowland native grasslands, much of the current monitoring conducted in grasslands focuses primarily on monitoring of management actions, not conservation outcomes (Stevenson and Seddon, 2014). Most monitoring programs that do focus on conservation values and that have been conducted over long periods tend to follow trends in condition rather than being driven by explicit questions. This includes a number of mandate monitoring programs for threatened species that occurs under the guidance of relevant Action Plans.

Even so, while many long term monitoring programs were not question driven, the diversity of temporal and spatial scales of monitoring and research projects contributing to metric data and assessment was beneficial to our assessment. This is because different projects retained inherent strength and weakness but often complimented each other on both a spatial and temporal scale, providing a more complete understanding of ecosystem function and the importance of long term drivers, such as climate or past land use, against the effect of short-term management changes. In addition, more recently, question driven research projects have commenced that focused on the effect of changes in herbivore density, fire regimes, grazing of livestock and slashing on biodiversity values within lowland native grasslands. The outcomes of these research projects, combined with robust long term data, should provide valuable insights for management of grassland ecosystems in the future.

Existing fauna monitoring focuses primarily on threatened reptiles and herbivores (rabbits and kangaroos). Birds and small mammals are generally not monitored within this ecosystem due to low numbers of species and abundance. Long-term monitoring of more ecologically representative fauna groups, such as reptiles and invertebrates (particularly key functional invertebrate species such as burrowers), is likely to provide more robust information about ecosystem condition and function than single species monitoring programs alone. The inclusion of additional metrics which assess diversity, rather than populations of threatened species, may lead to future management targets

becoming more aligned to landscape scale objectives of habitat heterogeneity, minimising habitat fragmentation, and enhancing connectivity, and understanding the role of keystone species in lowland native grassland ecosystem function. Notwithstanding this, the threatened status of Natural Temperate Grassland communities and many grassland species may present an opportunity to identify areas for conservation and implement management strategies which will serve more than one conservation objective.

The maintenance of monitoring data has arisen as a limitation when collating data to inform analyses within this plan. Issues found included errors due to duplication, inconstancies in data storage formats and changes in field methods either over time or between data collectors. These issues made comparability between datasets difficult. The consolidation of aligned datasets in addition to consistent field methods is an important step in improving data validity, information flow and accessibility across the Environment Division. It is recommended that long-term data sets, including those shared across units within the Environment Division (such as vegetation and threatened species data) be collected and placed into specifically designed relational databases (such as MS Access) for long term data integrity and accessibility. More streamlined and robust data collection through the use of mobile data capture devises would also increase opportunities for community involvement in monitoring. Programs that may benefit from community involvement include Golden Sun Moth surveys and monitoring of the response of native vegetation to weed control.

An overall recommendation from this plan is to make long term monitoring programs more robust to statistical analysis, requiring general improvements in survey design, data collection methods and data storage. For many programs, monitoring of important covariates, increased replication of plots, better data management, recording underlying management histories, the addition of more representative sites and more consistent field methods would enable much more informative data analyses. Much of the data used in this plan had limitations for the purpose of CEMP, although we acknowledge that this is not necessarily the case for the specific purposes for which the data were originally collected. Having all monitoring programs tailored to feed into CEMP assessments may not be feasible; however an overall recommendation from this plan is to make long term monitoring programs more robust to statistical analysis for a range of programs and end users. Consistency of monitoring methods between projects would also provide larger baseline datasets representative of different management histories and strategies at a landscape scale across reserves. In some cases the establishment of monitoring sites in areas in poor or moderate condition in addition to high quality sites would reduce bias in assessments and assist in the ability to track change in response to management actions and climatic variation.

Recommendations for management

Perhaps the most important finding of this plan is a general lack of fire across much of the extent of lowland native grassland ecosystems over the past 50 years or more. This has likely had significant impacts on species diversity and ecosystem heterogeneity and highlights a clear need for reserve managers to consider more widespread use of fire as an ecological tool in lowlands native grasslands. There is also an opportunity to incorporate cultural burns into grassland burning.

There is a need for accessible, accurate and detailed mapping of grassland communities within reserves, and possibly other habitat elements (such as biomass), across the spatial extent of native grasslands. This spatially explicit mapping could be used to assess changes over time and help tease out the effects of management and climate on grassland communities. The use of newly available

remote sensing data (such as airborne imagery collected routinely from drones) could make collection of such broad scale data possible on a regular basis although the cost effectiveness of such an approach should be compared with other options such as ground based mapping.

A further priority is research into cost effective and achievable restoration techniques that both enhance floristic and structural diversity as well as minimising negative impact on native fauna in lowland native grasslands. The effect of different management strategies, such as burning, slashing, and grazing on both flora and fauna is currently being studied in a number of research programs. The use of alternative management strategies on a day to day basis may also provide opportunistic information on response to such actions, provided monitoring is conducted consistently and effectively designed prior to any change in management. Findings from such monitoring then may enable a more coordinated and informed approach to site- specific biomass management, in addition to clarifying best practice for lowland grassland restoration and conservation.

Following this, there remains an overall need for succinct documentation that captures the biomass needs and management tools available for different grassland associations, biomass and thatch levels and threatened species in lowland native grassland ecosystems. This knowledge is critical for retaining or improving both the extent and condition of grassland reserves. The capture of such knowledge is likely to be an iterative process as more knowledge on the response of grassland communities to biomass management is gained.

There is very limited information available on the distribution, abundance or impacts of introduced predators in lowland grassland ecosystems, particularly cats. Whether more active management of introduced predator populations is required has not been verified and is a knowledge gap in this ecosystem.

There is a need for better record keeping and data collection around grazing activities that are under taken within lowland native grassland reserves. Currently stock grazing is conducted *ad hoc* with minimal records kept and no data collection on the impacts/benefits of grazing undertaken. This issue is currently in review, and may be assisted with the development of land management units within lowland grassland reserves.

It is important that we establish robust pathways for the incorporation of information and recommendations made through the Conservation Effectiveness Monitoring Program and associated ecosystem monitoring plans into management planning. In this way insights gained through monitoring and analysis may best serve to inform future monitoring and management actions. Information from CEMP plans may best be fed into management practice through formal mechanisms, such as annual meetings between the CEMP officer, ecologists and appropriate PCS staff during the development of reserve operational plans (ROPs). Additionally, knowledge gained through the CEMP analyses and collation of monitoring data can be used to advise on design of both existing and future monitoring programs. Where possible, the CEMP officer should be involved in discussions around monitoring program development in order to assist in aligning monitoring and research across the Environment Division, facilitating more integrated outcomes between programs.

Finally, there are some metrics incorporated into this ecosystem condition plan for which no or limited data were available and recommendations are to include these metrics in future monitoring to improve ecosystem condition assessment in future. It is important that the pathways for the incorporation of information and recommendations made under this monitoring plan into

management are considered, so that it may best serve to inform future monitoring and management actions.

Findings from this plan highlight the need for a long-term commitment to effective monitoring that is linked to management decision making. Many of the key management questions within lowland native grassland ecosystems are complex and require teasing out to separate the effects of management from underlying historical influences such as land use and from key drivers such as climate. In addition, the indicators selected for monitoring in this plan are by no means exhaustive; the ability of chosen indicators to detect early change to ecosystem condition will be assessed in an ongoing way and reviewed in future plans.

Table 4. Key recommendations by indicator from the Lowland Native Grassland Ecosystem Condition Monitoring Plan.

Indicator	Key recommendations
C1. Natural Temperate Grassland	• Further research into successful management strategies for restoration of native pasture to NTG status, with a focus on cost effective, non-invasive methods that are not detrimental to fauna. • More accurate mapping of grass associations across CNP will enable more informed management decisions, including habitat connectivity mapping.
C2. Native Flora general	• Establish monitoring sites which are representative of all condition states across the landscape including poor and moderate condition sites. • Clarification of the best practice for increasing native dominance, and what management methods to use under which circumstances.
C4. Native Fauna general	• Complete current studies examining the effect of burning and grazing on reptile communities. • Increase the utility of reptile community data through more consistent methods and better data management. • An annual monitoring program for reptiles needs to be established.
C5. Threatened Fauna	• Collection of data on habitat variables, ambient air temperature, and arthropod burrows (including abundance of burrow occupancy) during Grassland Earless Dragon monitoring programs. • Research into what drives populations of burrow producing arthropods is required as a high priority. • Annual Golden Sun Moth surveys need to be established, with monitoring of relevant habitat variables.
S1. Herbivore pressure	• Research into the optimal density to maintain rabbit populations at in grasslands and on whether rabbits impact species richness through selective grazing pressure. • Trial the use of land management units (LMUs) to assist with accurate and consistent record keeping when domestic stock grazing is used for biomass control in reserves.
S2. Fire regimes	• Increased ecological burning in lowland native grasslands. • Current recommended fire frequency and seasonal thresholds area based on flora fire response; there is a need to revise thresholds and to include fauna fire responses. • Research into the impact of fire on C3 dominated grasslands. • Research into the scale and nature of patchiness to promote conservation outcomes. • There is an information gap that burning information carried out on non-PCS managed lands currently is not recorded in the burn history layer.
S3. Invasive weeds	• Monitoring of native flora in response to weed control to demonstrate benefits for conservation. • Standardisation of effort through recording of complete searches vs. opportunistic sightings, including recording weeds not treated.
S4. Introduced predators	• The impact of foxes and cats on grassland fauna is yet to be quantified.

PART TWO: TECHNICAL ANALYSIS OF ECOSYSTEM INDICATORS AND METRICS

Delma inornata during reptile surveys – Photo credit Sam Murphy

MONITORING OF THE NTG ECOLOGICAL COMMUNITY

C 1. NATURAL TEMPERATE GRASSLAND (NTG)

Natural temperate grassland (NTG) at Dunlop NR – Photo credit Emma Cook.

C1: NATURAL TEMPERATE GRASSLAND (NTG)

C1.1. Extent of native vs. exotic grasslands in reserves

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: This metric tracks the extent of native dominated grassland within reserves. This is a new metric for which data collection will be commencing in 2017/18. Current mapping suggests there is approximately 3300ha of native dominated grassland in the ACT, which is approximately one fifth of its former extent prior to European settlement. Long term data that record these fluctuations are needed to gain an accurate assessment of change in condition over time. It is proposed that the distribution of native and exotic dominated areas within grassland reserves be measured seasonally over time to account for natural variation.

Metric Assessment: The Natural Resource Management (NRM) team has mapped the distribution of native and exotic dominated grasslands across five reserves using remote imagery (Figures 6-10), with mapping of others reserves currently underway. Current limitations of this method include seasonality of exotic grasses and the inability to apply the method at seasonal intervals. Future data may be gathered using quarterly 'health checks' in grassland reserves and/or the use of drones as a means of collecting remote sensing data on grass association distribution. Methods are to be further refined with advice from PCS and should be reviewed in light of cost effectiveness for supporting management decision making.

Class: Core	**Category:** Statutory (Threatened Ecological Community)	
Primary Drivers context: Warm year with average rainfall in 2016. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: The condition of native grasslands in reserves is threatened due to weed invasion, inappropriate biomass management and disturbance from adjacent urban developments.

Projects contributing to metric: PCS health checks, CR vegetation mapping, NRM team spatial mapping and Offsets team grasslands monitoring program.

Sampling periodicity: Quarterly health checks to capture seasonal changes (dependant on resources) and detailed mapping every 5-10 years.

Baseline: TBA – first round of data 2017.

Reference condition: Estimated at approximately 15,500 ha of native grassland prior to European settlement (ACT pre-1750 vegetation mapping).

Target condition: Overall aim is to increase dominance of native species cover.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil

Future research questions, management directions, knowledge gaps and recommendations: Connectivity analysis for grasslands is required to assist with targeting restoration programs and assist with species/population resilience assessments. There is also a need for accurate and detailed mapping of grassland communities (and possibly other habitat elements such as biomass) across the spatial extent of native grasslands. This spatially explicit mapping could be used to monitor changes over time and help tease out the effects of management and climate on grassland communities.

Figure 6. The distribution of grass associations within Crace Nature Reserve (DRAFT only; NRM Projects)

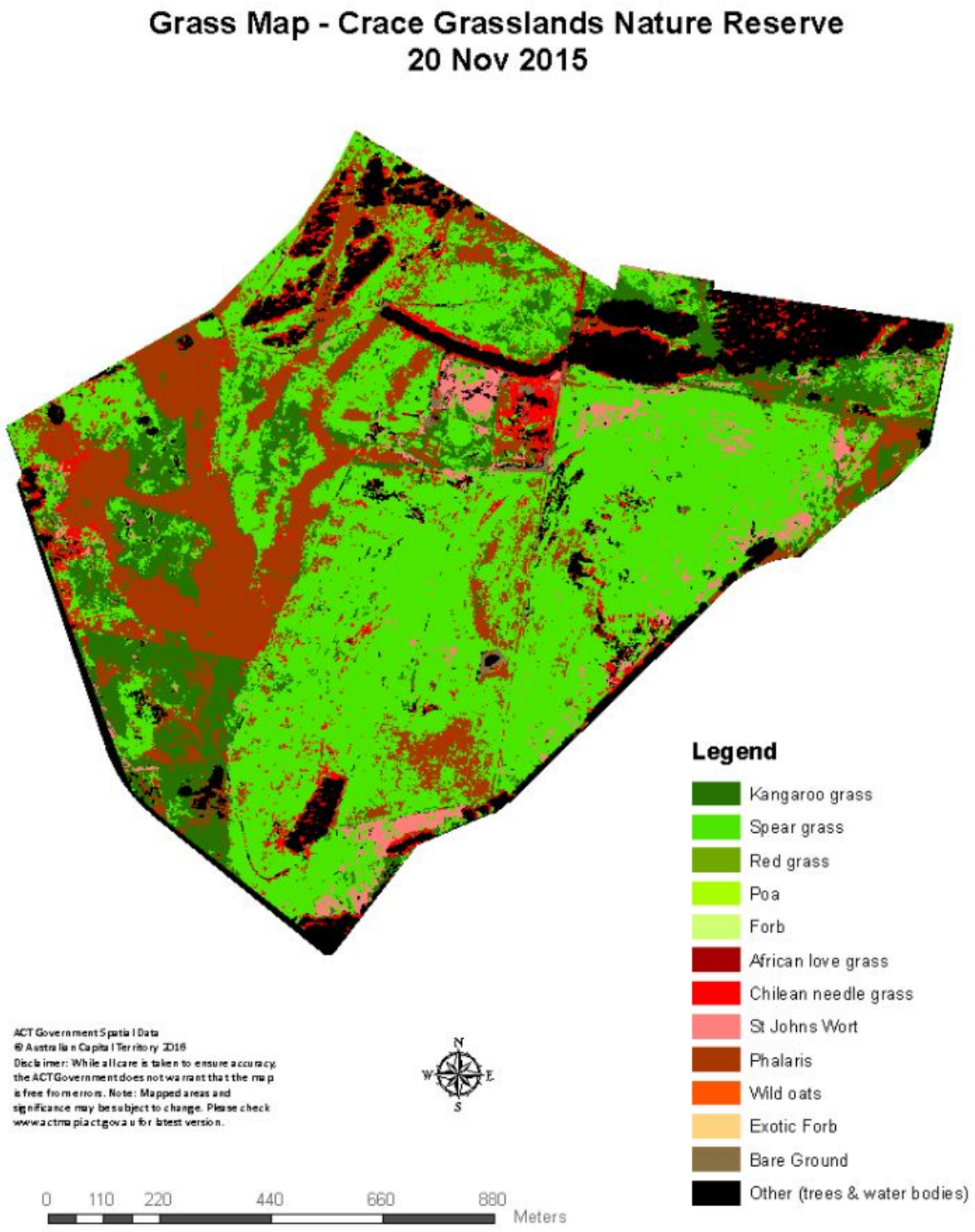


Figure 7. The distribution of grass associations within Jerrabomberra Nature Reserve (DRAFT only; NRM Projects)

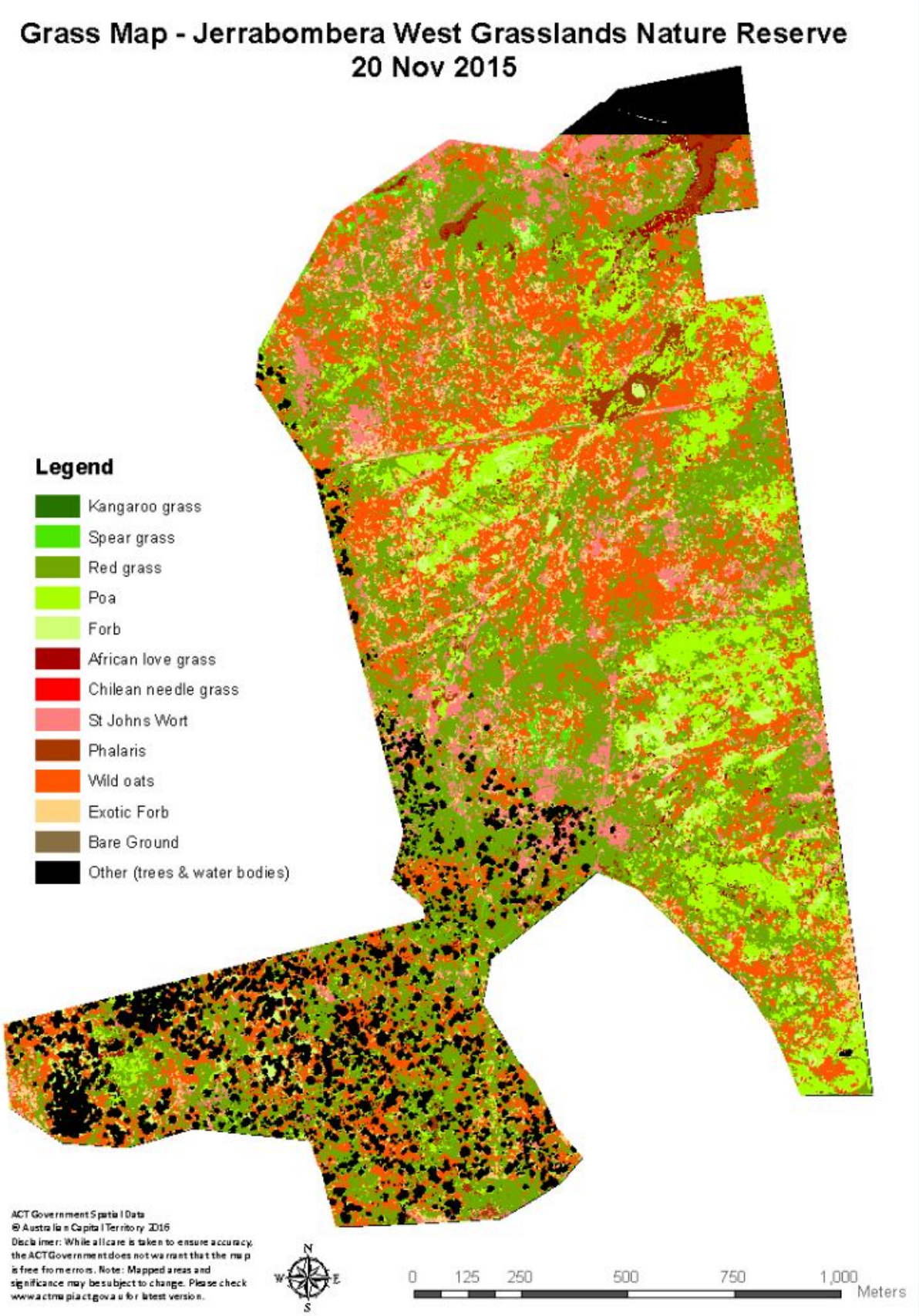


Figure 8. The distribution of grass associations within Jerrabomberra Nature Reserve (DRAFT only; NRM Projects)

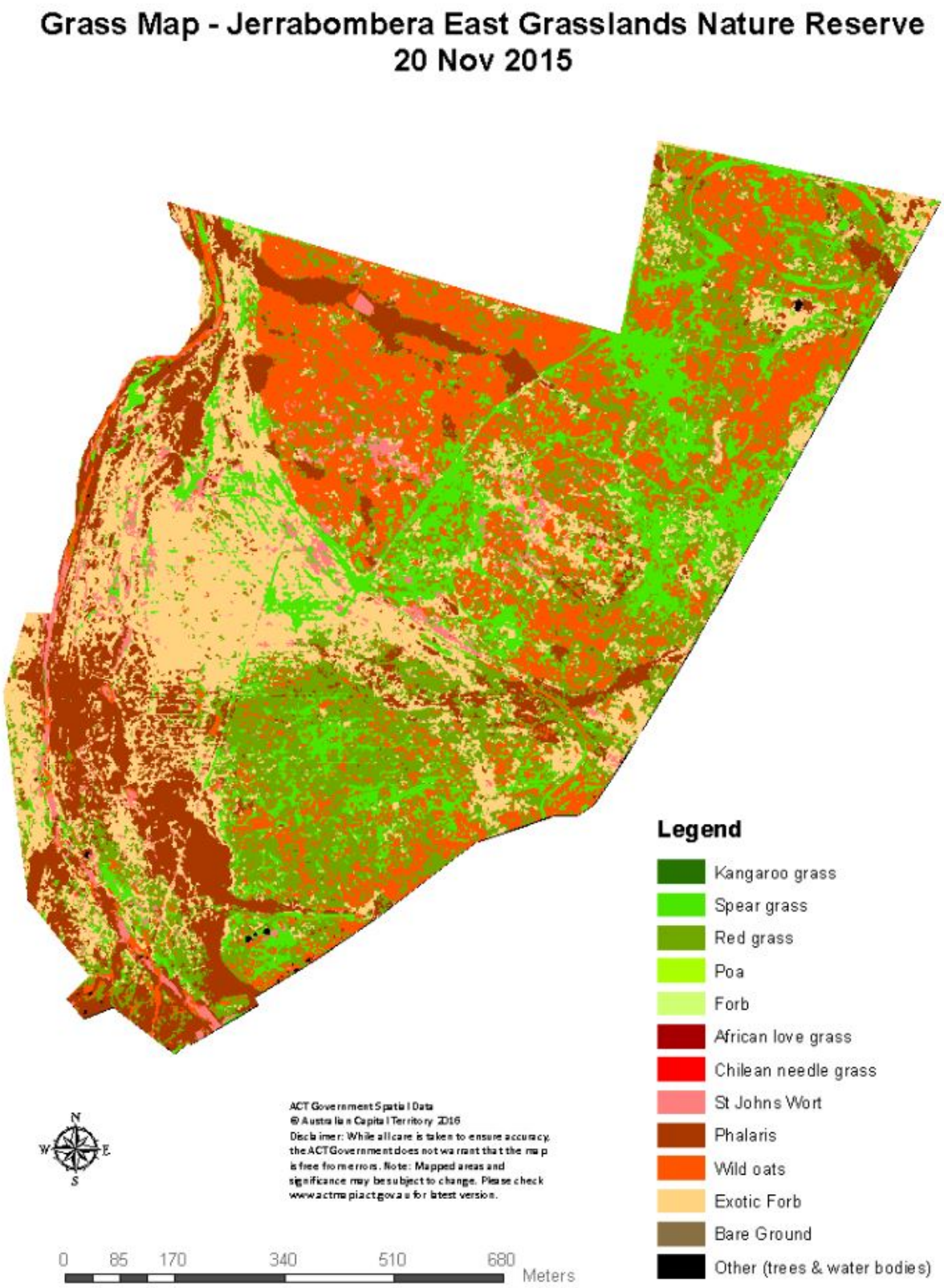


Figure 9. The distribution of grass associations within Gungaderra Nature Reserve (DRAFT only; NRM Projects)

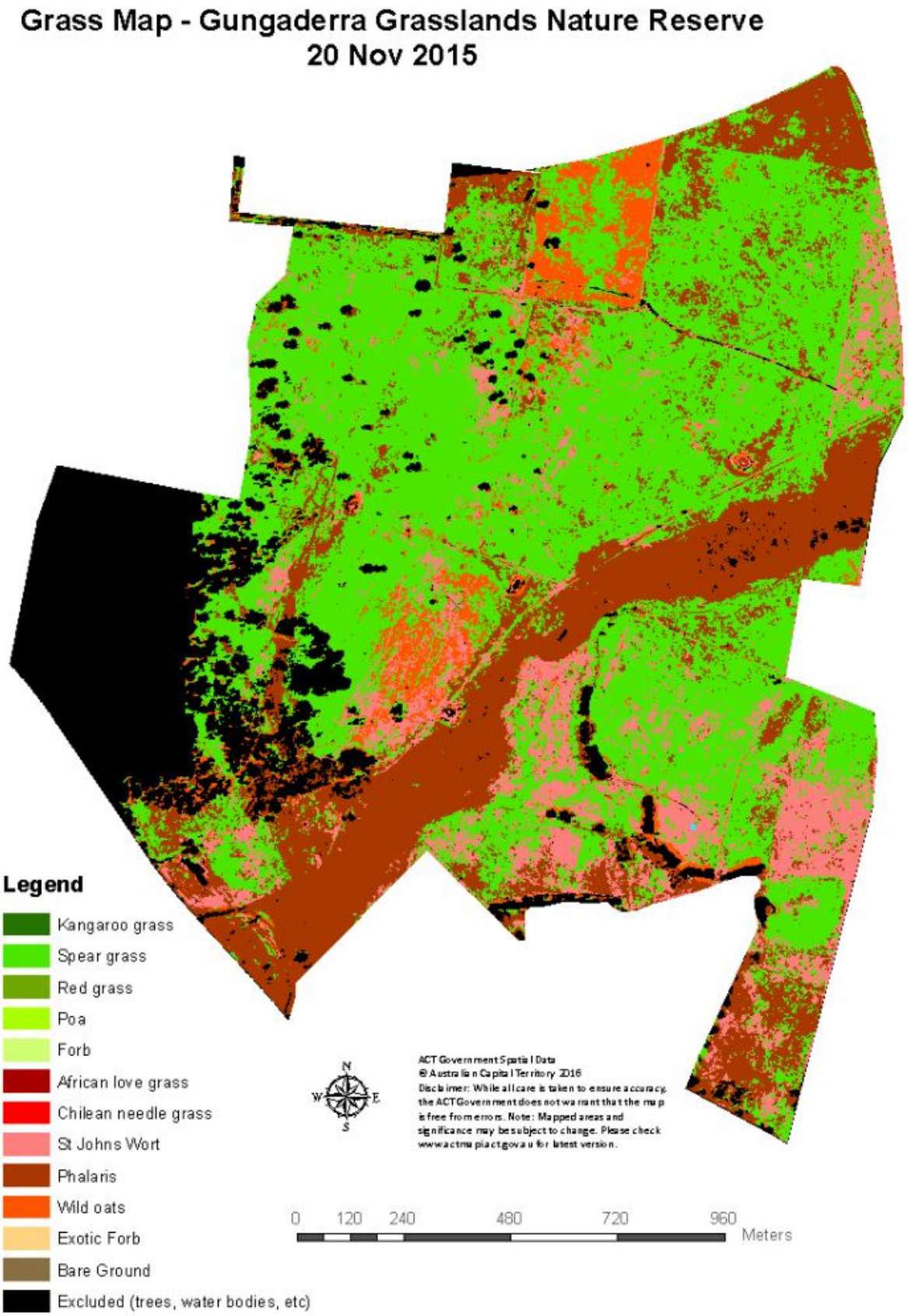
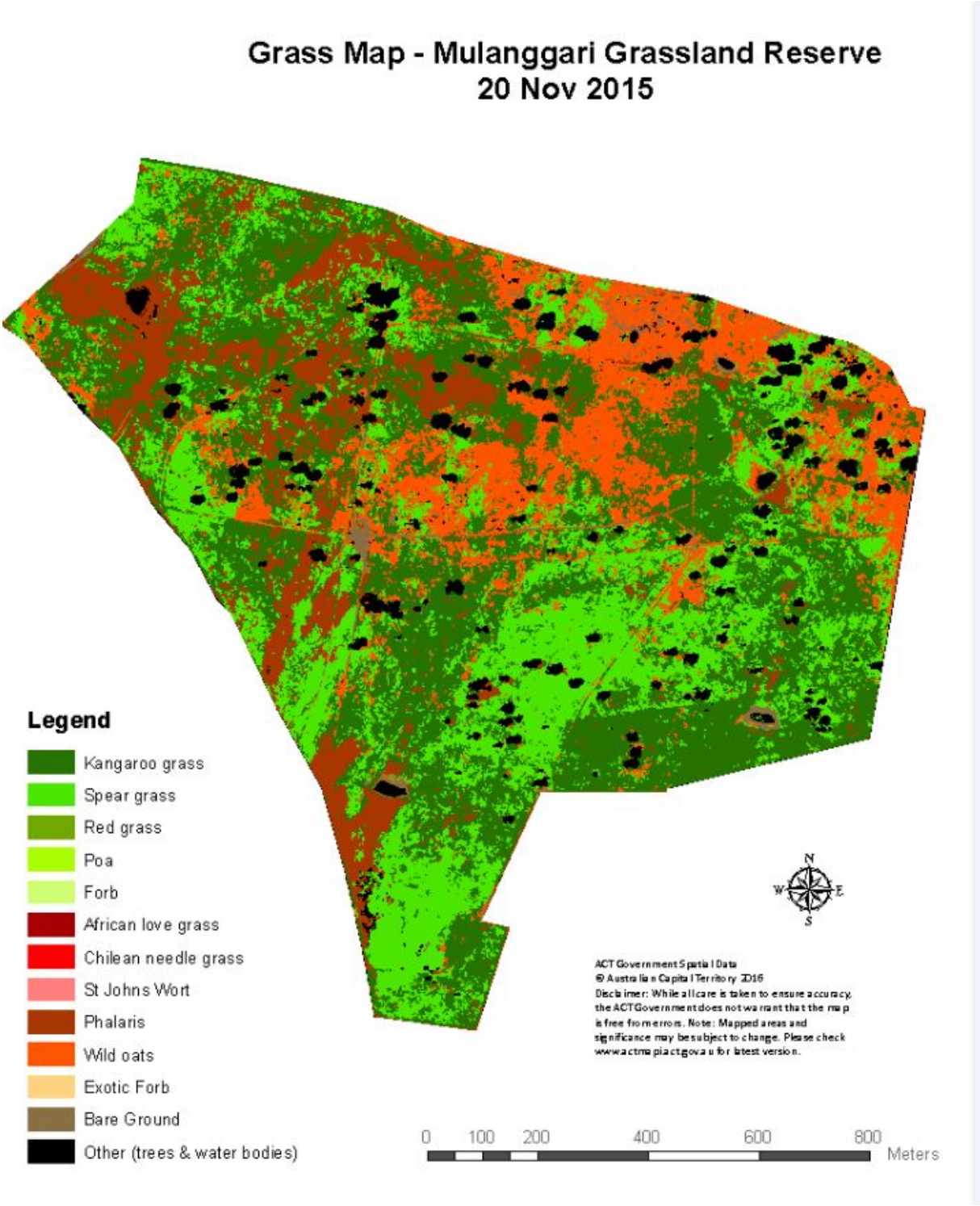


Figure 10. The distribution of grass associations within Mulanggari Nature Reserve (DRAFT only; NRM Projects)



C1.2. Extent of NTG in reserve areas.

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: The extent of NTG within ACT reserves in 2016 will be used as the baseline for tracking changes in this metric over time. Around six percent of the original pre-European extent of NTG (approx. 15,500 ha) remains (approx. 900 ha), less than half of which (approx. 400 ha) is in ACT reserve estate. There is currently a larger area of NTG remaining off reserve lands than within reserves, but many of the larger intact tracts off reserve are contained within Commonwealth/Defence lands. Threats to NTG are urban development, inappropriate biomass management and invasion by exotics.

Metric Assessment: This assessment looks at changes in the extent of NTG on reserve lands and environmental offset areas. Changes in this metric will be monitored through comparing the patch size of 10 patches of NTG on reserves over time (Figure 11**,** Table 5). The condition of NTG at these 10 patches is currently assessed through Indicator C3 (Native Flora, general).

Class: Mandate	**Category:** Statutory (Threatened Ecological Community)	
Primary Drivers context: Warm year with average rainfall in 2016. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale NTG is a Threatened Ecological Community and important habitat for native flora and fauna species of the region. Urban and agricultural development may reduce the patch size of remaining NTG areas by dividing larger patches, hence impacting on flora and fauna dispersal and ecosystem resilience. Invasion by weeds, inappropriate biomass management and exotic grasses may reduce native species diversity and richness, degrading NTG sites.

Projects contributing to metric: ACT Government spatial mapping

Sampling periodicity: 5-10 years

Baseline: 2016 mapping extent.

Reference condition: Estimated at approximately 15,500 ha of NTG prior to European settlement (ACT pre-1750 vegetation mapping).

Target condition: Management aims to maintain or increase extent of NTG on reserve lands and to assist in future preservation of NTG areas off reserve. Action Plan No. 28

Trigger point for management: No trigger point at this time.

Qualitative input: Nil

Future research questions, management directions, knowledge gaps and recommendations: Two reviews are needed: 1) an assessment of the relative impacts of urban development and weed invasion over time on the quality and distribution of NTG (and how these impacts can be managed); 2) a review of successful management strategies for restoration of native pasture to NTG status, with a focus on cost effective, non-invasive methods that are not detrimental to fauna. Preliminary monitoring indicates that the preferred habitat of the Canberra Raspy Cricket (*Cooraboorama canberrae*) may be high quality NTG; if so this species may be useful as a future indicator of NTG condition if robust sampling methods can be developed**.**

Data Analysis

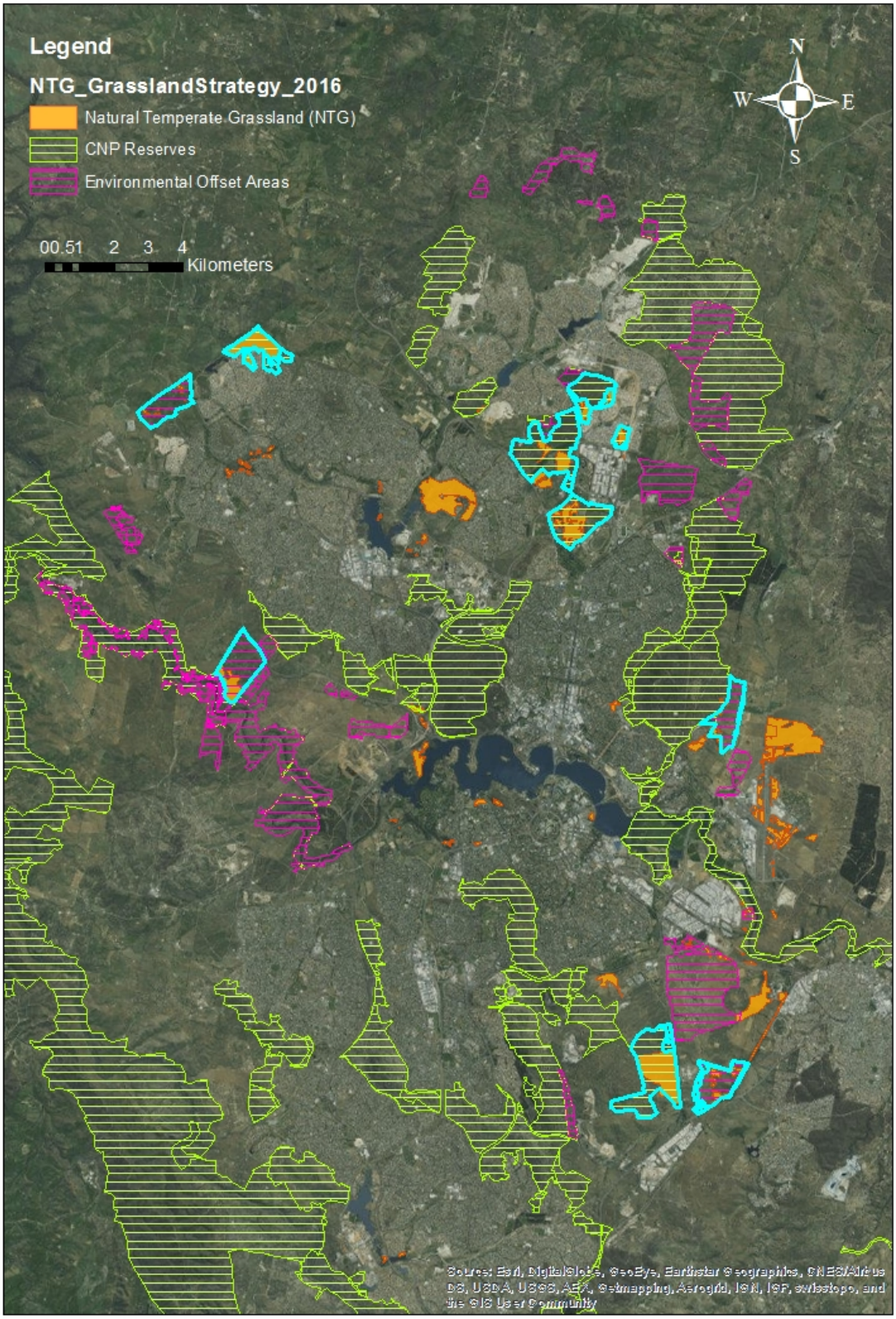
From an original distribution of approximately 15,500 ha, only around 900 ha of Natural Temperate Grassland (NTG) remains in the ACT. Less than half of this area (approx. 400 ha) is in ACT reserve estate. While the protection of NTG within the ACT at a landscape scale is primarily guided by planning and policy decisions, the conservation and restoration of NTG within reserve estate is guided by reserve management decisions.

Currently restoration projects in lowland native grasslands are trialling biomass management actions such as burning, grazing and slashing to improve the condition of native grasslands and habitat quality (ACT Government Grassland Restoration Project and Kama forb enhancement program). Scraping (the removal of the topsoil from a site, including seed bank and plant propogules) is currently being trialled at Kama NR to enhance grassland condition; however this method is mostly suitable for highly degraded areas and is expensive. At Crace Nature Reserve direct planting of *Themeda* tubestock and *Themeda* thatch placement in pre and post burn plots were trialled as methods for restoring *Themeda* grasslands but early results indicate that this method was unsuccessful. Planted and burn sites are currently monitored by photo monitoring, with the intention of trialling additional sites over the next year. The disadvantages of these restoration techniques are that they are labour intensive, logistically challenging and cost prohibitive, with success rates yet to be determined. There is a need to find cost effective and achievable restoration techniques to improve the quality of degraded grasslands back to NTG, that also have minimum impact on fauna populations. There is an opportunity for community involvement in grassland restoration programs to make them more cost effective and achievable in the longer term.

Table 5. Area of NTG in 10 standardised patches within select reserve and offset locations. Future data analysis will compare changes in the proportion of NTG at these sites over time.

NTG patch (including reserve and offset areas)	Patch size (ha - standardised)	Area of NTG 2016 (ha)	Area of NTG 2016 (approx % of total area)
Dunlop	105	81	77%
North Mitchell	21	15	71%
Jerrabomberra West	261	115	44%
Crace	160	61	38%
Kama	155	37	24%
Jerrabomberra East	112	22	20%
Mulanggari	140	26	19%
Gungaderra	282	32	11%
Jarramalee	112	4	3%
Majura West	115	1	1%

Figure 11: Distribution of NTG in 2016 relative to CNP reserve and Environmental Offsets areas. Highlighted light blue lines indicate the boundaries of the ten monitoring sites to be used for monitoring change in extent of NTG over time in CEMP.



MONITORING OF GRASSLAND FLORA

C2. NATIVE FLORA GENERAL

C3. THREATENED FLORA

Rutidosis leptorryhnchoides at Jerrabomberra East NR – Photo credit Emma Cook

C2: NATIVE FLORA GENERAL

C2.1: Native plant species richness (NSR)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Of 13 sites sampled in annual floristic surveys, 10 sites showed an increasing or stable trend in native plant species richness (NSR) over time while three sites showed a decreasing trend; these results are bias as only high quality grassland plots were sampled. Native plant species richness was found to differ across different slope gradients, grass associations, and to increase with grass height variability and the presence of rocks. Recent research shows that slashing and burning increase native plant species richness while results from grazing trials and rock additions will be available in the next CEMP plan.

Metric Assessment: The number of native plant species per standardised area at selected monitoring sites. CR annual floristic survey plots were initially chosen to represent high quality native grassland with most of the original plots located in patches of NTG. In 2016, five new sites were established to make monitoring representative of grasslands over all and to monitor long term changes in lower condition plots in response to management actions. Findings from relevant research projects are also included in metric assessment.

Class: Core	**Category:** Statutory- Threatened Ecological Community	
Primary Drivers context: Data sourced from years 2009-2016; Millennium drought 2001- 2009. Moderate climatic conditions since. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: The richness of native plant species is a key indicator of biodiversity and ecosystem condition in lowland native grasslands.

Projects contributing to metric: CR annual grassland monitoring, ACT Government Grassland Restoration Project, Kama forb enhancement program, Offsets grassland monitoring.

Sampling periodicity: Annually at selected sites, additional sites as part of research projects.

Baseline: Baseline data for the CR annual floristic survey sites were collected in 2009. Five lower condition sites were established in 2016 to capture more representative data.

Reference condition: Reference condition values were derived from statistical analysis of previous monitoring data. A native plant species richness value of 24 or above represents good condition, 13-23 represents good with some concerns, 3-12 represents moderate condition and <2 represents poor condition. Some sites are inherently lower or higher in native plant species richness and this will be considered in interpretation of assessments. More situation specific reference conditions may need to be defined in the future.

Target condition: Reference condition.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil

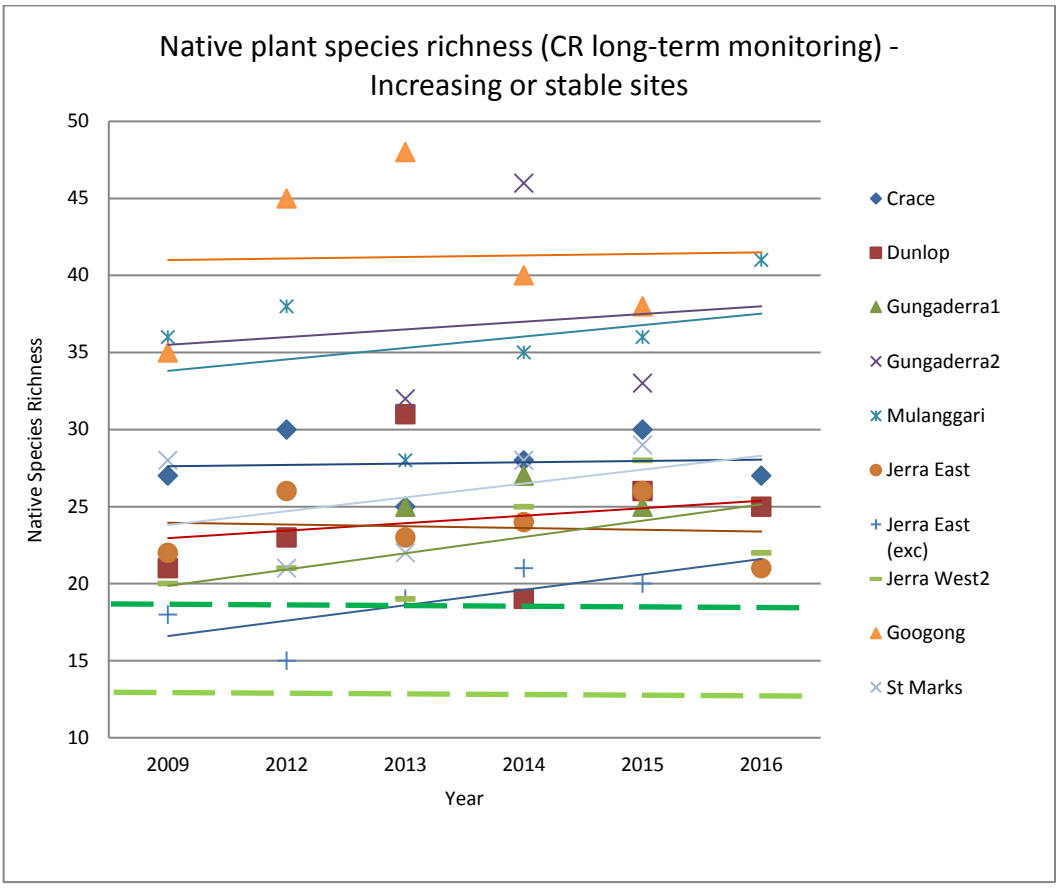
Future research questions, management directions, knowledge gaps and recommendations: Findings from grazing and rock addition trials to be added to the metric next CEMP plan. Need to establish long term monitoring sites which are in poor or moderate condition to be able to track change and response to both climatic variations and management actions. Need to refine reference condition thresholds to account for intrinsic differences in native plant species richness between grassland communities and define trigger points for management actions.

Data Analysis

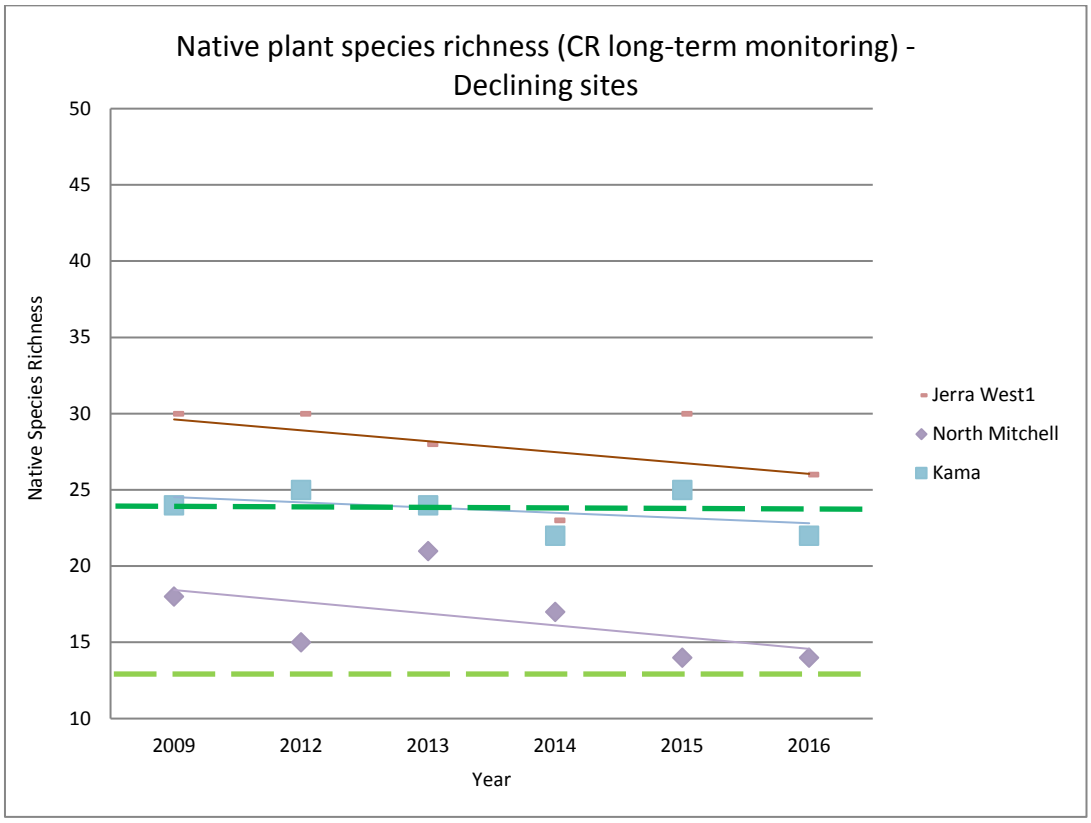
Most CR long-term monitoring sites have been monitored since 2009, but a significant limitation to these data is that the sites sampled only represent high condition native grasslands and are therefore not representative of a range of conditions over the broader landscape. For this reason the CR long-term monitoring sites have been used to inform the reference condition for future native plant species richness assessments. However, for this assessment, confidence in data for this metric is only moderate due to the lack of representation of broader ecosystem condition. We recommend the establishment of floristic monitoring sites in poor and moderate quality lowland native grasslands to enable monitoring of change in response to both climatic variations and management actions. The first moderate quality floristic sites were monitored in 2016.

Most sites showed an increasing or stable trend in native plant species richness over time (Figure 12), with only three sites (North Mitchell, Kama and Jerrabomberra West) showing a small decline in native plant species richness. For most sites native plant species richness was at or above reference level, with all sites within one standard deviation of reference level.

Figure 12. Increasing (a) and decreasing (b) trend in native plant species richness at CR long term monitoring sites. Results for Gungaderra sites are limited to three years of data. Green dashed lines show the values for reference condition (dark green) and for condition that is 'good with some concerns' (light green).



(a)



(b)

The CR long term data were analysed for response to different management regimes and environmental conditions using Generalised Additive Mixed Models (GAMMs) with the 'mgcv' package in R version 3.3.2. The data were collected using multiple observations from some plots and additionally multiple plots were nested within some reserves. To deal with these violations of independence, plot nested within reserve was used as a random term in each model. Multiple candidate models were run and compared and selected using Akaike Information Criterion (AIC) (N. Wilson *Pers comm*. 27th Feb 2017).

The only variable found to be a significant predictor of native plant species richness at the 90% level was slope; native plant species richness increased with increasing slope (Figure 13). Based on the analysis of monitoring plots there were generally only minor differences in grassland condition between reserves, with a high level of variation within reserves. The soil landscape that each plot occurred on was substantially different between some plots, however many soil landscapes were not sufficiently represented for any meaningful statistical analysis.

Early results from the ACT Government Grassland Restoration Project show a correlation between native plant species richness and biomass (as measured with the 'golf ball' method (Morgan, 2015)), with native plant species richness increasing at lower biomass (Figure 14a). Native plant species richness appeared to also be influenced by percentage cover of dead material and by litter depth, with correlations showing higher native plant species richness found at lower percentages cover of dead material and shallower litter depths (Figure 14b, d). Preliminary exploration of the relationship between native plant species richness and grass height showed a quadratic response; with native plant species richness highest when grass height was between 5 – 10 cm (Figure 14c).

Figure 13. Predicted native plant species richness in response to the logarithm of slope.

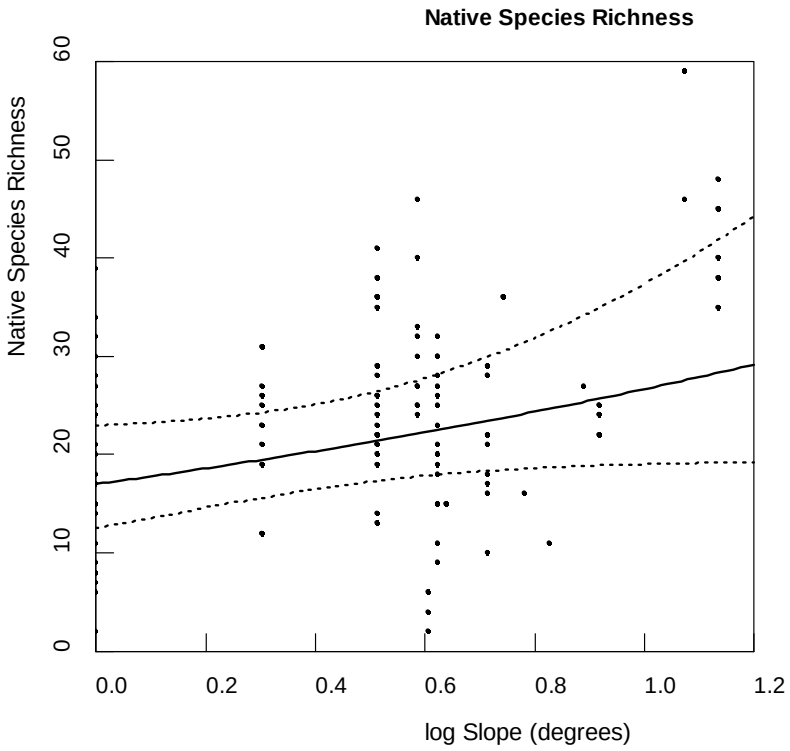
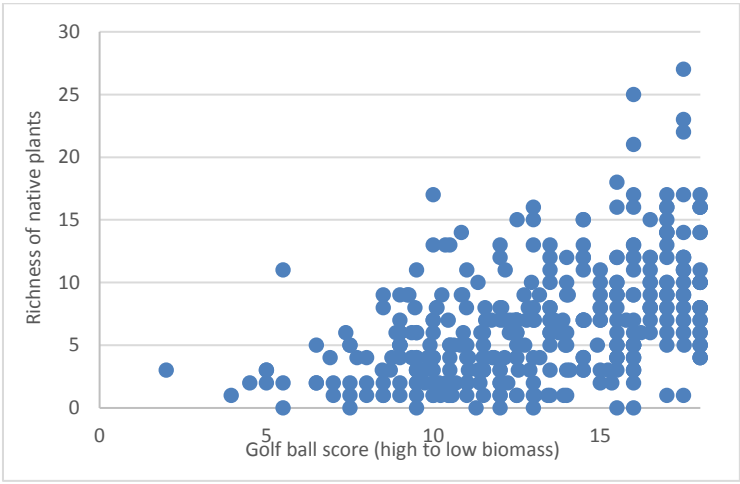
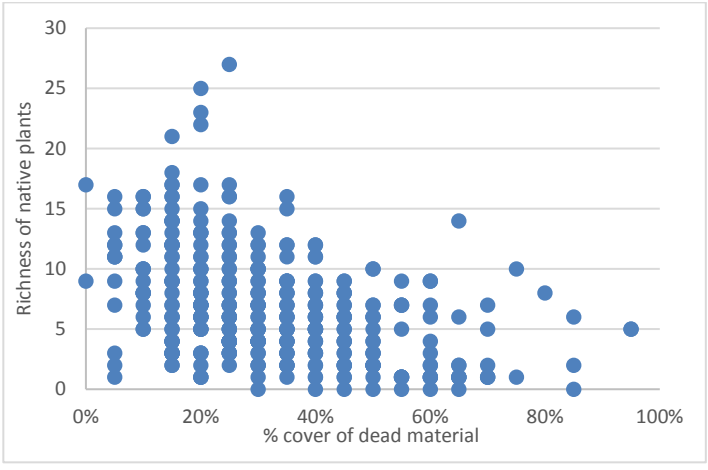


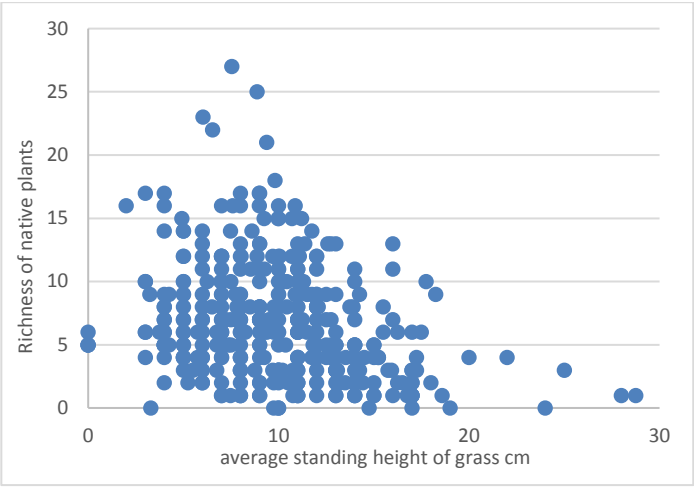
Figure 14. Native plant species richness in response to (a) grass biomass (golf ball score), (b) percent cover of dead material, (c) average standing height of grass, and (d) litter depth.



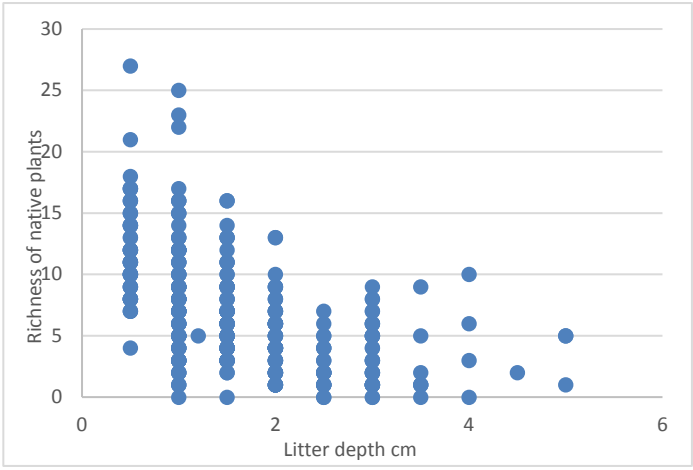
(a)


Richness of native plants
30
25
20
15
10
5
0
0%
20%
40%
60%
80%
100%
% cover of dead material

(b)


Richness of native plants
30
25
20
15
10
5
0
0
10
20
30
average standing height of grass cm

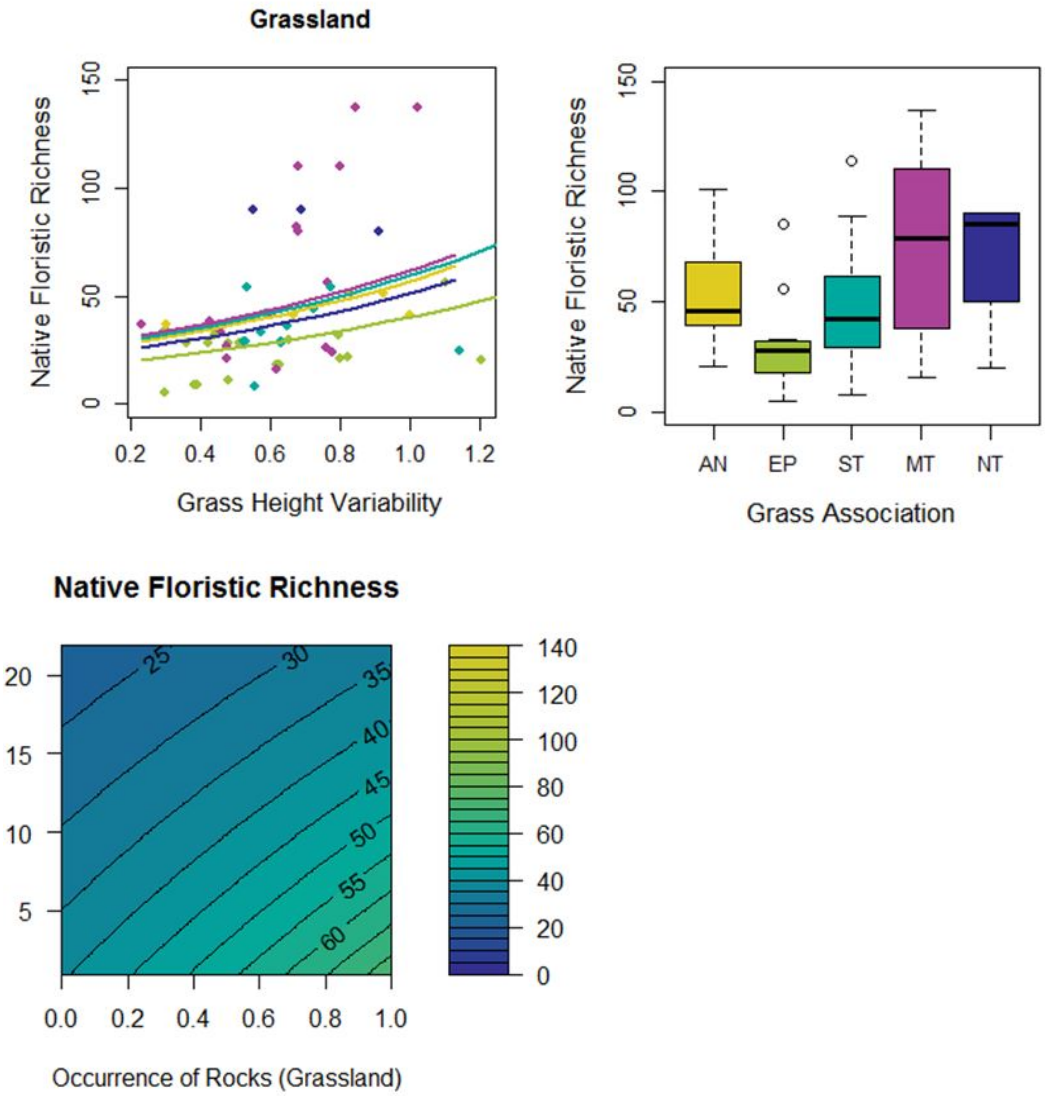
(c)


Richness of native plants
30
25
20
15
10
5
0
0
2
4
6
Litter depth cm

(d)

Recent CR research has shown that native plant species richness in grassland increases with grass height variability. Grass associations, as defined in Snape et al., (in review), also determined native plant species richness; with medium tussock and native tuft dominated grass associations containing the highest numbers of native plant species. Rocks were found to have a positive effect on native plant species richness in grasslands (Snape et al., in review) (Figure 15).

Figure 15. The effect of (a) grass height variability, (b) grass association and, (c) occurrence of rocks on native floristic richness. Figure sourced from Snape et al., (in review).



Over a long time period insufficient disturbance in grassland may lead to loss of native species. Recent research by Molonglo Implementation Team (PCS) has examined the impacts of long-term slashing regimes on native and exotic species composition and habitat structure for grassland fauna. Surveys post-slashing were conducted in October – November 2015. Slashing sites were along management trails where slashing had been undertaken annually between November – December

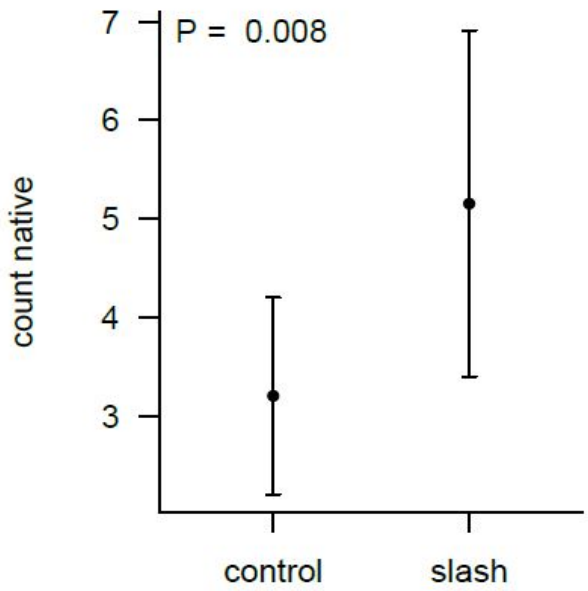
and only sites that had been slashed annually for at least 10 years were used in the experiment. These sites were compared to control areas where no slashing has been conducted in the past.

Preliminary results show native plant species richness and diversity is significantly greater in slashed plots compared to plots that were not slashed (Smith et al., in review) (Figure 16a, b). This includes significant higher native herb species richness and native grass species richness (

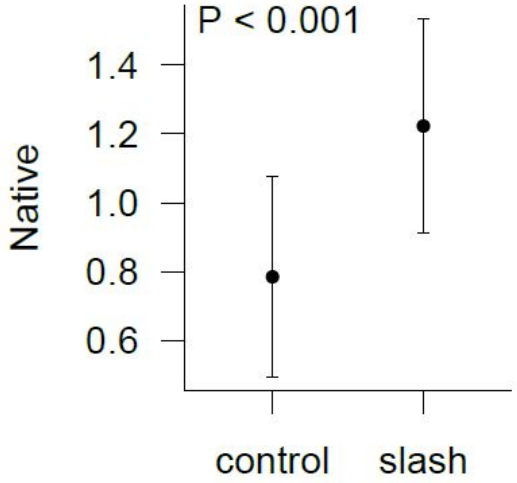
Figure 16c, d, e) as well as a non-significant trend for slashed plots to support a greater diversity of conservation significant species and higher indicator species richness. Effects of slashing on native plant species richness differed between grassland communities with a positive effect of slashing on native grass richness in communities dominated by *Austrostipa / Rytidosperma* (C3 grasses) but not in communities dominated by *Themeda* (C4 grasses) (Figure 16f).

Overall species richness (exotic and native) was also highest in slashed plots. Exotic annual grasses and leguminous herbs, common increaser species, and exotic C3 grass species richness were all significantly higher in response to slashing, in addition to the positive response of native species (Smith et al., in review). This suggests slashing may also benefit non-native species.

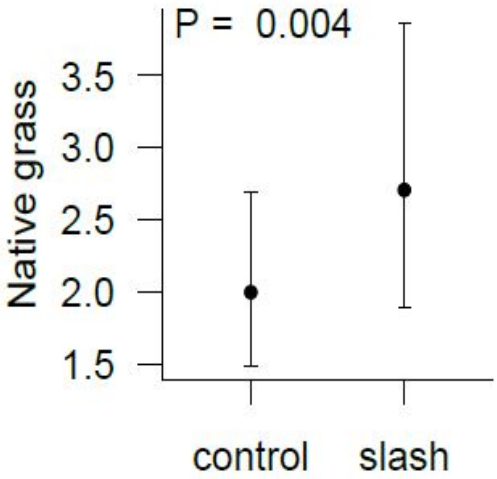
Figure 16. Native floristic response to slashing in grasslands: (a) mean overall native plant species richness (b) mean overall native species diversity, (c) mean native grass, (d) mean native herbs and, (e) mean native non-legume herbs in control and slashed plots. Effects of slashing on Aust = *Austrostipa* / *Rytidosperma* (C3 grasses) and Them = *Themeda* (C4 grasses) is shown in (f).



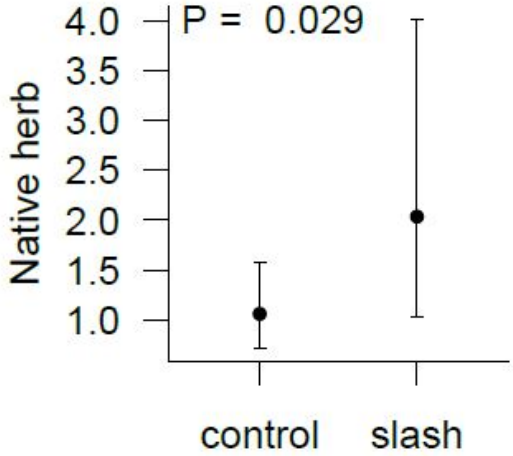
(a)


P < 0.001
Native
1.4
1.2
1.0
0.8
0.6
control
slash

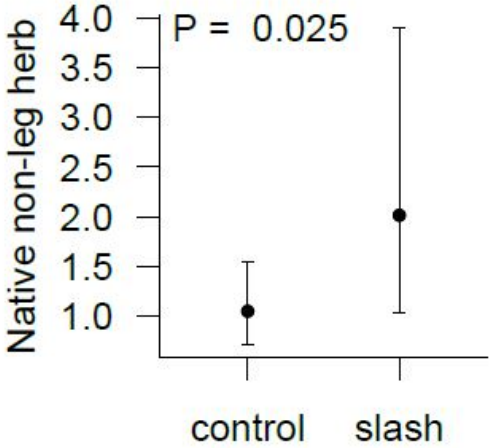
(b)


P = 0.004
Native grass
3.5
3.0
2.5
2.0
1.5
control
slash

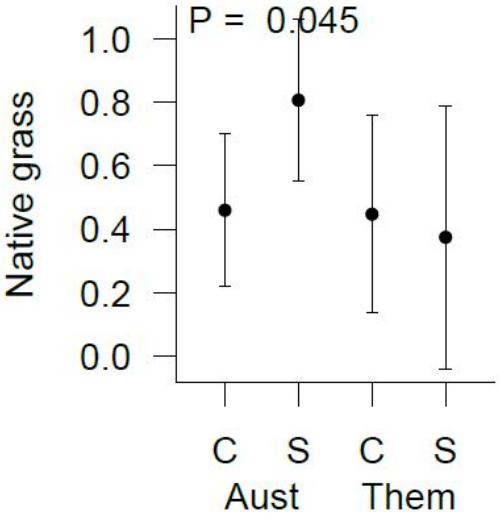
(c)


P = 0.029
Native herb
4.0
3.5
3.0
2.5
2.0
1.5
1.0
control
slash

(d)


P = 0.025
Native non-leg herb
4.0
3.5
3.0
2.5
2.0
1.5
1.0
control
slash

(e)


P = 0.045
Native grass
1.0
0.8
0.6
0.4
0.2
0.0
C
S
C
S
Aust
Them

(f)

The ACT Government Grassland Restoration Project is trialling autumn and spring burning as management tools for increasing native species dominance in lowland native grasslands. Sampling was conducted during spring. Early results from the research show that response of native plant species richness following burns conducted the previous autumn (approximately 6 months prior to sampling) are so far inconclusive, with small increased in native plant species richness captured at both burnt and control plots over the same period (Figure 17).

Results from spring burns (conducted 12 months prior to sampling) show a larger increase in native plant species richness at the treatment sites than control, particularly for Jerrabomberra West site (Figure 18). However different responses to fire between sites may be dependent on site-specific factors, rather than season. For example, at Jerrabomberra West, prior to burning the site had high amounts of thatch and biomass. Fire removed the dense thatch layer allowing native species present in soil (tubers or seed) to emerge (R. Milner and B. Howland *Pers comm*. 13th and 17th Feb 2017). Sites high in native plant species richness with low thatch may also show a positive response to fire, although the magnitude of response may be less (R. Milner and B. Howland *Pers comm*. 13th and 17th Feb 2017). At sites with more bare ground and lower grass biomass, native plant species richness response to fire may be much weaker or even negative.

Figure 17. Changes to native plant species richness at treatment vs. control plots following burns conducted the previous autumn.

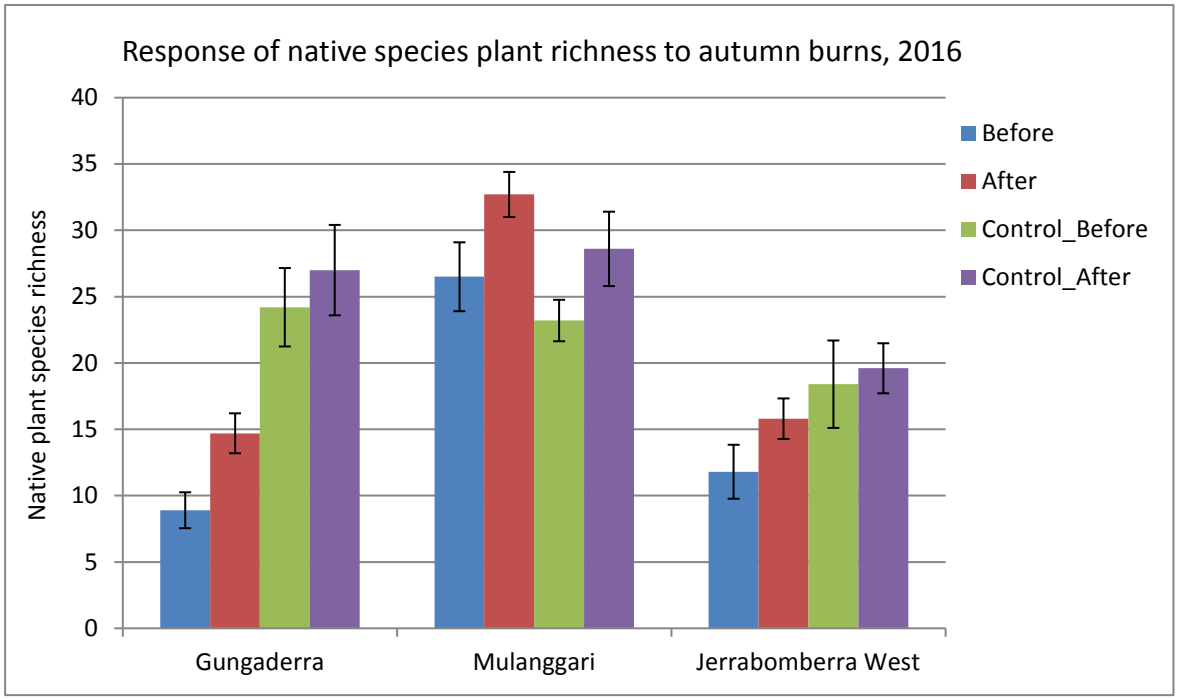
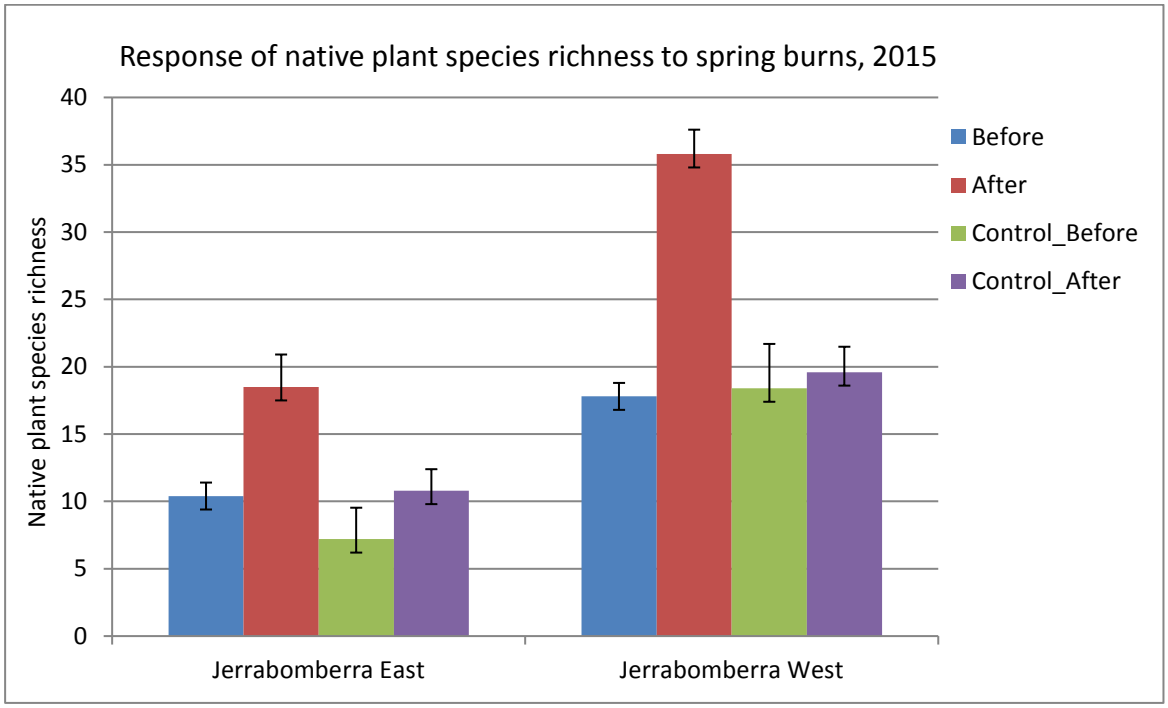


Figure 18. Changes to native plant species richness at treatment vs. control plots following burns conducted the previous spring.



Spring burns conducted at Jerrabomberra East also increased native plant species richness, but the magnitude of response may have been reduced for two reasons; first the site did not burn well during the trials, and secondly the initial condition of the site may have been lower (less native tubers and seed in the soil) (R. Milner and B. Howland Pers comm. 13th and 17th Feb 2017). It may be that sites that benefit most from burning are those that have been previously in high condition but have recently degraded through biomass accumulation (R. Milner and B. Howland Pers comm. 13th and 17th Feb 2017). These early results suggest that site history and burn intensity will be important in determining fire response, and will need to be considered when determining when and where to burn to increase native plant species richness.

C2.2 Ground cover

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Results from CR annual floristic surveys indicate cover of plant species fluctuates over time at all sites, but at some sites the proportion of native cover has declined. The mechanism behind this is unclear. Recent research has shown slashing increases native grass cover, litter cover and bare ground.

Metric Assessment: Cover and structure of functional groups measured annually at select long-term monitoring sites. CR annual floristic survey plots were chosen to represent high quality native grassland, with most of the original plots located in patches of NTG. In 2016 five new sites were added to monitor changes in lower quality plots and to capture any changes in condition in response to climatic variation and management actions.

Class: Core	**Category:** Non-statutory	
Primary Drivers context: Data sourced from years 2009-2016; Millennium drought 2001- 2009. , followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Key indicator of biodiversity and ecosystem health. Maintaining ground cover of native species is essential to maintaining grasslands that are resilient to external pressures.

Projects contributing to metric: CR annual grassland monitoring, ACT Government Grassland Restoration Project, Kama forb enhancement program, Offsets grassland monitoring.

Sampling periodicity: Annually at selected sites, additional sites as part of research projects.

Baseline: Baseline data for the CR annual floristic survey sites were collected in 2009. Five lower quality sites were established in 2016 to enable capture of increasing trend in data.

Reference condition: See Table 6 for reference condition ranges. Mean +/- 1 SD values from reference sites were used as a reference condition to capture variation between grassland communities.

Target condition: Reference condition.

Trigger point for management: No trigger point at this time.

Qualitative input: Factors including past grazing history, remnant native plant species (seed bank in soil) and environmental variables such as soil and slope may determine the ability of a site to be rehabilitated to reference condition.

Future research questions, management directions, knowledge gaps and recommendations: Data quality is somewhat deficient for this metric in that there is insufficient replication, with some sites only having one quadrat for sampling at that site. There is also some discussion around the issue of sampling scale, in that current sampling methods may be too coarse to be valuable in the long term. ACT Government Grassland Restoration Project is trialling measurement of cover at a finer scale, which will be reviewed and incorporated into long term monitoring if proven to improve data and efficiency. The impact of locusts may need to be considerable in plague years, but is currently not measured. There is a need to establish long term monitoring sites which were of poor or moderate condition to be able to track change and response to both climatic variations and management actions.

Data Analysis

Ground cover was annually sampled in 13 high condition grassland sites as part of the CR long-term floristic surveys. As with native plant species richness (see metric 2.1) a significant limitation is that the CR long-term monitoring sites represent high condition native grassland. Thus these sites capture cover values in 'good' condition grasslands and have been used to inform the broad reference condition ranges for cover of structural groups within grassland communities. The reference condition ranges are shown in Table 6. Over time it is the intent to develop preferred ranges of cover metrics for other indicator metrics to better inform site-specific management of biodiversity.

Confidence in data for this metric is only moderate due to the lack of representation of broader ecosystem condition. As long term monitoring sites are not representative of the full range of grassland condition over the broader landscape, our recommendation for this metric is to establish monitoring sites which are representative of poor and moderate condition thereby providing data that are better to able to track change and response to both climatic variations and management actions. The first moderate condition sites were monitored in 2016.

Perennial exotic and perennial native grass cover were key determinates of condition at sites, and were weighted in assessments. Most sites were within the reference range over all years for cryptograms, bare earth and rocks. Cover of bare earth was higher than reference condition at St Marks in 2013 and at both Jerrabomberra East and Googong in 2009. Similarly, cover of rock was higher than reference conditions at Googong and Kama in 2009 (Figure 19). Increases in cover of bare earth and cover of rock at sites in 2009 were likely driven by a combination of a drier than average year (drought) and high grazing pressure by kangaroos.

Litter cover exceeded reference conditions at Googong in 2009 and 2013, Jerrabomberra East in 2009 (including within the kangaroo exclusion area during 2009 and 2015), Kama in 2015, North Mitchell in 2013 plus 2016 and at the Jerrabomberra West 1 site in 2012, 2014 and 2015, until it was burnt in autumn 2016 (Figure 19).

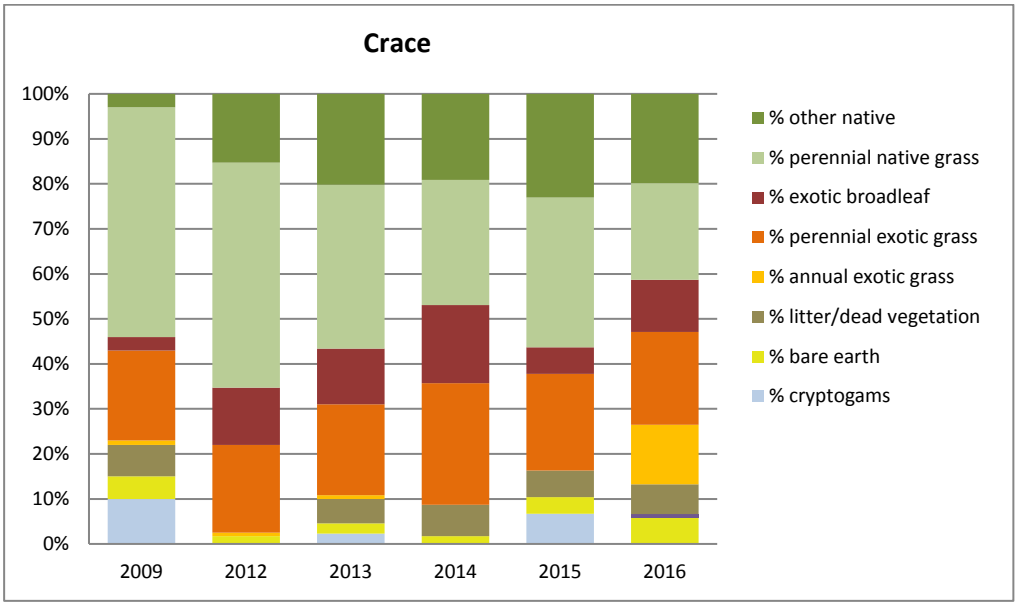
Annual exotic cover exceeded the reference condition at Jerrabomberra West 2 and Gungaderra 2 in 2015 and at Dunlop in all years. Reference conditions for annual exotic cover was greatly exceeded at the North Mitchell site in 2014 and 2015 (>60% cover). Perennial exotic cover exceeded the reference condition range at Crace in 2014 (but was generally high over all years at this site) and was greatly exceeded at the North Mitchell site in 2012, 2013 and 2016 (>40% cover). Exotic broadleaf cover exceeded reference condition at Gungaderra 1 in 2015 (but was also high at Gungaderra 2 in 2014), Jerrabomberra West in 2014 and 2016 (>40%) and greatly exceeded reference condition at Jerrabomberra East in 2014 (>50%) and remained high during 2015 and 2016 (Figure 19).

Perennial native grass cover was higher than reference condition and dominated the site of St Marks most years, reaching >80% of cover in 2012. Perennial native grass cover also exceeded reference condition at Kama in 2012-2014 (>90%), Jerrabomberra East and Jerrabomberra West in 2012 and at Mulanggari from 2012-2015. Cover of other natives was above reference conditions at Googong since 2012 but below reference condition at Kama, North Mitchell and Jerrabomberra West 2 (all years). Overall most sites exhibited stable cover, with the exception of North Mitchell and Jerrabomberra West 2 (unburnt) which have both shown a decline in native cover since 2013. Kama, while high in perennial native grass cover, is low in diversity of other native species, and had an increase in litter cover in 2015 (Figure 19).

Table 6. Mean ground cover of grassland functional and structural components across 13 good condition grassland sites and the upper and lower limits for 1 SD from the mean.

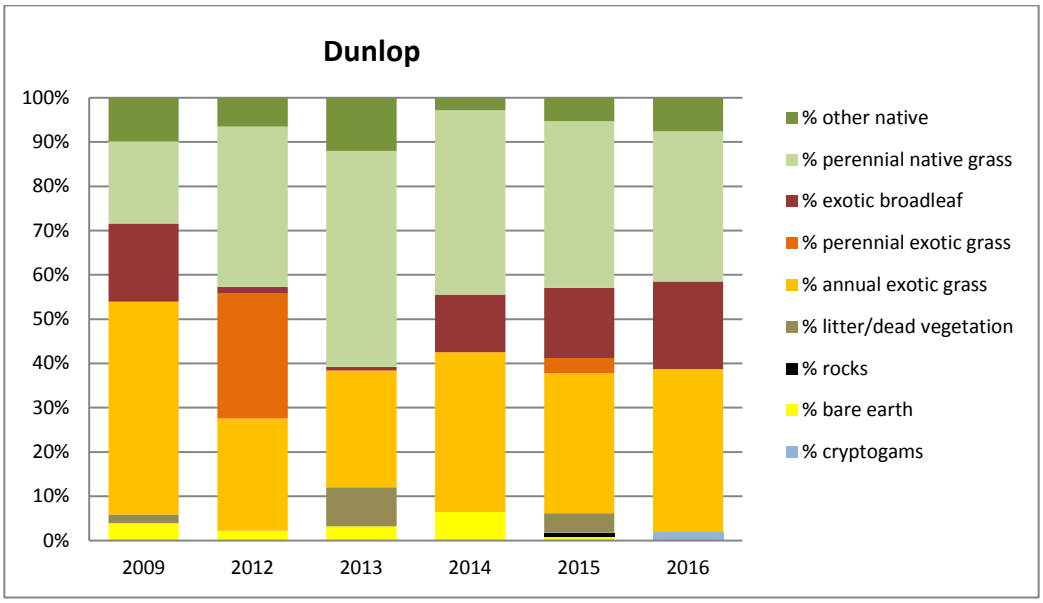
	Mean	Lower Limit of range	Upper Limit of range
Cryptogam Cover	0.8	0.0	3.2
Bare Earth Cover	2.5	0.0	5.7
Rock Cover	0.7	0.0	2.8
Litter Cover	6.5	0.0	15.4
Annual Exotic Grass Cover	13.6	0.0	28.5
Perennial Exotic Grass Cover	10.7	0.0	29.9
Exotic Broadleaf Cover	16.3	0.0	27.8
Perennial Native Grass Cover	39.7	17.8	61.6
Other Native Species Cover	9.1	0.0	18.5

Figure 19 (a-m). Changes in ground cover of grassland structural and functional components over time CR long-term vegetation monitoring plots. Five sites were not sampled in 2016. Results for Gungaderra sites are limited to three years of data (2013-2015). Denotes burning of site occurred between sampling periods

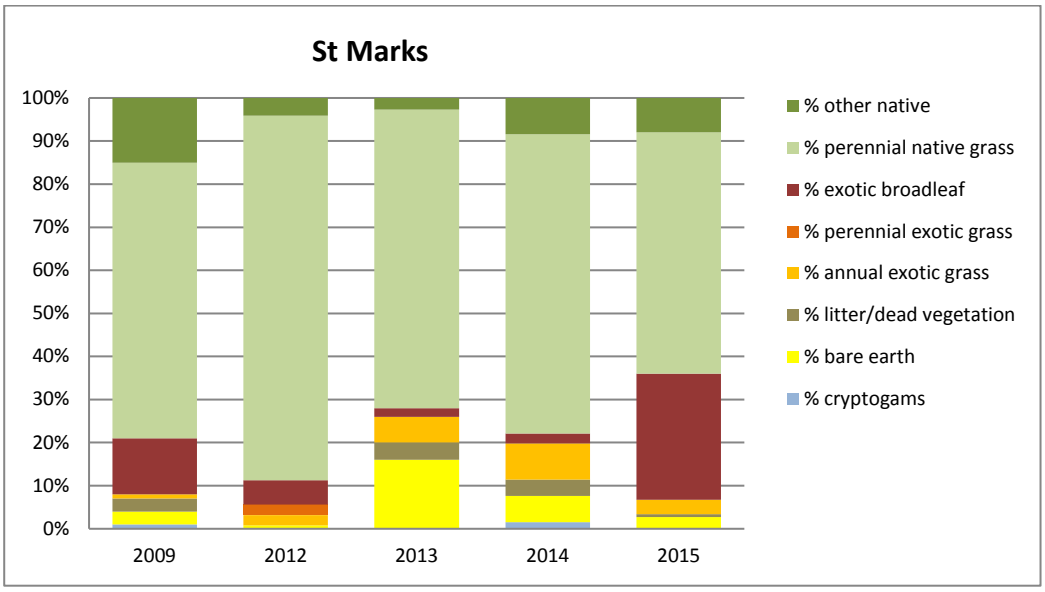


(a)

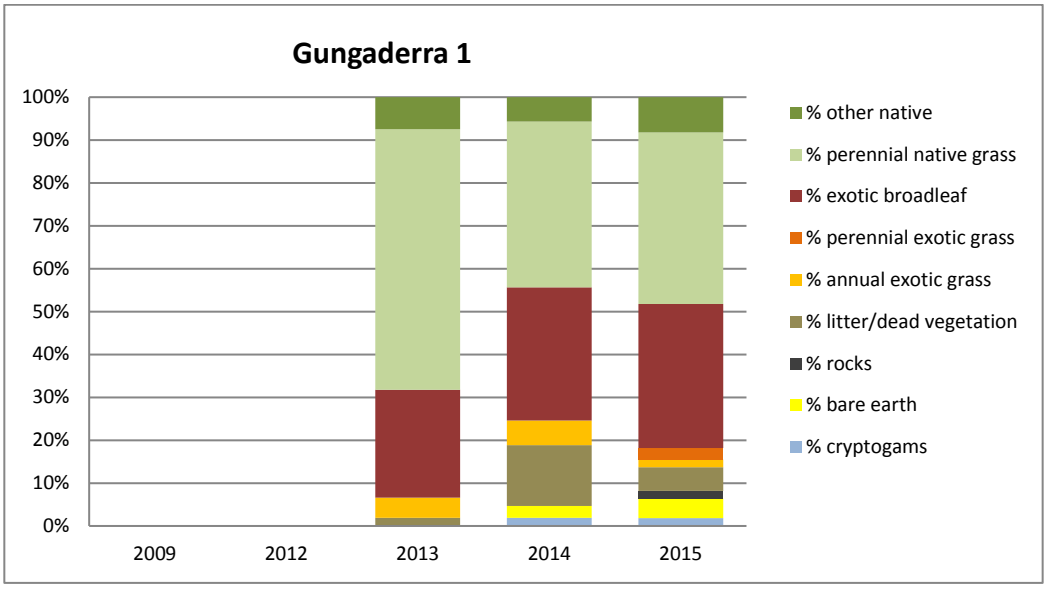
(b)


Dunlop
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth
% cryptogams

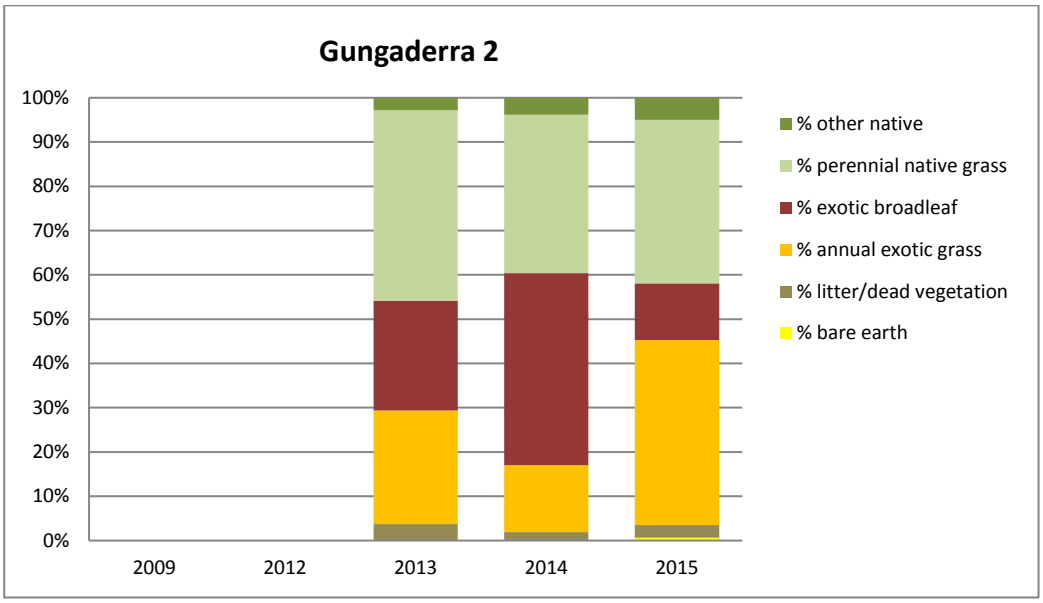
(c)


St Marks
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% bare earth
% cryptogams

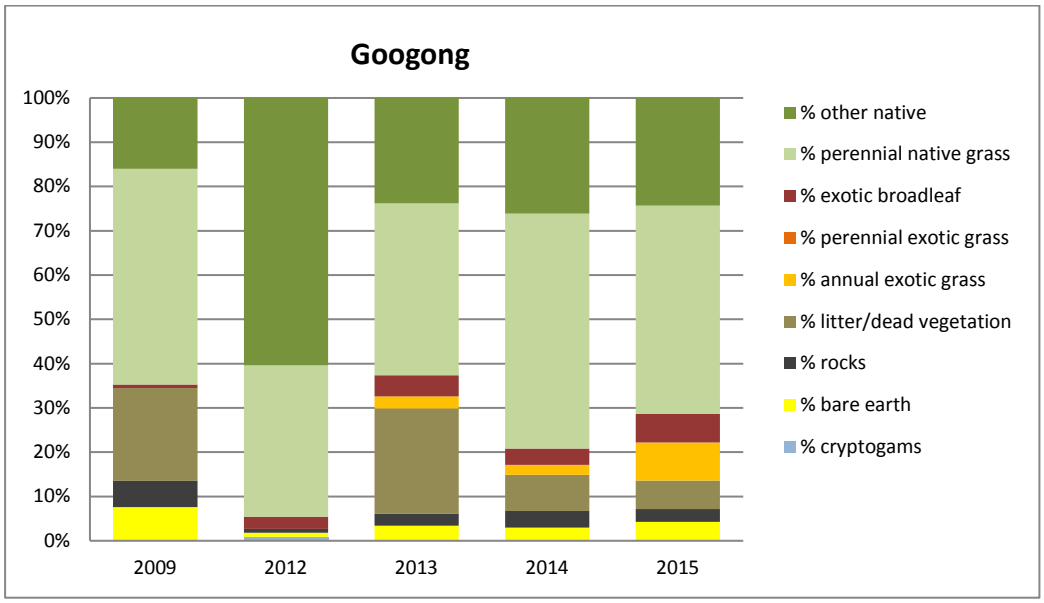
(d)


Gungaderra 1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth
% cryptogams

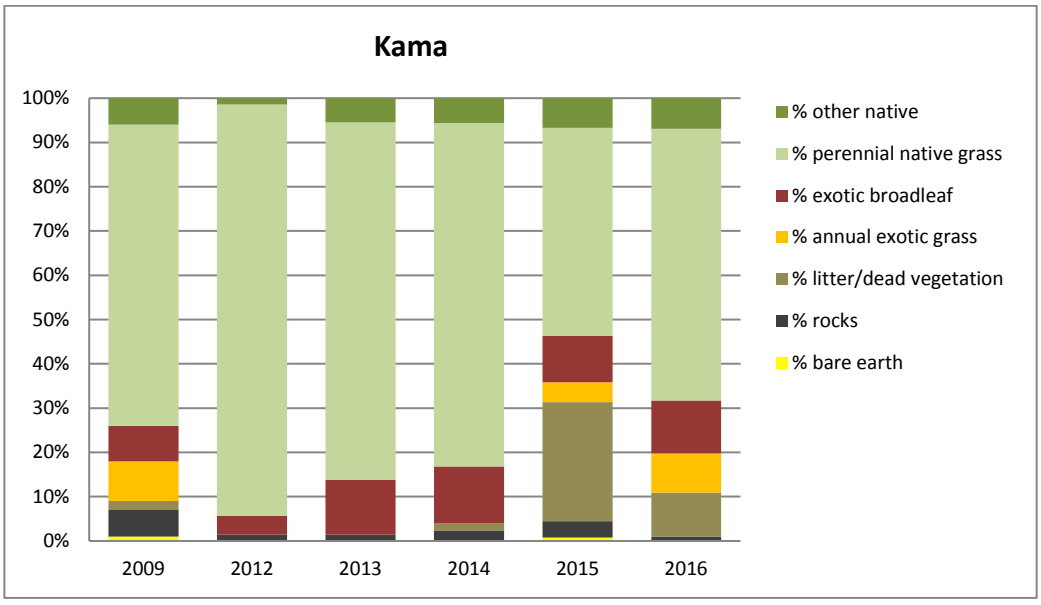
(e)


Gungaderra 2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
% other native
% perennial native grass
% exotic broadleaf
% annual exotic grass
% litter/dead vegetation
% bare earth

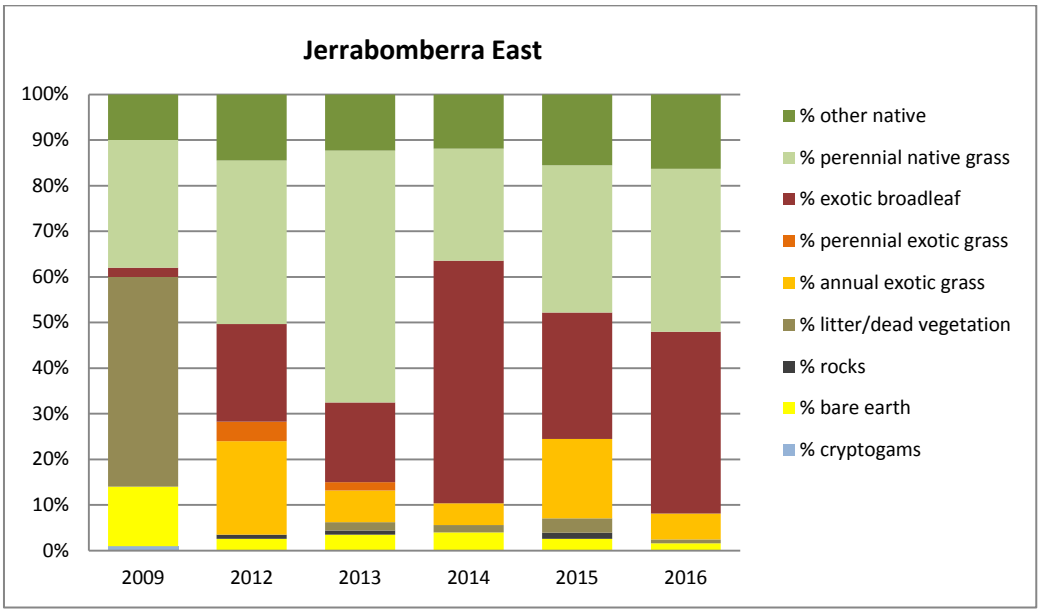
(f)


Googong
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth
% cryptogams

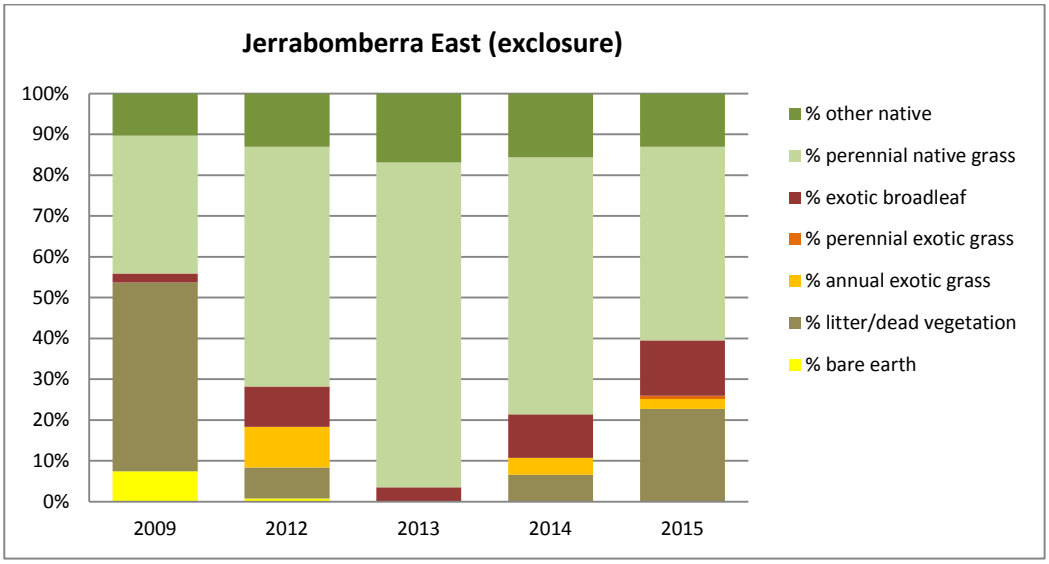
(g)


Kama
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth

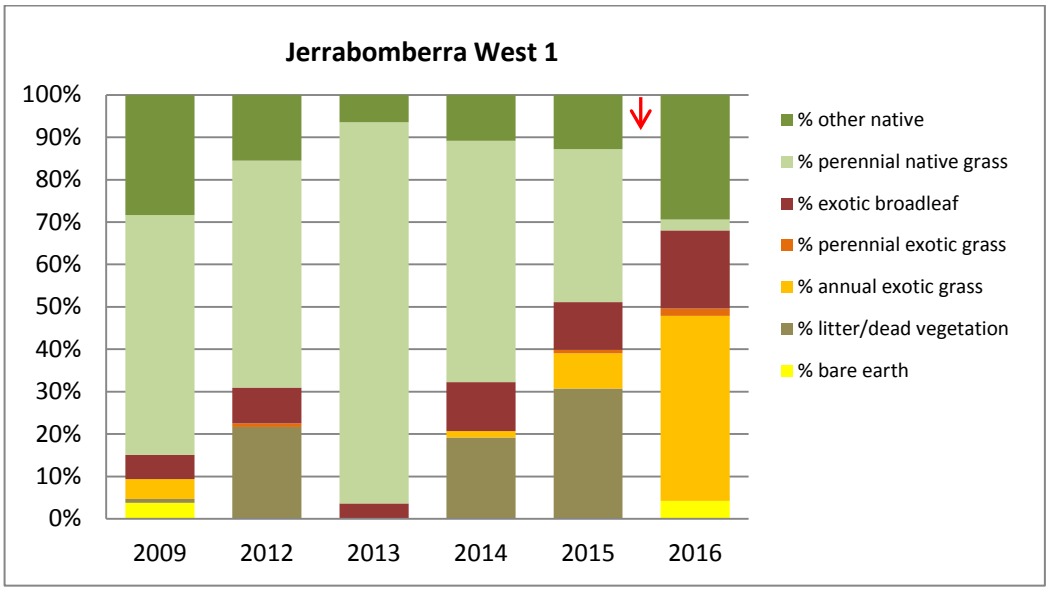
(h)


Jerrabomberra East
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth
% cryptogams

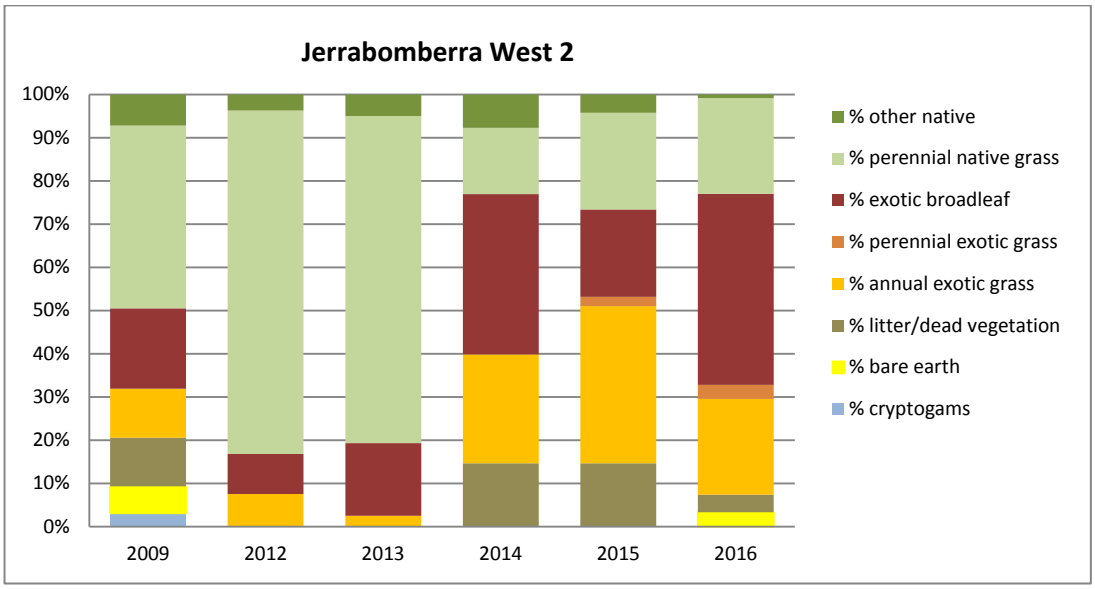
(i)


Jerrabomberra East (exclosure)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% bare earth

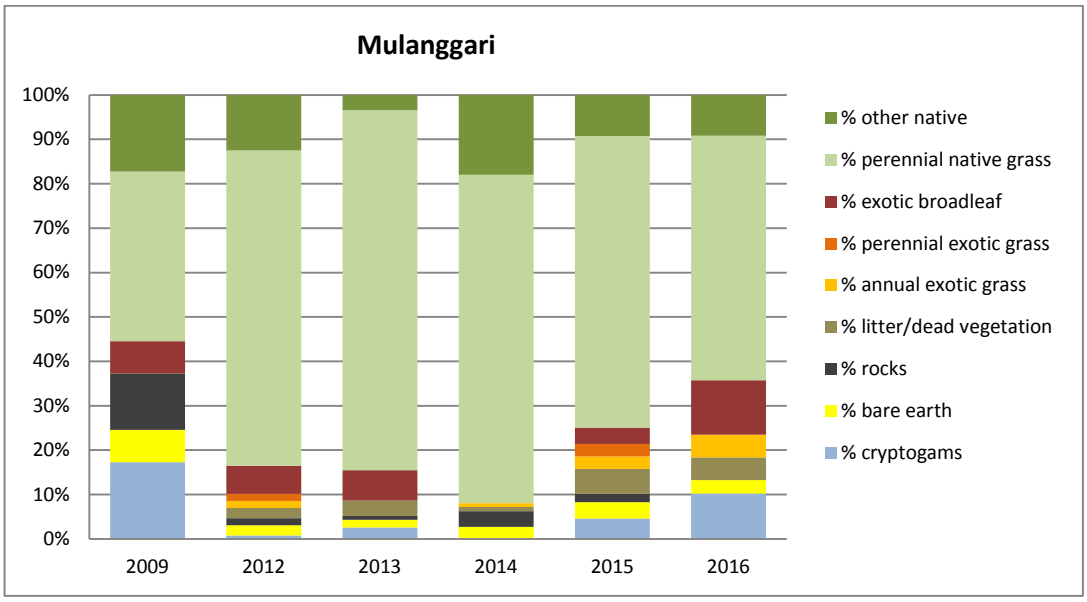
(j)


Jerrabomberra West 1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% bare earth

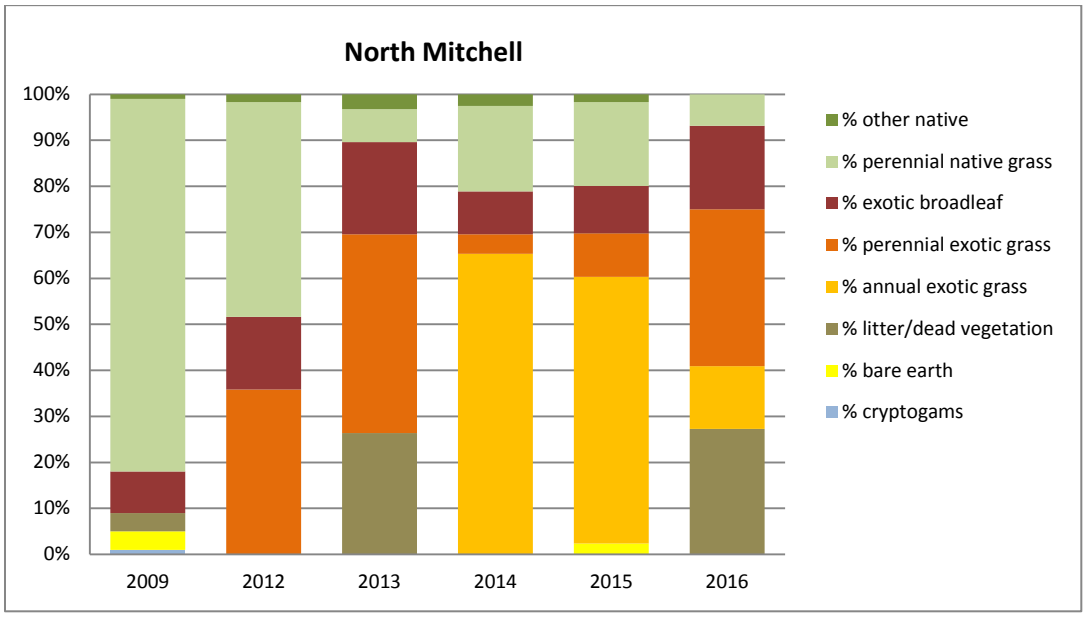
(k)


Jerrabomberra West 2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% bare earth
% cryptogams

(l)


Mulanggari
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% rocks
% bare earth
% cryptogams

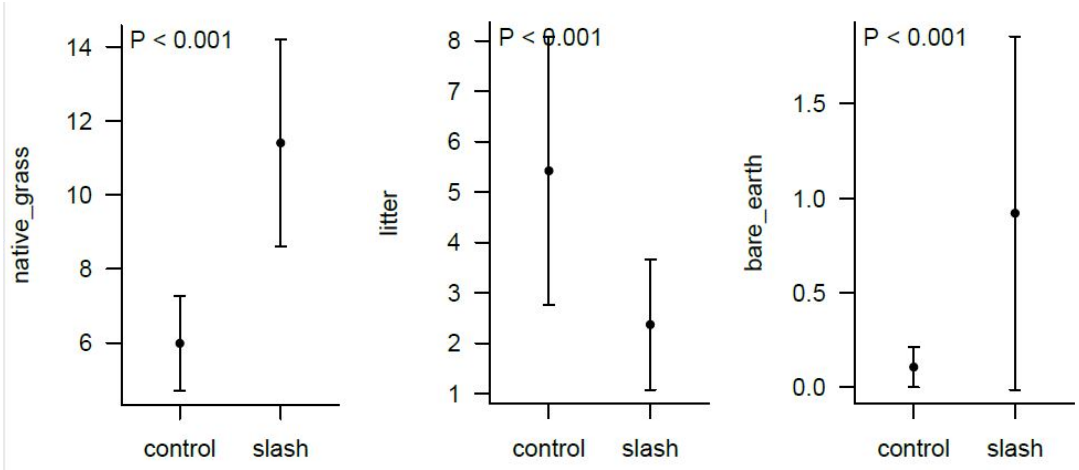
(m)


North Mitchell
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2009
2012
2013
2014
2015
2016
% other native
% perennial native grass
% exotic broadleaf
% perennial exotic grass
% annual exotic grass
% litter/dead vegetation
% bare earth
% cryptogams

Recent research by the Molonglo Implementation Team (PCS) examined the impacts of long-term slashing regimes on ground cover. Surveys post-slashing were conducted in October – November 2015. Slashing sites were along management trails where slashing had been undertaken annually between November – December and only sites that had been slashed annually for at least 10 years were used in the experiment. These sites were compared to controls where no slashing was conducted.

The research found that in slashed plots native grass cover and bare ground increased, while litter and exotic perennial grass cover decreased (Figure 20). The effect of slashing was independent of dominant grass type in 14 of 16 functional groups that responded positively slashing, indicating that slashing has a relatively consistent effect across grassland communities.

Figure 20. The effect of slashing on ground cover of native grass, litter and bare earth.



C2.3: Indicator 2 species richness

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Indicator 2 species are species that are uncommon in the region and where they occur, generally indicates grassland sites of high to very high value. Results from CR annual floristic surveys showed Indicator 2 species richness is increasing at all but two sites over the sampling period, with a long term decline evident at Jerrabomberra West. Statistical analysis of long term floristic data showed an increasing trend in indicator two species richness with increasing time since addition to reserve estate. These results are biased as only high quality plots were sampled and analysed this CEMP plan. It is recommended this bias be addressed

Metric Assessment: The number of Indicator 2 species within standardised areas at select long-term monitoring sites. CR annual floristic survey plots were chosen to represent high condition native grassland, with most of the original plots located in patches of NTG. In 2016 five new sites were added to monitor changes in lower condition plots and to capture any increases in condition in response to climatic variation and management actions.

Class: Minor	**Category:** Non-statutory	
Primary Drivers context: Data sourced from years 2009-2016; Millennium drought 2001- 2009, followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C3. Threatened Flora	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Indicator species can be used as a relative measure to determine the quality of native flora patches.

Projects contributing to metric: CR annual grassland monitoring, ACT Government Grassland Restoration Project, Kama forb enhancement program, Offsets grassland monitoring

Sampling periodicity: Annually at selected sites, additional sites as part of research projects.

Baseline: Baseline data for the CR annual floristic survey sites were collected in 2009, although 5 new sites were established in 2016 that represented more degraded sites.

Reference condition: Indicator 2 species richness of 8 or above for good condition, between 3-7 for good with some concerns, 0-2 for moderate condition (combined with average-high native plant species richness) and 0 for poor condition.

Target condition: Reference condition.

Trigger point for management: No trigger point at this time. Factors including past grazing history, remnant native species (seed bank in soil) and environmental variables such as soil and slope may determine the ability of a site to be rehabilitated.

Qualitative input: CR annual floristic survey plots were chosen to represent high quality native grassland, with most of the original plots located in patches of NTG. In 2016 five new sites were added to monitor changes in lower quality plots and to capture any increases in quality in response to climatic variation and management.

Future research questions, management directions, knowledge gaps and recommendations: Little research has been conducted into management options for improving the occurrence of indicator 2 species. Outcomes from the NRM Grasslands Restoration Project examining the impact of fire, grazing, rock addition and slashing can be incorporated into this metric. Grazing trials with domestic livestock are expected to commence 2017 at sites within Crace NR and Jerrabomberra Wetlands. The results of these trials will be included in the next assessment.

Data Analysis

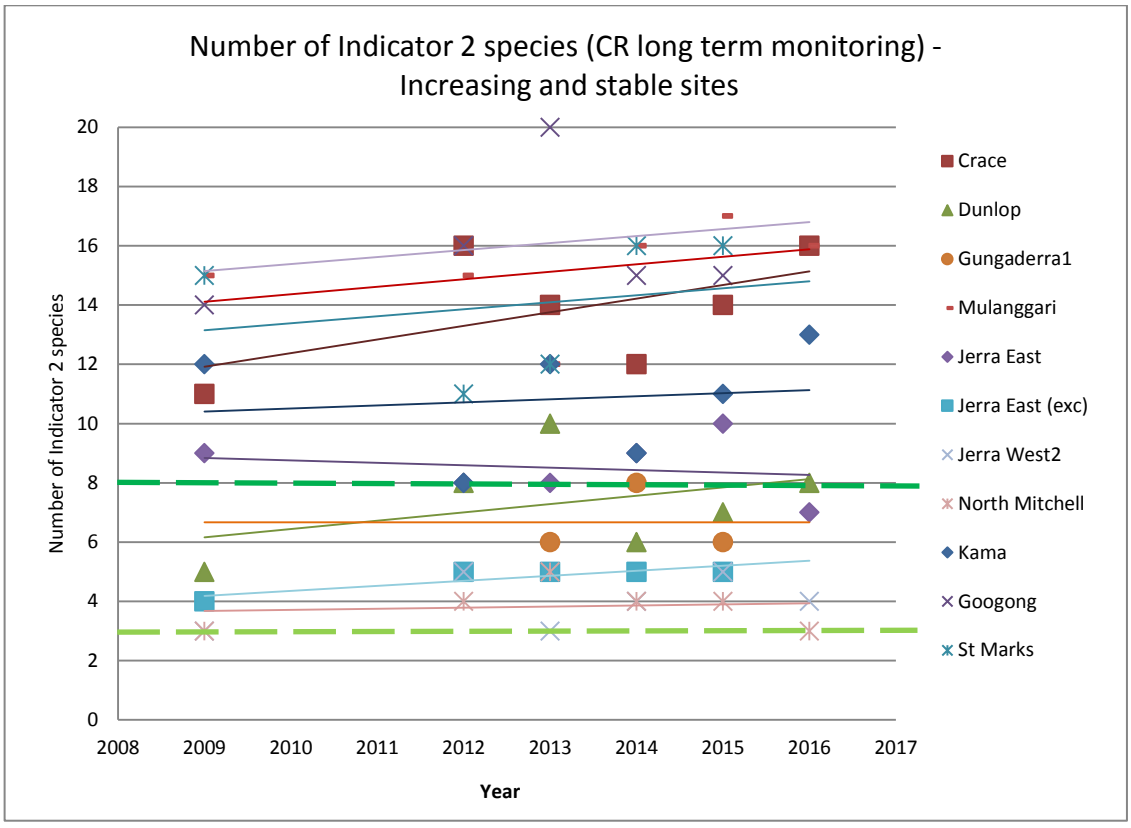
CR long-term floristic surveys have monitored the number of indicator 2 species at 13 high quality grassland sites since 2008. As with the data for native plant species richness (metric C2.1) and cover (metric C2.2) a significant limitation of the data set is that only high quality native grassland sites were monitored, and therefore capture indicator 2 richness in 'good' quality grasslands only. As such data from these sites have been used to create the reference condition for the indicator 2 species metric, but data confidence is only 'moderate' due to the lack of representation of condition in the ecosystem more broadly. Consequently a recommendation for this metric is to establish monitoring sites which are representative of poor and moderate quality. This will enable better tracking of change and response to both climatic variations and management actions. The first moderate quality sites were monitored in 2016.

Results from CR annual floristic surveys indicate Indicator 2 species richness is increasing at all but two sites over the sampling period, with a long term decline evident at Jerrabomberra West (Figure 22).

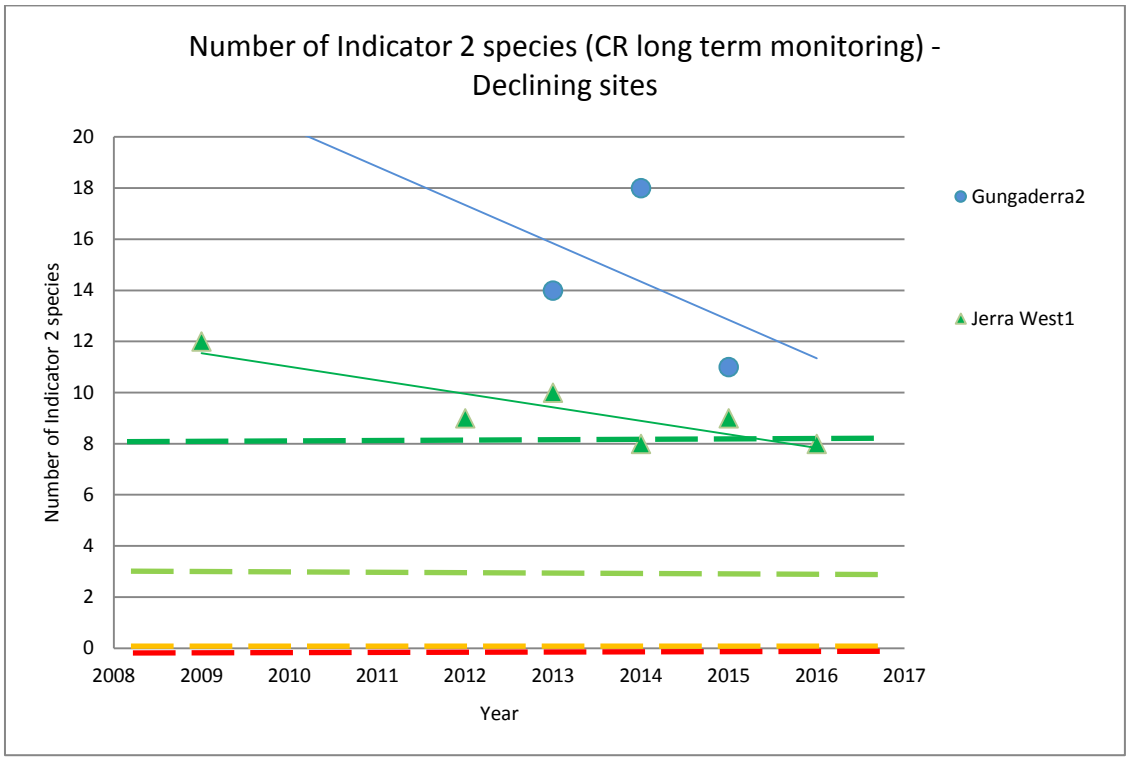
Indicator 2 species richness was analysed for trends in response to management and environmental conditions using GAMM in R version 3.3.2 (N. Wilson Pers comm. 27th Feb 2017), with plot nested within reserve as a random term in each model. Multiple candidate models were run and compared using Akaike's Information Criterion (AIC), from which the model with the lowest AIC was selected. The only variable found to be significant at the 90% level was 'Years in Reserve'; Indicator 2 species richness increased with increasing time as reserve estate (Figure 21). Trends also indicated that there was some interaction with slope: steeper sites that have been in reserve for longer are likely to have grasslands with higher Indicator 2 species richness. Structured surveys designed to test if slope and time in reserve influence grassland condition are recommended.

Figure 21. Predicted Indicator 2 Species Richness in response to the logarithm of Years in Reserve.

Figure 22. Increasing (a) and decreasing (b) trend in indicator 2 species richness at CR long term survey sites. Results for Gungaderra sites are limited to 3 years of data. Dashed lines show the values for reference condition (dark green) and for condition rated as 'good with some concerns' (light green).



(a)



(b)

Recent research by PCS found a non-significant trend for slashed plots supporting higher indicator 2 species richness (Figure 23; Smith et al., in review) while preliminary results from the ACT Government Grassland Restoration Project showed a correlative relationship between indicator 2 species richness and golf ball score (as a measure of biomass) with indicator 2 species richness higher at lower biomass (Figure 24a). Indicator 2 species richness appears to be lower at higher levels of dead material and greater litter depths (Figure 24b, d), while optimal grass height for indicator 2 species richness was found to be 5 - 10 cm (Figure 24c). More research is needed to explore the strength of these relationships under different management and climatic conditions.

Figure 23. The effect of slashing on number of indicator 2 species.

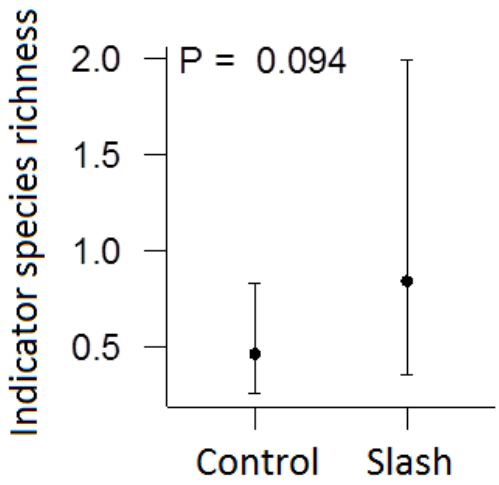
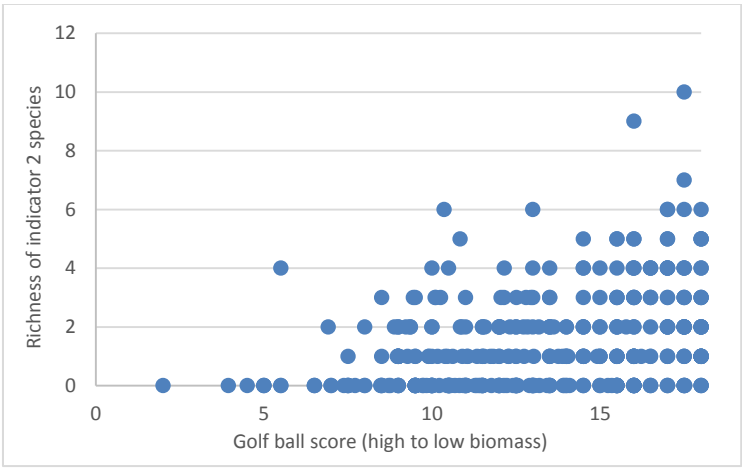
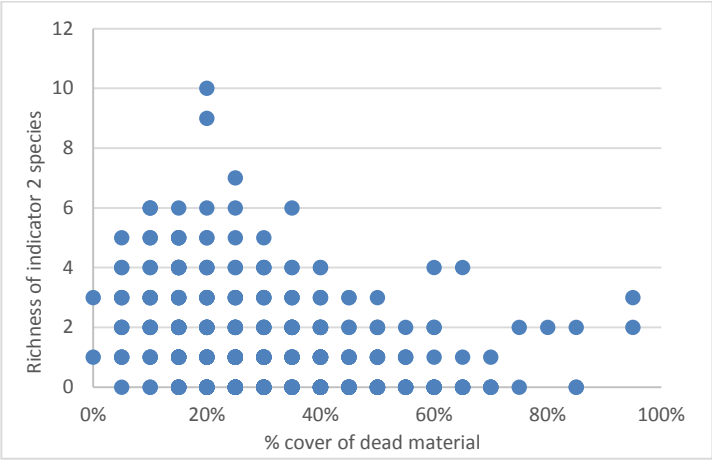


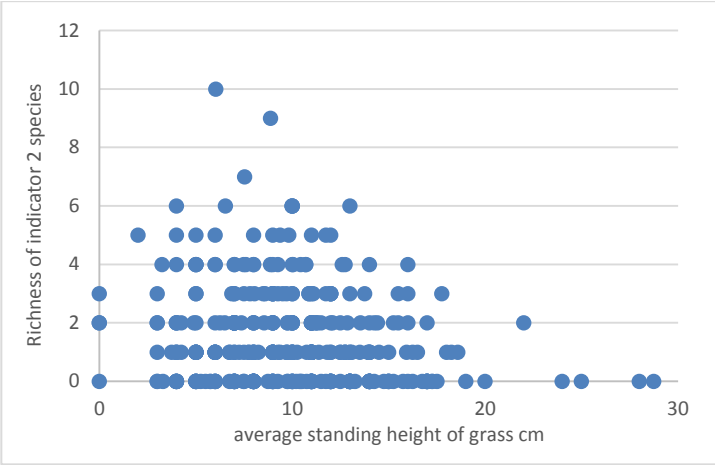
Figure 24. The relationship between biomass (a), percent cover of dead material (b), average grass height (c) and litter depth (d) on indicator 2 species richness.



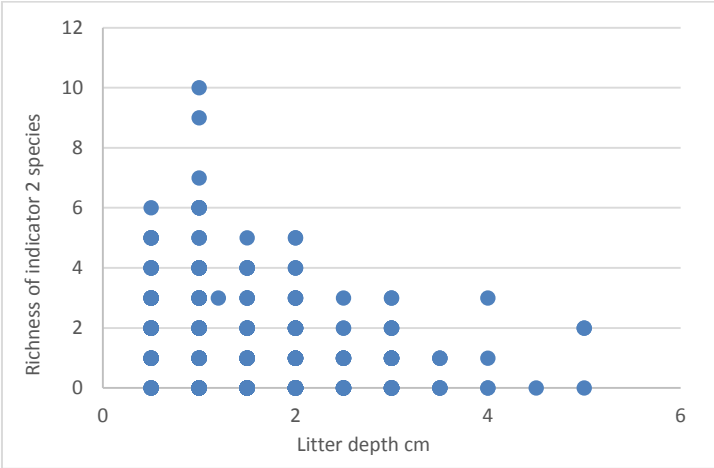
(a)


12
10
8
6
4
2
0
Richness of indicator 2 species
0%
20%
40%
60%
80%
100%
% cover of dead material

(b)


12
10
8
6
4
2
0
Richness of indicator 2 species
0
10
20
30
average standing height of grass cm

(c)


12
10
8
6
4
2
0
Richness of indicator 2 species
0
2
4
6
Litter depth cm

(d)

C3: THREATENED FLORA

C3.1. Button Wrinklewort (*Rutidosis leptorrhynchoides*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Distribution of known Button Wrinklewort populations is increasing. Of the five identified populations in grasslands, three are stable or increasing, one is no longer monitored by CR (Campbell Park) and one population is experiencing long-term decline (St Marks). Translocations into Jerrabomberra East Nature Reserve have been successful in terms of individual survival, but the viability of translocated populations in the long term is yet to be determined. This species is found in both grassland and woodland; this metric reports on condition in lowland native grasslands and therefore uses sites in grassland only.

Metric Assessment: Monitors broad trends in abundance of Button Wrinklewort at the five grassland populations**.** Current monitoring uses broad categories with large numbers recorded at some locations (>1000 plants) and only a handful of plants recorded at other locations (<5). Such large differences in categories making fine scale assessment of changes in abundance, particularly for larger populations, very difficult to assess.

Class: Mandate	**Category:** Statutory – Threatened species	
Primary Drivers context: Data sourced from years 1998-2016; Millennium drought 2001- 2009 followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C3. Native Flora, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Button Wrinklewort is listed as endangered in both the ACT (*Nature Conservation Act 2014*) and under Commonwealth legislation (*EPBC Act 1999*).

Projects contributing to metric: CR Button Wrinklewort territory wide monitoring program and translocation projects (Jerrabomberra East and West NR, Woods Lane, Molonglo NR)

Sampling periodicity: Annual monitoring at selected sites, not all sites monitored all years.

Baseline: For this metric the current known distribution in 2016 will form the baseline for future assessments. Baseline for abundance is based on the first sampling at each site.

Reference condition: Original extent unknown. The EPBC status of the Button Wrinkewort in the ACT is Endangered (Action Plan No. 8).

Target condition: 200 plants per effective population (combined sites where pollination between sites can be achieved) (Action Plan No. 8). Maintain known population sizes and distribution; for those below effective population size target is to increase to 200 plants.

Trigger point for management: Halving of populations for two consecutive monitoring periods or falling below target condition.

Qualitative input: Button Wrinklewort populations are generally stable across region.

Future research questions, management directions, knowledge gaps and recommendations: There is a need to establish a more robust and quantifiable survey method to monitor abundance of populations so that declines in larger populations can be identified. The introduction of new plants into the St Marks site to enhance genetic diversity should be explored as an option to enhance the viability of this population. Research into what factors determine the survival and long term success of translocated populations is needed. Little is known about this specie's response to fire or other management actions; research is needed.

Data Analysis

There are five viable populations of Button Wrinklewort identified within grasslands in the ACT. A viable population consists of groups of plants that are within travelling range of individual pollinators (i.e. no greater than approximately 5 km apart) (Figure 25; Table 7). One population (Campbell Park) is on defence lands and no longer counted by CR. All other populations showed fluctuations in abundance over time, whereas Tennent St and Woods Lane populations have shown increasing trends, numbers have steadily declined within the St Marks population. There may be a need to introduce new plants into this population to enhance genetic diversity. At Crace the population appears to be stable but increasing in distribution within the reserve (G. Baines pers. comm. 6th March 2017).

Table 7. Number of Button Wrinklewort plants (by category) over time at grassland sites.

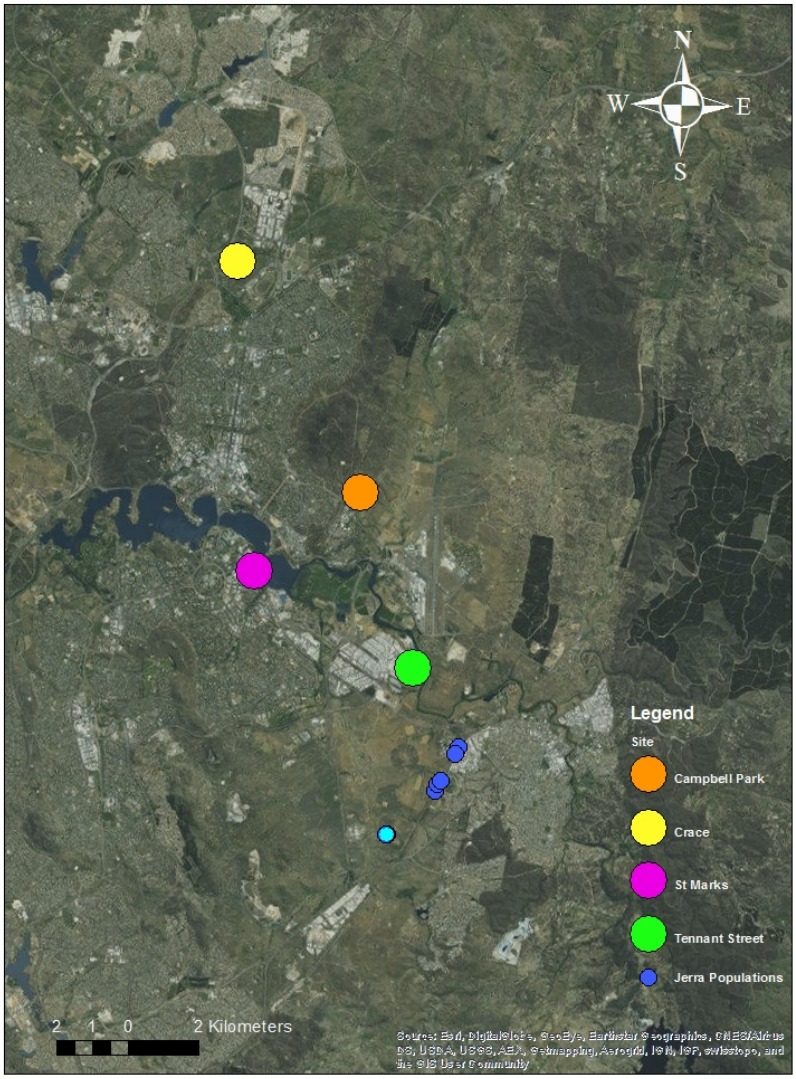
Year	Crace	Campbell Park	Tennent St	St Marks	Woods Lane populations (n=5)
1998	>1000	100-200			
1999				100-200	
2000	>1000	200-1000	25-50		
2002				50-100	
2003				100-200	
2004			100-200		
2006			200-1000		
2007	>1000	200-1000		50-100	
2012		50-100	100-200	25-50	100-200
2015			200-1000	25-50	200-1000
2016	200-1000		200-1000	25-50	200-1000

The population density of this species affects seed production highlighting the need to maintain larger, standing populations for long-term viability (Morgan, 1995). Recruitment into populations may be limited by deep shading and therefore management may be needed to control competing species or biomass (Morgan, 1997). Grazing is not currently recommended as a routine management method but occasional slashing in late summer may be an appropriate method to control biomass.

ACT monitoring indicates that the maintenance of reproductive plants should be given priority over increasing germination and seedling establishment. Further research is needed into the role of fire (including preferred season of burning) in maintaining and increasing populations (Ross and Macris, 2012). Current recommendation is that burning should not be used as a broad-scale management tool for Button Wrinklewort in the ACT until it has been established by experimentation that the benefits (seedling establishment) are likely to outweigh the costs (mortality of adult plants). Small scale patch burning may be appropriate at some sites and a small burning trial was under taken at populations on the eastern side of Woods Lane in winter 2015. The burns were quite cool and slow moving, so that green leaves were largely undamaged. The burns covered 10-60% of the population with a number of individuals remaining unburnt at each site. Ten individuals were tagged along with a similar number of unburnt plants to track post burn survivorship, with all but one of the plants alive after 12 months. Changes in reproductive output post fire were not investigated.

Translocation trials were also carried out at Jerrabomberra East reserve during 2010 and 2011 to trial seed spreading and tubestock planting of the species. The trial found tubestock survival rates were much higher than plants established by seed across the two years of planting (tubestock survival 38.4%, seedling survival 4.1%) and the number of plants that flowered in 2012 was also much higher in tubestock versus seeds (128 tubestock plants flowered compared to only three flowering plants from seed spreading). Further translocation of the species is currently being carried out to four recipient sites in Molonglo River Reserve. An initial translocation of 1600 propagated plants followed by two enhancement plantings of 500 individuals will be carried out over three years (2017-2019) testing establishment design and propagation methods for the species.

Figure 25. Map showing effective populations of Button Wrinklewort in ACT grasslands, with translocated populations in Jerrabomberra East NR highlighted in light blue. Translocation sites for the Molonglo not shown.



C3.2 Ginninderra Peppercress (*Lepidium ginninderrense*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: There is a need to establish a robust and quantifiable survey method to monitor abundance within Ginninderra Peppercress populations. Little is known about what drives large fluctuations in numbers. Translocation was unsuccessful and plants did not establish and further research into the ecology of the species is required.

Metric Assessment: As there is only one CR monitored site on North Mitchell (Belconnen Navel Transmission station population is not currently monitored by CR), This metric measures persistence at the site (abundance), any finding of new locations and translocation success.

Class: Mandate	**Category:** Statutory – Threatened species	
Primary drivers context: Millennium drought 2001- 2009, followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016.	**Associated indicators:** C1. NTG C3. Native Flora, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Ginninderra Peppercress is listed as endangered in the ACT (*Nature Conservation Act 2014*) and vulnerable nationally (*EPBC Act 1999*). It is endemic to the ACT and only known to exist naturally in two locations, one of which is monitored by the ACT Government. The main threat to the survival is likely to be deliberate or unintended actions associated with visitor and/or land management activities in the local area.

Projects contributing to metric: Ginninderra Peppercress annual monitoring (CR).

Sampling periodicity: Monitored annually at one site (Action Plan No. 25).

Baseline: Status in 2016 – two known sites, no successful translocations.

Reference condition: Original extent unknown. The EPBC status of the Ginninderra Peppercress in the ACT is Endangered.

Target condition: To preserve ACT populations and to maintain the habitat so that natural ecological processes will continue to operate (Action Plan No. 25).

Trigger point for management: No trigger point at this time; species ecology not well known.

Qualitative input: There is large natural variability in the population; counts may be strongly driven by climate and not reflective of changes in status. Little is known on the ecology of the species.

Future research questions, management directions, knowledge gaps and recommendations: Research into ecology of the species is needed. Previous observations suggest that the species grows well in locations where competing plant growth is short and open and there is little competition for space and light. Inappropriate management leading to loss of such habitat may also be a threat to the species, and it is important to determine management practices that are most conducive to the maintenance of the population. Existing plants of *L. ginninderrense* support high seed set, allowing opportunities for translocation and ex-situ conservation. Initial translocation efforts failed, however using knowledge gained from these trials, further efforts at translocation may be conducted. Improved knowledge of the life cycle of the species is needed to inform best practice for management of populations.

MONITORING OF GRASSLAND FAUNA

C4. NATIVE FAUNA GENERAL

C5. THREATENED FAUNA

Tympanocryptis pinguicolla at 'Cookanalla' – Photo credit Lyndsey Vivian

C4: NATIVE FAUNA GENERAL

C4.1 Reptiles, general

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: 31 reptile species have been recorded in ACT grasslands**.** An analysis of available datasets showed that there were differences in reptile community composition between reserves and grass associations, but reptile community composition remained stable across most years. Recent research indicates reptile diversity is higher in the presence of rocks at sampling sites and with a higher proportion of bare ground. Herbage mass is a strong driver for reptile abundance, with higher abundance occurring at the lowest and highest ends of the range of herbage mass. A more statistically robust and consistent monitoring program is required.

Metric Assessment: Reptile community composition was monitored opportunistically with Striped-Legless Lizard monitoring (see metric 5.2 of this document) as part of the CR Grazing impacts study, ACT Government Grassland Restoration Project and Offsets monitoring. There are currently no standardised long-term monitoring programs for this metric. Reptile species included in this assessment are shown in Table 8.

Class: Core	**Category:** Non-statutory	
Primary drivers context: Reptile data was collected 2012-2015. Very warm conditions with average rainfall occurred during late 2012-2015. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Reptile abundance and community composition is used as an indicator of ground dwelling fauna populations in lowland native grasslands. Reptile species richness and abundance is correlated to grass structure and grazing pressure in grassy ecosystems(Howland et al., 2014). Reptiles are important predators of invertebrate fauna and also prey species to higher tropic levels, and therefore their diversity may be indicative of ecosystem functionality.

Projects contributing to metric: CR Kangaroo grazing impacts study, ACT Government Grassland Restoration Project, PCS Habitat rock placement, Offsets grassland monitoring programs (Striped Legless Lizard monitoring).

Sampling periodicity: Opportunistically as part of research projects, needs annual monitoring.

Baseline: Site analysis for this CEMP plan.

Reference condition: Reference condition 1) maximum number of reptile species captured at grassland sites (n=8) and 2) reptile composition at grassland sites with minimum amount of recent anthropogenic disturbance (not assessed in this CEMP plan due to data limitations).

Target condition: Reference condition.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: Current studies are examining the effect of burning and grazing regimes on reptile abundance and species richness, in addition to habitat restoration such as rock addition. The findings of these studies will be incorporated next CEMP plan. The primary gap for this metric is to increase the validity of data through more consistent methods and better data management.

Table 8. Species list for reptiles found in grasslands and their current status and EPBC listing as it applies to the ACT. For each species an indication on whether the field method used in this metric (searching underneath tiles) is appropriate for detecting presence/absence is given. 'Yes but not indicative' indicates that the species may be sampled but the method is not ideal for monitoring populations.

* Denotes species is addressed separately in a threatened fauna metric within this CEMP monitoring plan.

Common name	Scientific name	EPBC listing (ACT)	Can be captured in tile surveys
Grassland Earless Dragon	*Tympanocryptis pinguicolla*	Endangered*	Yes but not indicative
Eastern Bearded Dragon	*Pogona barbata*	Not listed	Yes but not indicative
Marbled Gecko	*Christinus marmoratus*	Not listed	Yes
Striped Legless-lizard	*Delma impar*	Vunerable*	Yes
Olive Legless-lizard	*Delma inornata*	Not listed	Yes
Pink-tailed Worm-lizard	*Aprasia parapulchella*	Vunerable*	Yes but not indicative
Common Scaly foot	*Pygopus lepidopodus*	Not listed	Yes
Eastern Brown Snake	*Pseudonaja textilis*	Not listed	Yes but not indicative
Tiger Snake	*Notechis scutatus*	Not listed	Yes but not indicative
Red-bellied Black Snake	*Pseudechis porphyriacus*	Not listed	Yes but not indicative
Blind Snake	*Ramphotyphlops nigrescens*	Not listed	Yes but not indicative
Dwyers Snake	*Parasuta dwyeri*	Not listed	Yes but not indicative
Small-eyed Snake	*Cryptophis nigrescens*	Not listed	Yes but not indicative
Eastern Blue-tongue	*Tiliqua scincoides*	Not listed	Yes but not indicative
Shingleback	*Tiliqua rugosa*	Not listed	Yes but not indicative
Delicate Skink	*Lampropholis delicata*	Not listed	Yes
Common Garden Skink	*Lampropholis guichenoti*	Not listed	Yes
Three-toed Skink	*Hemiergis decresiensis*	Not listed	Yes
Dwarf Skink	*Menetia greyii*	Not listed	Yes
Boulenger's Skink	*Morethia boulengeri*	Not listed	Yes
Spotted-backed Skink	*Ctenotus orientalis*	Not listed	Yes
Eastern Striped Skink	*Ctenotus robustus*	Not listed	Yes
Copper-tailed Skink	*Ctenotus taeniolatus*	Not listed	Yes
Cunningham's Skink	*Egernia cunninghami*	Not listed	Yes but not indicative
Eastern Three-lined Skink	*Acritoscincus duperreyi*	Not listed	Yes
White's Skink	*Liopholis whitii*	Not listed	Yes
Red-throated Skink	*Bassiana platynota*	Not listed	Yes

Data Analysis

The recording of the presence of reptile species has been included in most of the datasets collected for monitoring of Striped Legless Lizards (see metric C5.2 of this document). An attempt was made to compile reptile community data at the plot level, with data recording the presence/absence for each species in a particular sampling year. The reptile species for which the tile method is likely to be appropriate are listed in Table 8. Where available, observed dominant grass association (*Themeda* (T)*, Phalaris* (P) *or Austrostipa* (S)) was incorporated as part of analysis.

Similarities in reptile community composition were visualised with non-metric multidimensional scaling. Plots were arranged by year, reserve and observed grass association. An analysis of similarities (ANOSIM) was then run to compare average plot dissimilarities within and between years and grass associations (Table 9). Reserve could not be used for ANOSIM due to insufficient plots per reserve. There were significant differences between plots based on year and grass association. There were insufficient samples to run pairwise comparisons with effective correction for Type I error rate. As a result, the drivers of dissimilarities within factors were estimated only graphically.

Considerable limitations were revealed while attempting to analyse these data. Data analysis was challenging because of varying sampling effort between sites and the lack of consistent recording of reptile species to the plot level. Studies varied in number of reserves, plots, tiles and checks, the frequency of checks, as well as the plot condition and sampling design. Data overlaps between different contributing data sets were present but not easily identifiable. Few environmental parameters (e.g. temperature, time) were measured during sampling, restricting in-depth statistical analysis. Plot names varied depending on the data collector and inconsistencies in collection dates were found, with the same date used multiple times for different checks and multiple dates (weeks apart) reported as the same check. These errors were often difficult to diagnose as checks were not separated by a standardised time period. The sampling of reptiles using standardised tile arrays needs thoughtful experimental design, a review of sampling methods including the monitoring of appropriate covariates in addition to more careful data management.

Table 9: Summary of Analysis of Similarity (ANOSIM) conducted on reptile community presence/absence data at plot scale (grassland plots only).

Factor	ANOSIM test statistic R	p-value	Driver
Year	0.1357	0.001	2012, 2016
Observed pasture	0.0790	0.001	T, P

Overall, there appeared to be a large overlap in reptile community composition across years with the exception of 2012 and 2016, which were significantly different to each other (Table 9, Figure 26). Composition of reptile communities appeared to be different between reserves, possibly due to dominant grass associations and management histories, however due to lack of replication within reserves this could not be confirmed with formal data analysis. Googong in particular appeared quite different to other reserves which may reflect its status as secondary grassland (Figure 27). Reptile species composition in *Phalaris* grass associations was different to that found in *Themeda* grass associations (Table 9; Figure 28).

Subsets of plots at five grassland locations (Mulungarri, Gungaderra, Crace, Broadcast Australia and Campbell Park) were selected as trial reference sites for this metric. Data from non-reference native grassland sites and exotic grasslands (*Phalaris*) sites were then graphically compared to the trial reference sites (Figure 29). The plot showed more variation in reptile community composition of the non-reference native grasslands, while reptile composition of exotic grasslands was similar to reference sites. An ANOSIM found no significant difference between reptile composition at the reference condition and non-reference condition sites (ANOSIM R-value= -0.02848, p = 0.757). It is likely that this result is due to a combination of the very limited data from reference plots and low numbers of reptile captures overall. It is hoped that an increase in strategically placed monitoring plots and larger, longer-term data sets on reptile diversity within different grassland associations will enable more robust analysis to be conducted next CEMP plan.

Figure 26. NMDS plot of presence/absence data for reptile communities at grassland reserves. Points represent plots (grassland only), colour coded (and bounded by ellipses) by year.

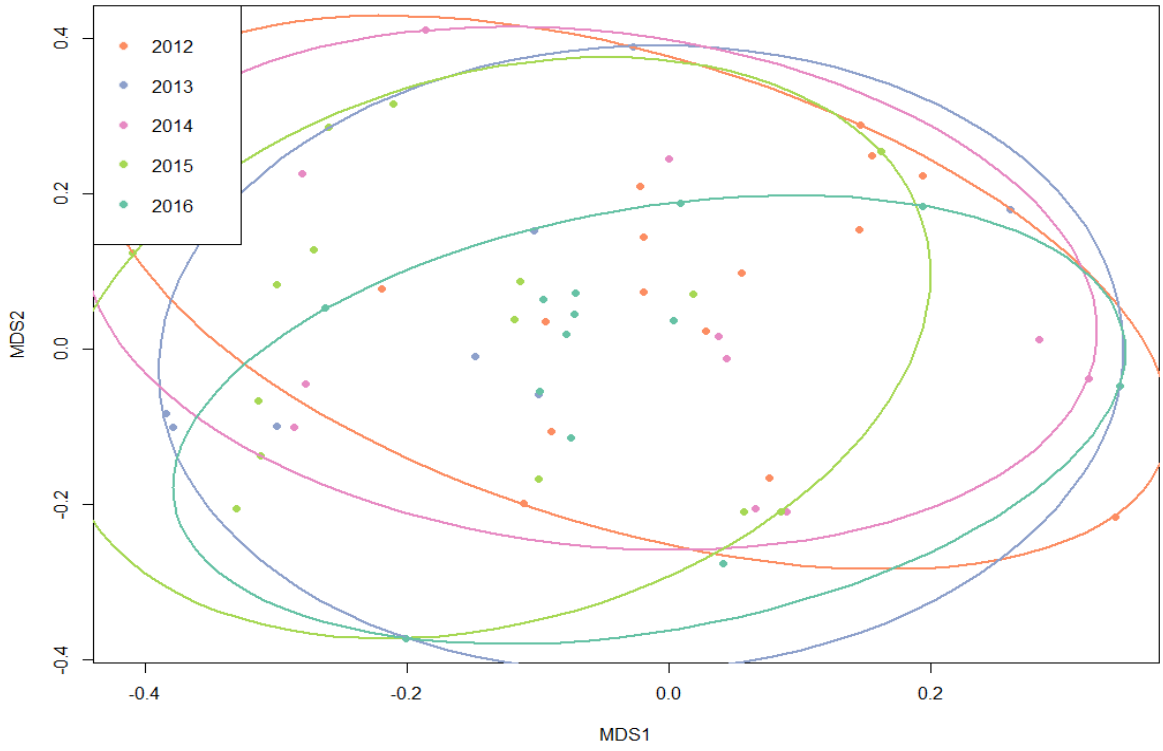


Figure 27. NMDS plot of presence/absence data for reptile communities at grassland reserves. Points represent plots (grassland only), colour coded (and bounded by ellipses) by reserve.

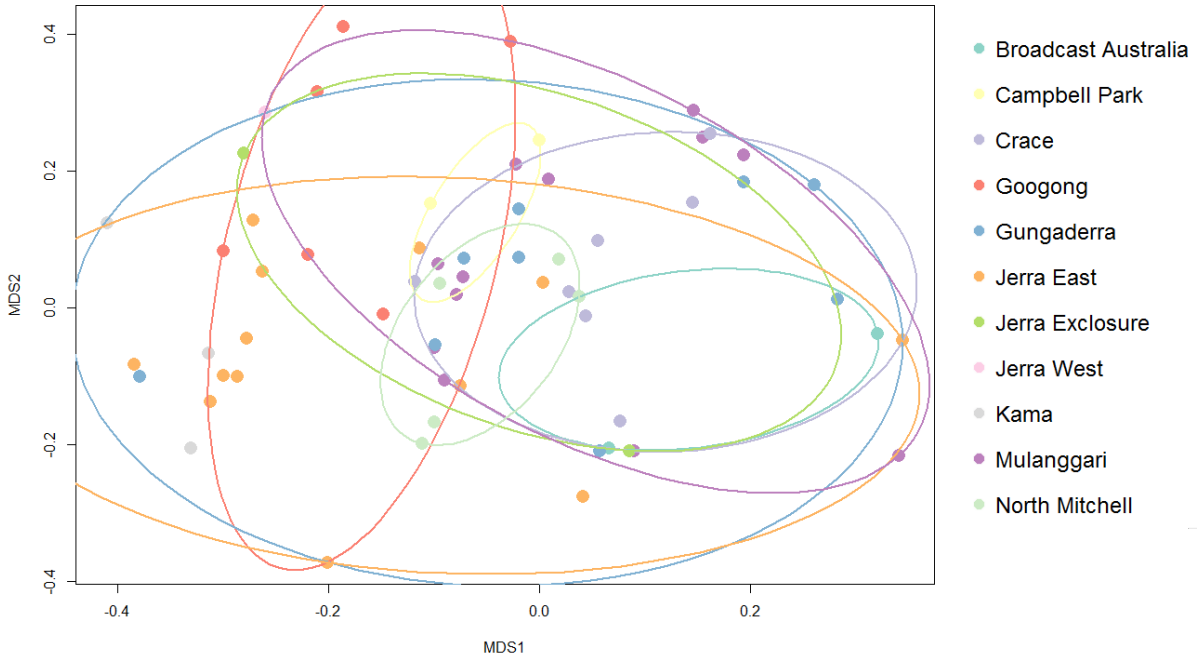


Figure 28. NMDS plot of presence/absence data for reptile communities at grassland reserves. Points represent plots, colour coded (and bounded by ellipses) by observed grass association.

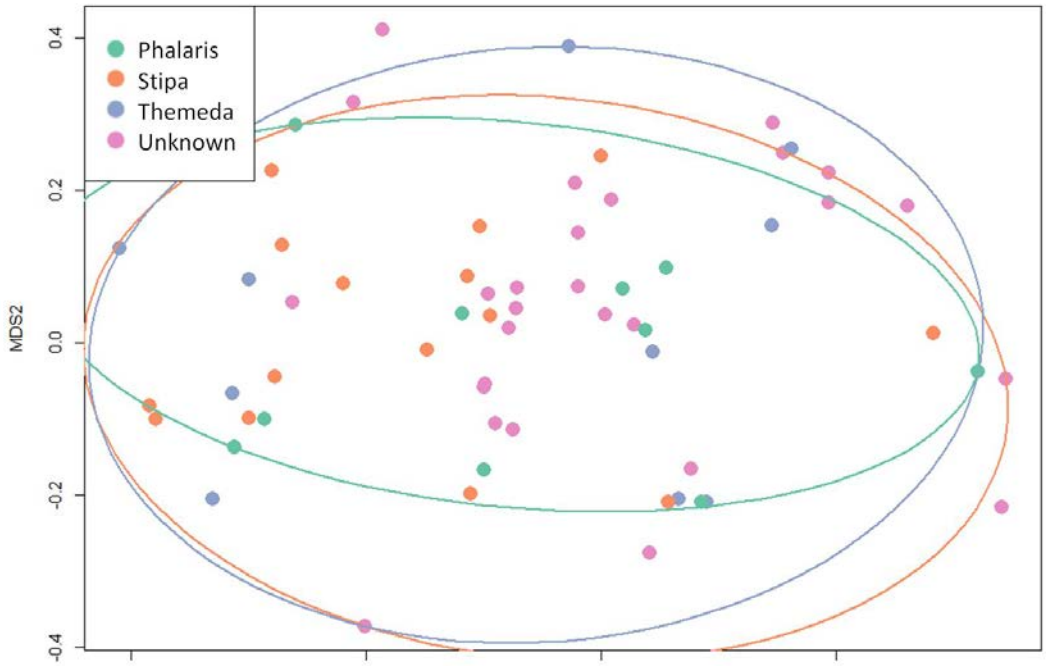
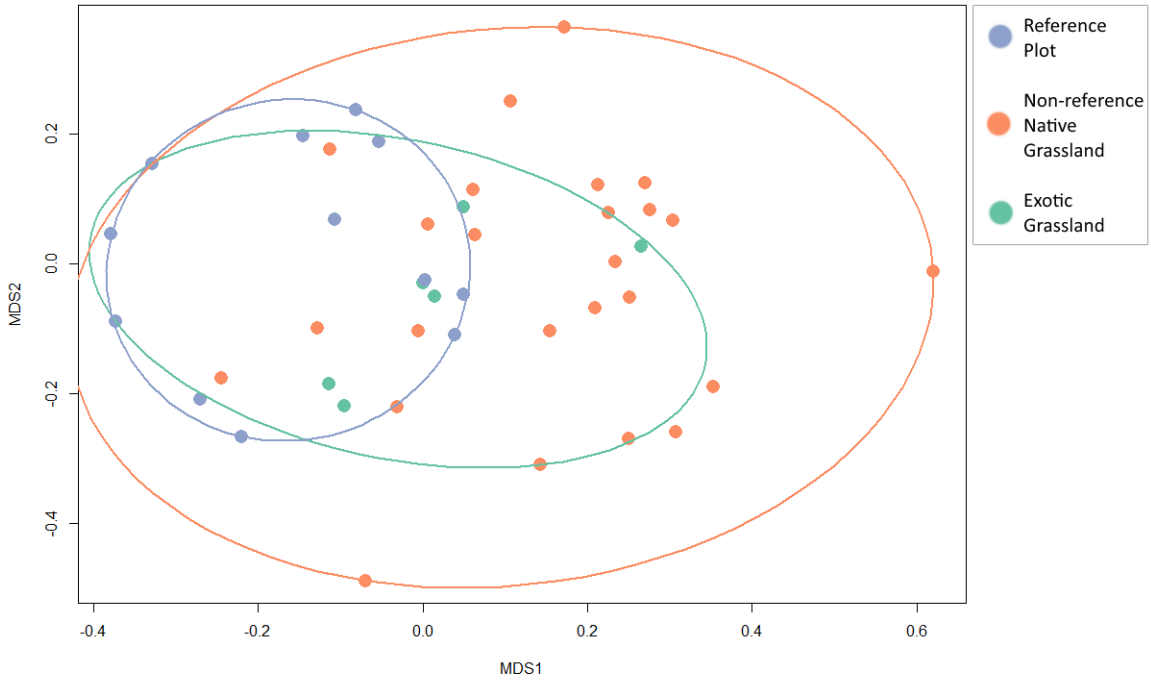
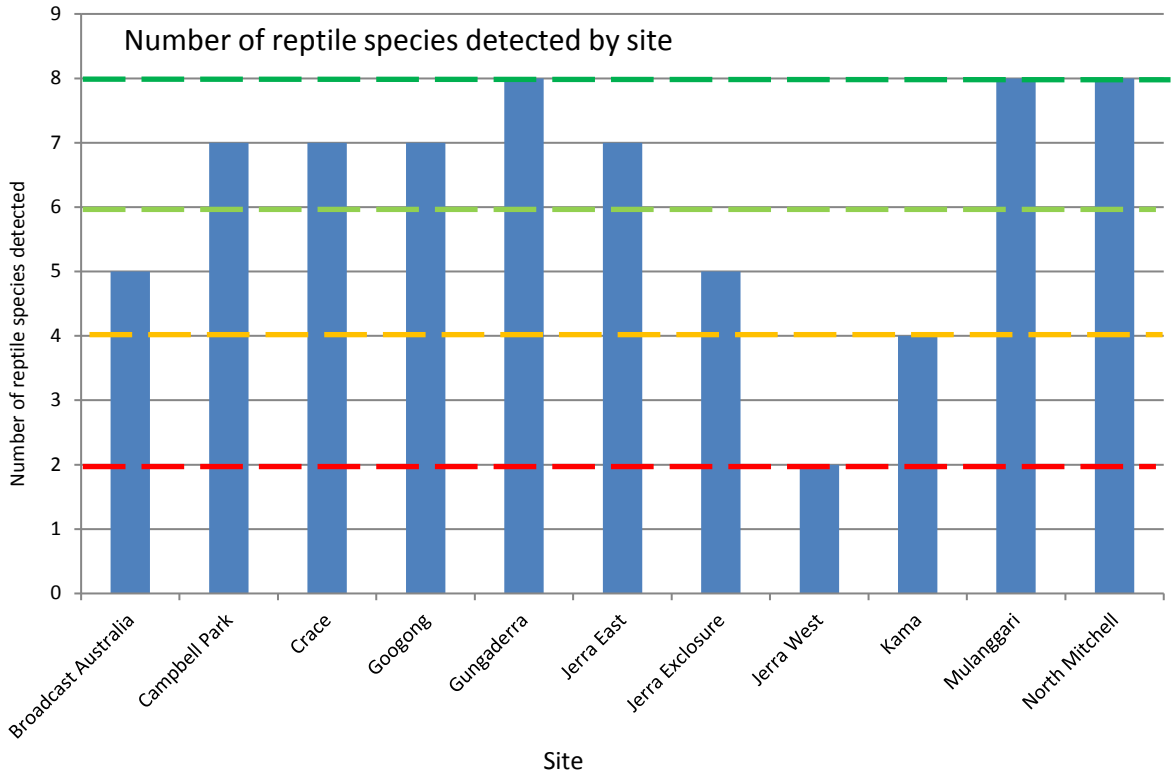


Figure 29. Conceptual NMDS plot of presence/absence data for reptile communities at reference plots (blue) in comparison to non-reference native grassland plots (orange) and exotic grassland plots (green). Reference plot condition is based on limited data from five sites with the least recent anthropogenic modification.



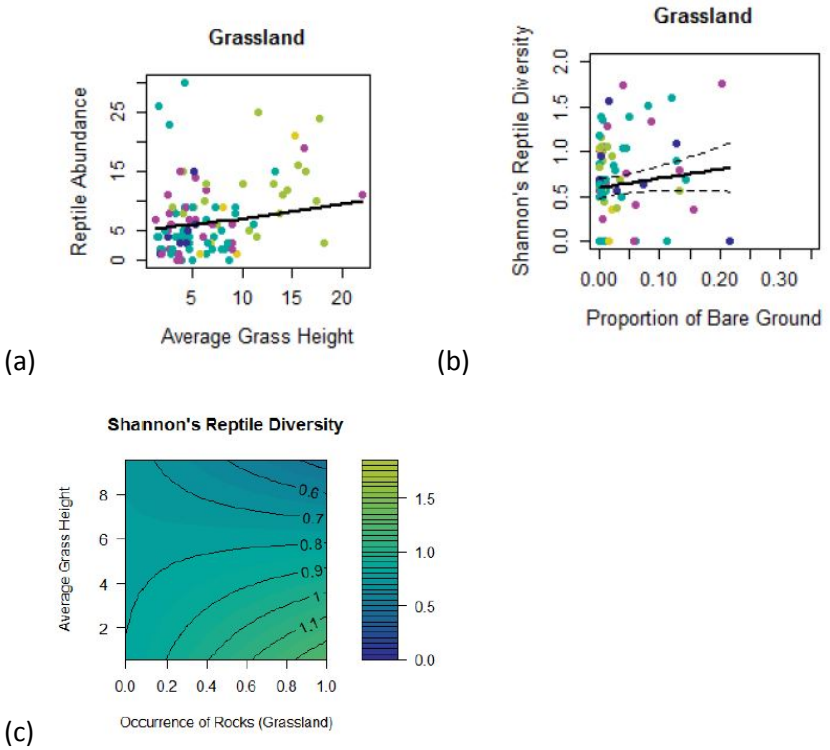
The second method of assessing condition of reptile species richness against reference condition was to use the maximum number of reptile species detected at eleven grassland sites. When the number of reptile species found at each site was examined, three sites met reference condition, four sites were rated 'good with some concerns', one site (Kama) was rated as being in 'moderate' condition, and one site (Jerrabomberra West) was as in 'poor' condition (Figure 30). Kama and Jerrabomberra West have shown a decline in floristic condition (native plant species richness, see metric C2.1) since 2008, which may have been a contributing factor to lower reptile species richness. However, the reptile data are highly confounded by differences in sampling effort between sites, with some sites sampled up to four times and others only sampled once, with between year variations in detectability likely to be an influence on results. Ideally in future analysis with more robust data sets, reptile species richness will be related to management history to enable interactions to be examined.

Figure 30. The number of reptile species detected at 11 monitoring sites between the years 2012-2015. Note that these results are confounded by uneven sampling effort and variability of conditions between years.



A study on the impacts of grazing pressure on reptile diversity showed dominant grass association was found to be an important predictor for total reptile abundance (Snape et al., in review) (Figure 31). The same study showed that in grasslands, overall reptile abundance is greater where grass height is higher while reptile diversity was found to be higher in the presence of rocks and an increased proportion of bare ground. Herbage mass was also found to be a strong driver of the total number (abundance) of reptiles overall, but not for reptile diversity. The highest abundance estimates occurred at the lowest and highest ends of the range of herbage masses; lowest abundances were found at intermediate levels (Snape et al., in review) (Figure 31).

Figure 31. The effect of average grass height on (a) reptile abundance, and the effects of proportion of bare ground (b) and occurrence of rocks (c) on reptile diversity. Sourced from ACT Government 2016



The ACT Government Grassland Restoration Project is currently examining changes in abundance of five reptile species after large scale (10 - 20 ha) autumn burns and small scale (20 x 20 m) spring burns. Early results from this study have shown response to seasonal fire is highly variable with no clear pattern shown for any species at this time, although most species appear to be present after autumn fire. Further monitoring will be conducted over the next two years.

Declines in numbers of individuals after fire may reflect a removal of species because of fire or a behavioural response of movement to nearby unburnt areas. The effect of fire on total reptile abundance may also be associated with the life history of each species and its ability to avoid fire, with fossorial and semi-fossorial species increasing or remaining stable after fire, while ground-dwelling species may initially decline. Time of day in which a burn occurs as well as the speed of the fire front may also be important factors in determining reptile species response. It is important that research is continued on the response of reptile communities to seasonality of burns and grazing, and that data are analysed in a robust way to determine the most appropriate management actions to maintain reptile communities.

While this metric is potentially very useful for assessing ecosystem condition, there is a need to establish regular and consistent monitoring programs for at least five reference condition sites (with replication) in addition to the long-term monitoring of priority areas to increase diversity estimations and enable robust analysis of trends.

C4.2 Invertebrates, general

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: No data are currently available for this metric. In 2016 baseline data were collected for invertebrates in grassland plots as part of the ACT Government Grassland Restoration Project. Over 10,000 samples were collected and are currently being analysed. This collection will form baseline knowledge for further research. Two invertebrate species of particular conservation concern are the threatened Perunga Grasshopper (*Perunga ochracea*) and the Canberra Raspy Cricket (*Cooraboorama canberrae*), populations of which appear to be declining but as yet no standardised survey methods are in place to monitor populations.

Metric Assessment: Invertebrate samples have been collected from five sites using pitfall traps as part of the ACT Government Grassland Restoration Project. The first collection will form the baseline data for this metric and future surveys will be compared to this baseline.

Class: Core	**Category:** Non-statutory	
Primary drivers context: Millennium drought 2001- 2009, followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: The role of invertebrates in lowland native grasslands is poorly known, however they are suspected to play a primary role in flora pollination and dispersal, burrow creation and fauna food webs. Two species are known to be declining: Perunga Grasshopper has been listed as vulnerable in the ACT and Canberra Raspy Cricket populations are suspected to be declining. More information is needed about this important trophic group.

Projects contributing to metric: ACT Government Grassland Restoration Project

Sampling periodicity: TBA, none at present, annual surveys of some species may be required.

Baseline: First data collected (available 2017)

Reference condition: TBA from data 2017

Target condition: Reference condition to be established from forthcoming data.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: Analysis of the baseline data collected in 2016 and the formation of a reference collection of invertebrates for grasslands is needed. Future assessments from this data may include examining the relationship between climate, vegetation structure, floristic diversity and invertebrate diversity. Invertebrate response to rock addition works will also be included in the next CEMP plan. The Canberra Raspy Cricket and Wolf Spider are often recorded during the ACT Government Grassland Earless Dragon monitoring program, and more robust recording of these data in addition to active burrow searches during surveys may be a good survey method for these two invertebrates. Such data may also provide an opportunity for research into interactions with habitat variables and climatic fluctuations for these species. An effective method for monitoring the vulnerable Perunga Grasshopper needs to be established. Monitoring of locust populations, particularly in relation to the impacts of high numbers of locusts on flora in lowland native grassland ecosystems, is needed.

C5: THREATENED FAUNA

C5.1 Grassland Earless Dragon (*Tympanocryptis pinguicolla*)			
ASSESSMENT AGAINST REFERENCE CONDITION		**ASSESSMENT AGAINST TARGET CONDITION**	

Summary: Grassland Earless Dragon (GED) populations at long term monitoring sites appear to fluctuate with climatic conditions and are also likely related to habitat variables such as percent bare ground, grass height, litter and biomass, which may in turn be driven by grazing pressure and/or fire regimes. There has been a long term decline in number of GEDs captures at Jerrabomberra West, which has been associated with high biomass and low burrow counts. Issues of detectability under different habitat conditions and with addition of artificial shelter needs to be resolved. Current research has demonstrated critical thermal limits for the species suggesting the importance of arthropod burrows and a mosaic habitat for its persistence.

Metric Assessment: GEDs have been monitored over the long term at four key sites within the ACT; Jerrabomberra East and West, 'Cookanalla' and Majura Training Area (MTA). Population estimates and trends have been calculated using monitoring data from these sites. Results from ACT government and external research projects on GED ecology are also included.

Class: Mandate	**Category:** Statutory – Threatened species	
Primary Driver context: Data sourced from years 2002-2016. Millennium drought 2001- 2009, followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016.	**Associated indicators:** C1. NTG C2. Native Flora, general C5. Native Fauna, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Grassland Earless Dragons now occurring only in fragmented native grasslands in the ACT region and Monaro plains between Cooma and Nimittabel. Maintenance of suitable habitat and no further fragmentation is essential for the long-term conservation of the species.

Projects contributing to metric: CR long-term monitoring (GED), Offsets grassland monitoring, ACT Government Grassland Restoration Project, PCS Habitat rock placement.

Sampling periodicity: Annually in summer over a 6 week period (CR long-term monitoring)

Baseline: First sampling at each site where possible.

Reference condition: Original distribution unknown but likely former extent of NTG. The EPBC status of the GED in the ACT is Endangered.

Target condition: Maintain populations of GED in reserves and offset areas managed specifically for their conservation (Action Plan No. 3).

Trigger point for management: Greater than 1 year of extreme herbage mass (very high or very low) at sites of known GED populations, which is creating unsuitable habitat for GEDs.

Qualitative input: Nil.

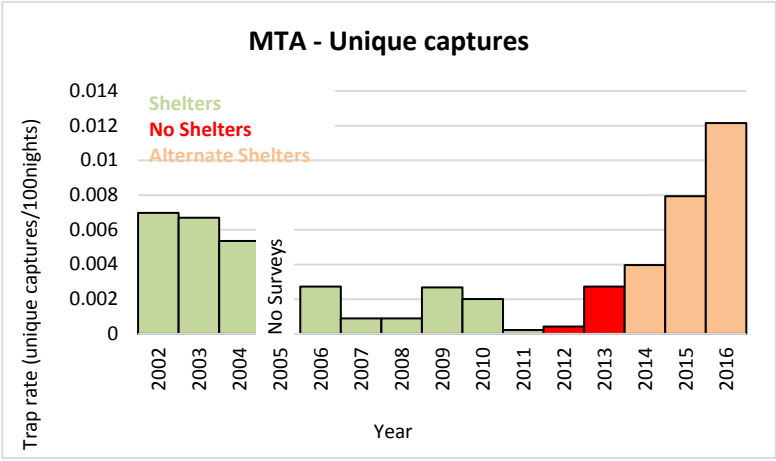
Future research questions, management directions, knowledge gaps and recommendations: Collection of data on covariates such as habitat variables, ambient air temperature and abundance of arthropod burrows during long term monitoring surveys is needed. Research into drives of populations of burrow producing arthropods is required as a high priority. Outcomes from research examining fine scale habitat use (UC) and the effect of seasonal burning on GED populations (ACT Government Grassland Restoration Project) will be incorporated next CEMP plan. Re-introduction of GEDs to identified priority areas and the restoration of habitat links between populations are key management actions for the species. Mapping the current distribution of the species is also of high priority.

Data Analysis

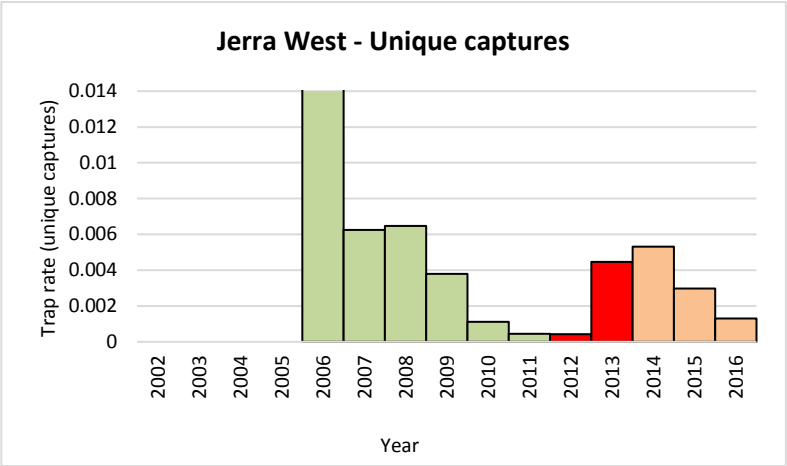
Mark recapture data for GEDs have been collected annually from four monitoring sites (Majura Defence Lands (MTA), 'Cookanalla', Jerrabomberra West NR and Jerrabomberra East NR), with monitoring commencing at MTA in 2002, with the exception of 2005 when road transects were used (Figure 32). Some previous data are available but due to inconsistencies in sampling methods these data were not used in this metric.

Examination of broad trends in GED populations at each site appears to indicate a steady decline in populations over drier years (2006-2010), with a steady increase in most GED populations post-drought (2012 onwards) (Figure 32, a-d). The only site that is not consistent with this general trend over time is Jerrabomberra West, which has seen a decline in unique capture rates of GEDs since 2014 (Figure 32, b). Trends in population data at these sites were confounded by sampling effort as the number of grids sampled at each site differed, therefore estimates are standardised by trap rate (number of unique capture per 100 trap nights). The use of artificial shelters over tubes also differed during this period as indicated by column colour on the graphs, and is likely to have affected capture rates over time.

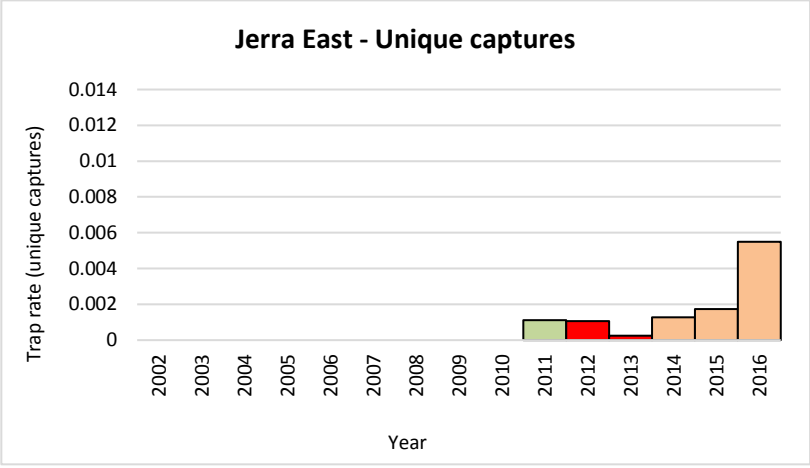
Figure 32(a-d). Annual numbers of unique captures of GEDs at each site per 100 trap nights. Colouring indicates the use of shelters (green), no shelters (red) or alternate shelters (beige) over tubes.



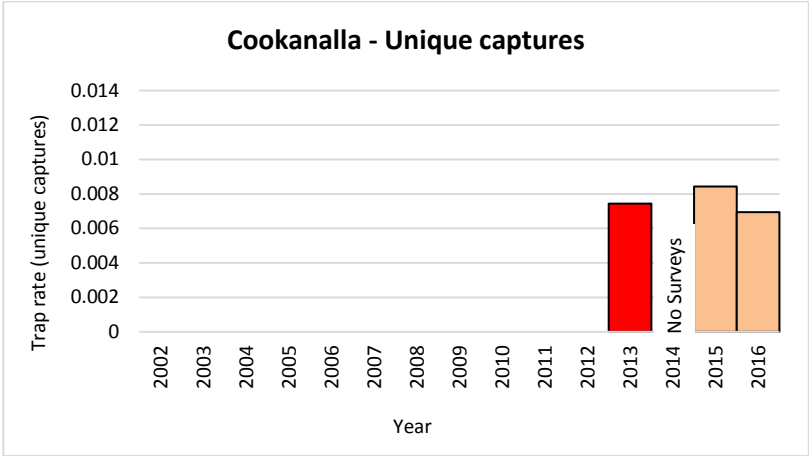
(a)



(b)



(c)



(d)

Initial data exploration of the same data set showed that at all sites unique individuals are captured at a constant rate throughout the annual 6-8 week survey period (i.e. the number of new individuals captured each survey remains steady) and roughly half of the unique individuals captured were juveniles. The long term monitoring data were analysed for trends in response to seasonal rainfall, the amount of bare ground (measured as the logarithm of percent fractional cover (logFC), which was created using remotely sensed data of bare ground estimation (spectral analysis) at 30 m x 30 m resolution), and the use of shelters over tubes (shelter/no shelter) using GAMM in R version 3.3.2. We used unique capture rate as our response variable (which was strongly correlated to total capture rate) and site as a random term in each model to account for repeated measurements at each site over time. The results showed trends found in unique capture rates at the landscape scale over the long term (Figure 33).

Results show a strong effect of logarithm of percent fractional cover (logFC) and winter rainfall on unique trap rate over the long term, between 2002 and 2016 (Figure 33). The number of unique GEDs caught was negatively correlated with increasing log percent fractional cover (logFC) and positively correlated to increasing winter rainfall. In addition, both year and shelter had a significant effect on unique capture rates of GEDs, with capture rates higher under shelters and differing between years (Figure 33). In summary, a large amount (over 60%) of variation in unique capture rates of GEDs was explained by climatic and environmental variables over the long term, with a smaller but significant affect of shelter use. How unique capture rate interacts with percent fractional

cover or winter rainfall and the use of shelters is unclear and needs further clarification. There may well be other drivers of variation in capture rates over time, for example grazing pressure possibly interacting with climatic patterns; however lack of long term data for likely covariates measured at appropriate scale limited our ability to explore further.

The confounding effect of addition of artificial shelters over all traps during the drought (2002-2010) and the removal of shelters from the sampling method after the drought (2011-2012) makes analysis of interactions between explanatory variables and shelter addition challenging. It is recommended that the current study design employing half shelter/ half no shelter is continued over years of differing winter rainfall until a correction for the effect of shelter on capture rates can be confidently calculated. There is a need to separate detectability and the preferred use of shelters from other causal influences (for example average grass height and biomass) when accounting for changes to GED populations at sites over the long term. This would be best be done using mark-recapture analysis. Other variables that may impact capture rate and therefore should be recorded in future monitoring include grazing pressure, time of day, cloud cover and temperature.

Results from the ACT Government Grassland Restoration Project have shown correlative trends in maximum GED capture rates over three years against average grass height, litter depth, biomass and percent bare ground (Figure 34a-d). Measurements of these habitat variables were conducted at the plot scale. Results from this study found that the maximum captures per day of Grassland Earless Dragons occurred at plots where bare ground was between 5-25%, litter depth was between 0.5 and 1cm, total above ground biomass was between 300 - 900 kg/ha and average grass height was 3-7 cm. This study was conducted during relatively stable rainfall where overgrazing was limited. How well these results translate to drier times when overgrazing is more likely to occur is unknown.

The presence of GEDs at two grids within Jerrabomberra West was recorded after spring burns. These same sites had no records of GEDs in the previous six years of surveys. These fires were patchy, providing about 50% burnt and unburnt habitat within monitoring grids.

Figure 33. Exploratory modelling of response in unique capture rates of GEDs to percent fractional cover (LogFC), winter rainfall, and year. The use of artificial shelters over tubes was a significant term in the model. Adjusted R^2 = 0.632.

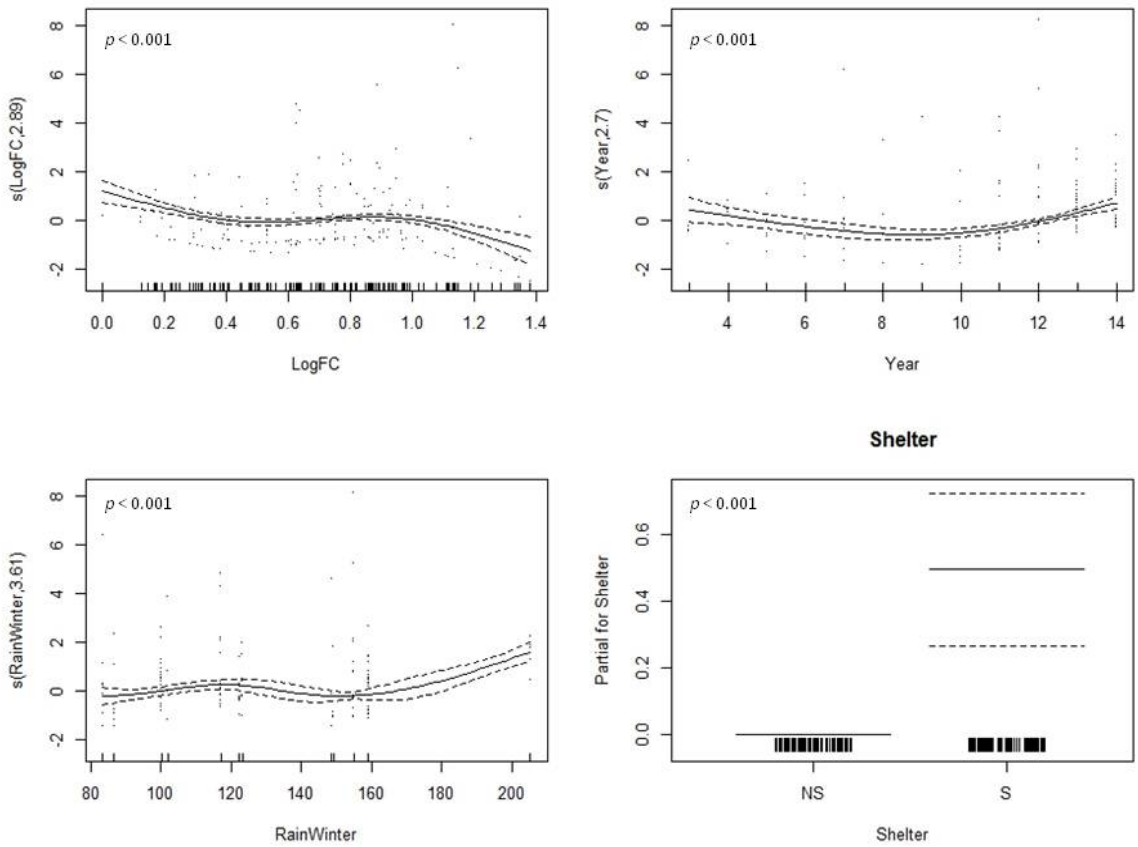
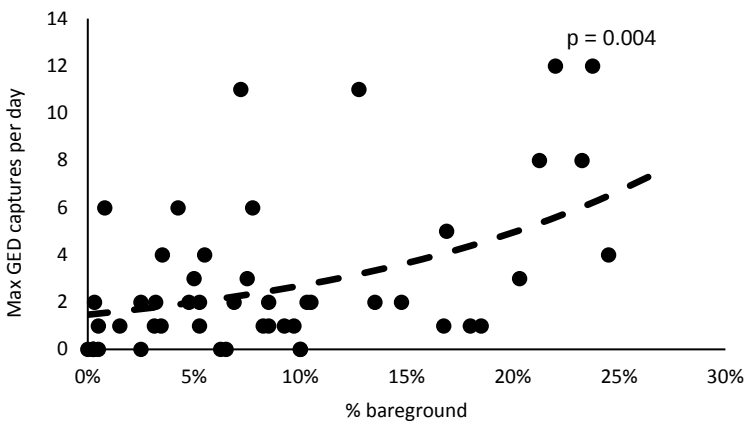
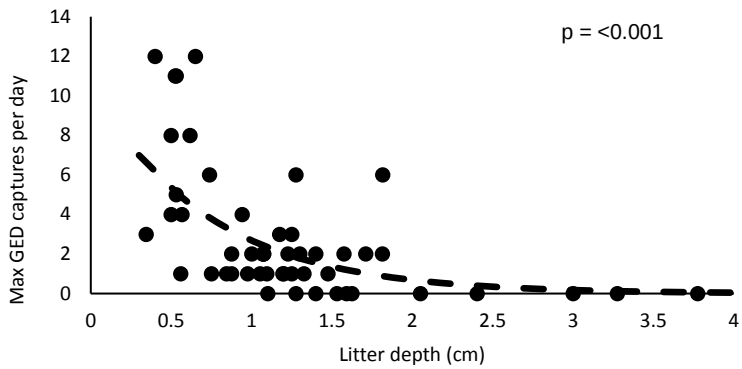


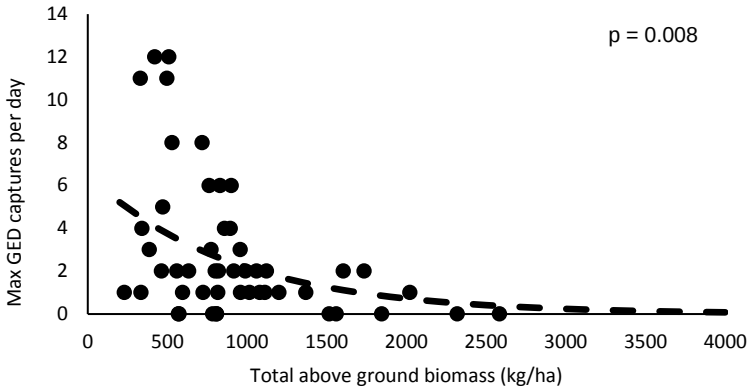
Figure 34 (a-d). Maximum GED captures per day in relation to (a) percent bare ground, (b) litter depth, (c) total above ground biomass and (d) average grass height.



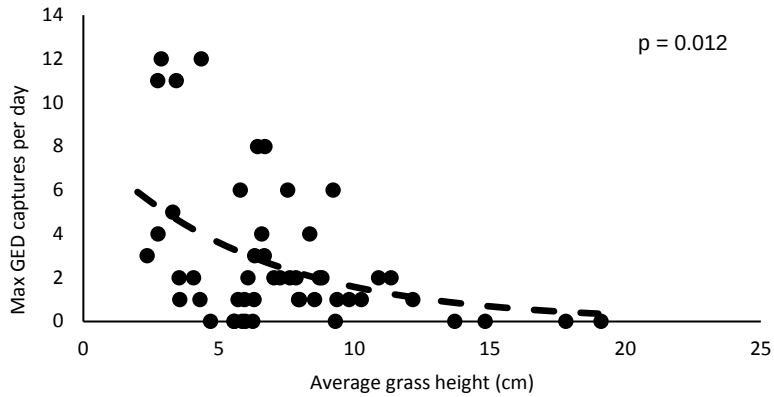
(a)



(b)



(c)



(d)

The University of Canberra has completed extensive research on the physiology of GEDs, in particular thermal thresholds of the species and this is currently in review for publication. The primary outcomes of this research were the discovery of a threshold body temperature (which was strongly associated with ambient air temperature) of around 37°C and that the species has a peak activity patterns. The need for the lizard to maintain its body temperature below this critical threshold, particularly with climate change which will see an increase in the days where maximum air temperature exceeds over 37°C in the ACT, demonstrates that burrows are an essential habitat element for the species to survive these very hot days. In addition, tussocks of grass can provide shelter for both GEDs and when located near burrows, reduce the temperature within, indicating that grass tussocks may also be an important element of habitat.

A key management focus in the long term is to maintain or improve habitat to promote dragon population persistence and resilience. Current known habitat for GEDs includes well-drained NTG that is relatively undisturbed. From the results of this analysis thus far, it is likely that the species requires a mosaic habitat of shorter grass and bare ground areas for foraging activities inter dispersed with larger tussocks and adequate burrows for shelter. Radio-tracking studies to determine fine scale movement patterns, juvenile dispersal and seasonal microhabitat preference have recently been carried out by University of Canberra and these results should be available next CEMP plan.

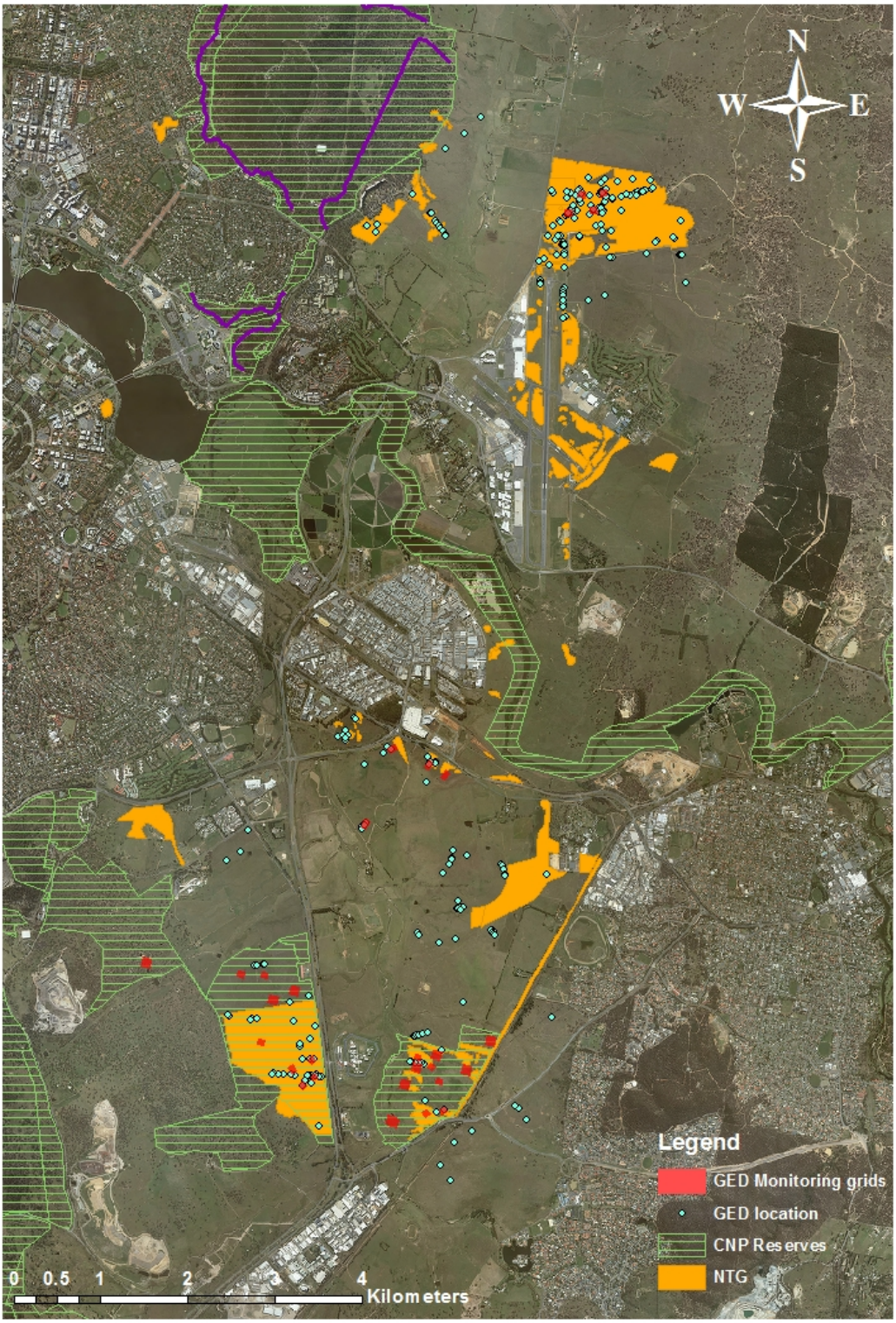
Observations at Jerrabomberra West have seen a steady and severe decline in the population since it crashed during the drought. The lack of recovery of this population may be the result of very high biomass levels (2000-4000kg/ha) and a deep layer of thatch at the site. In addition, the number of arthropod borrows per hectare is significantly lower than at other sites where healthy populations of GEDs persist (B Howland pers. comm. 16th May 2017). GEDs require arthropod burrows for shelter both during the heat of summer and during the cold months of winter, in addition to lay eggs in during the breeding season. Production of burrows may therefore be a key ecological function in healthy grassland ecosystems. Vegetation structure, ground cover and number of available arthropod burrows may be strong determinants in GED population persistence at a site.

Species such as the Canberra Raspy Cricket (*Cooraboorama canberrae*) and Wolf Spiders (*Lycosidae* spp.) are thought to be important burrow creators and users in ACT lowland native grasslands, but little is known about what drives populations of these burrow producers. While biomass is likely to be a strong driver, more research is needed into habitat requirements of burrow-producing arthropods and what drives burrow-producing arthropod populations in these ecosystems. CEMP recommends that future GED monitoring incorporates monitoring of the number of arthropod burrows and habitat variables (such as grass height and biomass), temperature at the time of survey and a consistence use of shelter/no shelter when monitoring so that more robust analysis can be undertaken regarding the influence of these parameters on GED populations.

One of the most pressing issues is to resolve detectability concerns in current monitoring techniques and clarify the influence of environmental and habitat parameters on populations, which could then be manipulated for the benefit of GEDs using varied habitat management techniques (e.g. fire, livestock grazing). Monitoring the impact of changes in management practices including grazing, weed control, mowing and fire will be an important component for managing the species.

Future potential actions for the long term conservation of the species should include the maintenance of captive colonies of GEDs to improve understanding of biology and as a potential source of animals for re-introduction; a review of strategies for re-introduction of GEDs to identified priority sites (such as areas of potential habitat or to sites where the species has previously been found but is now absent) including appropriate habitat restoration and on-going habitat management at these sites and the promotion of off-reserve conservation initiatives. Using an experimental approach to reintroductions would also further our knowledge of habitat requirements and survey techniques. Active burrow search methods, including the use of endoscopes to examine burrow occupancy, may be a quick method to assess GED presence and broad distribution at a site. Populations of GEDs in the ACT are now highly fragmented and restoration of habitat to provide better connectivity across areas of suitable habitat is required. Research into the impact of predation by introduced and native predators is currently unknown and needs to be explored, particularly in relation to changes in management actions, as discussed under section S4 of this document.

Figure 35: Known distribution of GEDs and current ACT government monitoring sites in relation to reserve lands and the extent of Natural Temperate Grasslands.



C5.2 Striped Legless Lizard (*Delma impar*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Monitoring of Striped Legless Lizards (SLLs) is conducted at relevant offset areas and as part of short term research projects (CR, NRM). The value of current datasets is limited by inaccuracies between datasets, invalid assumptions of the data, changes in field methods and sampling designs and a lack of monitoring important covariates, such as habitat variables and response to management actions. Current programs aim to examine the impact of fire and grazing on SLL populations (NRM and PCS projects). No discernible trend was found in population data to date, but analysis was severely limited by the issues listed above and population estimates contained a large amount of error. Monitoring of covariates and consistency of methods are recommended in the future.

Metric Assessment: Striped-Legless Lizard monitoring is conducted at relevant offset areas and opportunistically within research projects (CR Grazing impacts study, ACT Government Grassland Restoration Project and PCS grazing trials). Currently only offsets areas have a standardised long-term monitoring program proposed for this metric. Careful data collection and storage are required, in addition to monitoring of covariates such as habitat.

Class: Mandate	**Category:** Statutory – Threatened species	
Primary drivers context: Data sourced 2012-2016 which were very warm years with average rainfall. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C5. Native Fauna, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: The Striped legless lizard (SLL) is a vulnerable species in the ACT, occurring only in fragmented remaining areas of Natural Temperate Grassland. Threats include loss, fragmentation and degradation of habitat and possible increased predation from introduced predators (Action Plan No. 2). Reserves containing SLLs are managed to ensure the protection and maintenance of known habitat.

Projects contributing to metric: CR – Kangaroo grazing impacts study, Offsets grassland monitoring (SLL), ACT Government Grassland Restoration Project, PCS grazing trials, Bush Heritage translocation project (CR/NRM/PCS)

Sampling periodicity: Monitored regularly at relevant offsets sites and additional sites as part of research projects, regular monitoring within reserves may align with reptile monitoring.

Baseline: First sampling at each site.

Reference condition: Original distribution unknown but likely former extent of NTG. The EPBC status of the Striped Legless Lizard in the ACT is Vulnerable.

Target condition: Where possible, further fragmentation of populations will be minimised and habitat linkages will be maintained (Action Plan No. 2). Stable or increasing populations.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: Long-term SLL monitoring would benefit from consistent field methods, monitoring of covariates and better data management. Findings from research examining the effect of burning and grazing regimes on SLL abundance, in addition to habitat restoration such as rock addition, will be available next CEMP plan. Monitoring of the condition, extent and degree of fragmentation of Striped Legless Lizard habitat within known areas may be incorporated.

Data Analysis

Monitoring is essential to determine the long-term status of the Striped Legless Lizard (SLL) and for assessing efficacy of conservation measures and management actions. Monitoring of SLLs has previously occurred through Environmental Offsets monitoring requirements and shorter term, research focused projects. The purpose of monitoring, as per the Action Plan for the species, is to obtain information on population fluctuations over time, and more specifically on how populations respond to changes in the grassland habitat, specific management practices and pressures associated with urbanisation.

Various analyses were conducted on available data to examine SLL density, presence and detection using datasets obtained from both offsets (2012-2016) and CR (2012-2015) monitoring programs. The analysis included an exploration of factors potentially effecting SLL detection in monitoring surveys and a review of monitoring data examining changes in SLL density and their presence/absence.

Monitoring of SLL is aimed at assessing the number of individuals present in a population or area. Monitoring programs typically consist of searching for SLLs under rood tiles placed in a fixed grid array, and these tiles are sampled multiple times over a season (spring/summer). An earlier study found that the array of tiles (number and layout) affects density estimates (2012 Offsets), so only studies using the most common array were included in this analysis. This array is 30 tiles in five rows of six, with each tile 20 m & 25 m from its nearest neighbour. The total area for each plot, including a 10 m buffer around the edge of the array, is 1.44 ha.

This survey method assumes SLL have an average maximum range of movement of 10 m, thus re-sampling a tile introduces a high chance of recapturing the same individual multiple times in a season. Previous reports (offsets) generally deal with this by assuming all captures under a given tile is the same lizard. Using this assumption, the rate of recapture is 25.2% over the combined dataset, with the rate of recapture increasing as the number of checks increases (Figure 36). However when mark-recapture data (2012 Offsets) was examined, it was found that the assumption that finding an SLL under the same tile is that same individual may underestimate recapture rates (Figure 36). Recapture rates using mark-recapture data reported recapture rates of 29%, though importantly we note that tile layout within this study was different from all the other studies so may not be comparable.

A conservative estimate of density of SLL can be made for each reserve in each year by assuming the following: 1) that all lizards present within a grid were observed under a tile; 2) SLLs observed under different tiles are different individuals; a lizard observed on multiple checks under the same tile is the same individual and 3) SLLs are homogenously distributed throughout the reserve. Density for each reserve was calculated for each year as the number of individual SLL per hectare, pooled across all plots within a reserve. Given that a mark-recapture trial (2012 Offsets) showed that not all individuals are recaptured during a study, and that new individuals were found on every check (up to 10 checks), density estimate using this method are likely to be under estimates for the population.

While there is some variation within sites over years there appears no discernible trend to the data overall (Figure 37; Table 10). There is, however, a large amount of error around each point, which may be partially explained by large variations in sampling effort. The lack of monitoring covariates such as habitat variables means that little sense can be made of the declines and increases in capture

rates of lizards over time or between reserves. Ideally, probability of detection would also be assessed by testing for correlations between mark-recapture data and habitat.

Figure 36. Cumulative number of SLL against tile checks for 2012 offsets data. Lines represent cumulative number of unique individuals (blue) compared to total number of captures (red).

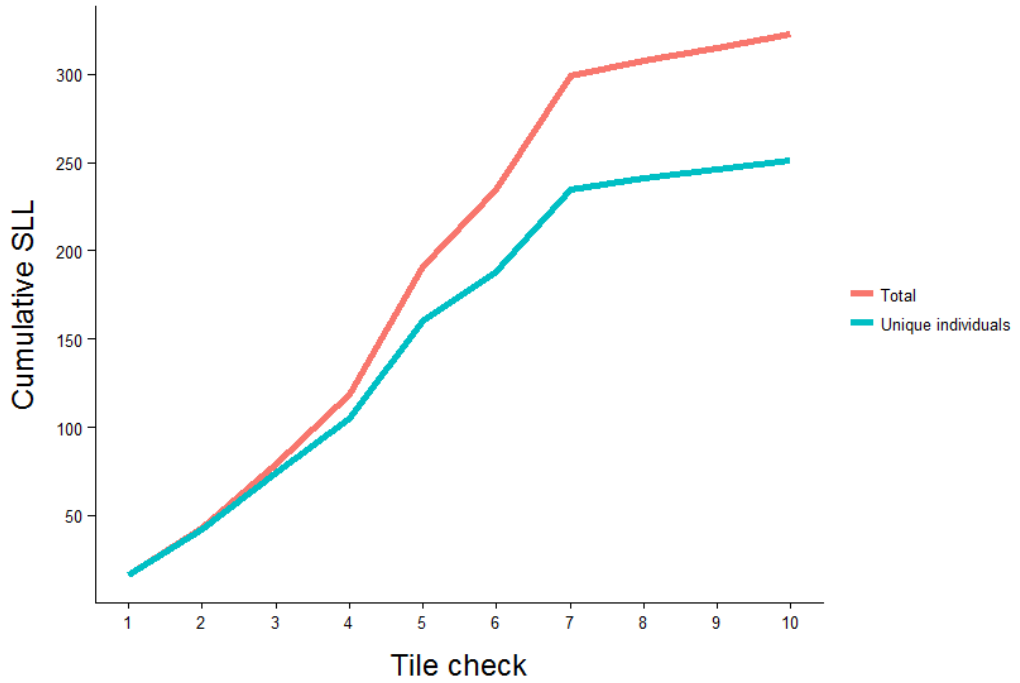


Figure 37: Estimates of density of SLLs (individuals per hectare) at grassland plots (averaged over reserve) as a function of year. Estimates are conservative, with considerable error around each point (not shown).

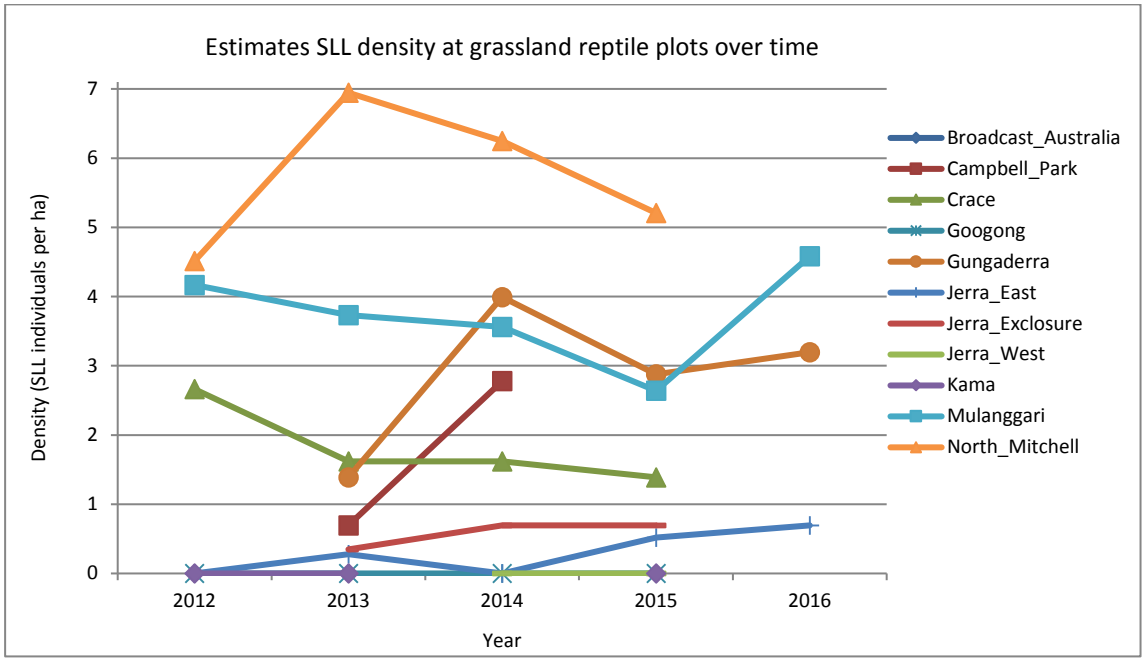
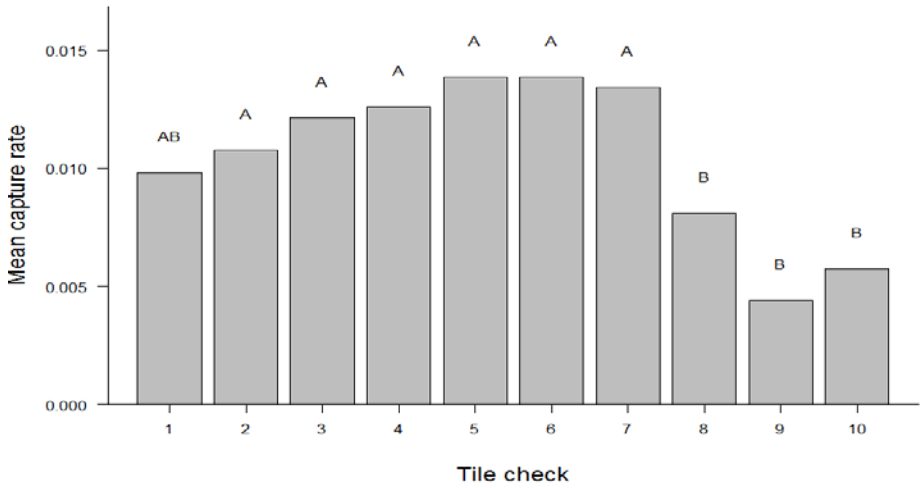


Table 10. Estimated number of SLLs (individuals) detected at each grassland (only) reserve pooled among plots in each monitoring year.

Reserve	2012		2013		2014		2015		2016	
	SLL individuals	# of samples	SLL individuals	# of samples	SLL individuals	# of samples	SLL individuals	# of samples	SLL individuals	# of samples
Broadcast_Australia					34	630				
Campbell_Park			3	630	4	210				
Crace	82	6160	7	630	7	630	8	840		
Googong	0	420	0	420	0	630	0	840		
Gungaderra	90	4800	20	2460	46	2130	29	1920	23	1500
Jerra_East	0	840	2	1050	0	840	3	840	8	2400
Jerra_Exclosure			1	420	2	420	2	420		
Jerra_West					0	420	0	420		
Kama	0	420	0	420			0	630		
Mulanggari	111	5950	43	2130	41	2130	19	1500	33	1500
North_Mitchell	13	420	20	420	9	210	15	420		

A preliminary examination of capture rates over time was undertaken. When the rate of capture (for both new and recaptured individuals) was examined, capture rates appeared to decrease following the 7th check. This trend was consistent across all data (Figure 38) although it's important to note that survey length differed; not all surveys included checks 8 to 10.

Figure 38. Capture rate (SLL individuals per sample) per tile check. Groups sharing letters are not significantly different (p<0.05) after multiple comparisons based on rank sums. Capture rate is standardised by total number of samples within each check.



While current datasets were expected to overlap, inconsistencies were discovered, meaning that some important analyses (e.g. probability of detection) have not been possible and there are questions in regard to accuracy of data. Ongoing assessment of SLL populations will benefit greatly from a systematic and rigorous approach to data collection, input and management.

Ideally future monitoring of SLL will collect data on habitat, land use and climatic variables to build on this knowledge and to investigate habitat/climate relationships for the species over time. The habitat associations of SLLs), including the impacts of grazing on SLL populations, have been previously investigated (Howland et al., 2016). The authors found SLL presence was negatively related to the density of native graziers and positively related to grass structural complexity. These relationships were analysed using two years of survey data at 6 reserves. Further investigations into required habitat patch size; factors limiting the distribution of the species (Figure 40); barriers to movement (connectivity analysis) and causes of mortality (such as predation) may assist in management of the species.

Monitoring of SLLs also needs to focus on the effect of different management actions such as fire, slashing and grazing by stock on the species, including different levels of intensity of these actions. Early results from the ACT Government Grassland Restoration Project showed no clear pattern in response of SLL's to autumn burns, but the species remained present at all plots after fire (Figure 39). Further monitoring of the species response to autumn and spring burns will be conducted over the next two years.

Some initial translocations of the species took place in 2015, with 116 animals translocated from a development site at Epic to Scotsdale (bush heritage managed property). A further translocation of 76 animals to Kama NR took place in 2016. Translocations of the species into areas with no resident populations may help tease out relationships between absolute population size and indices of abundance obtained during sampling and enable further investigation into the effectiveness and reliability of alternative marking techniques for the species.

Figure 39. Preliminary numbers of SLL before and after autumn fire at three study sites and control plots.

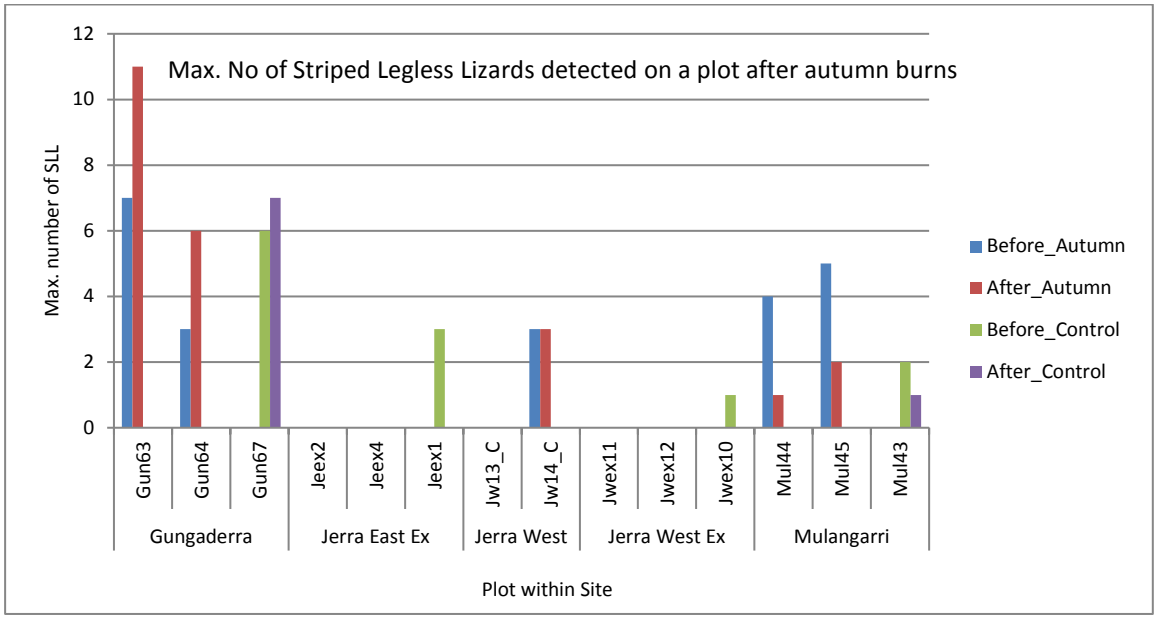
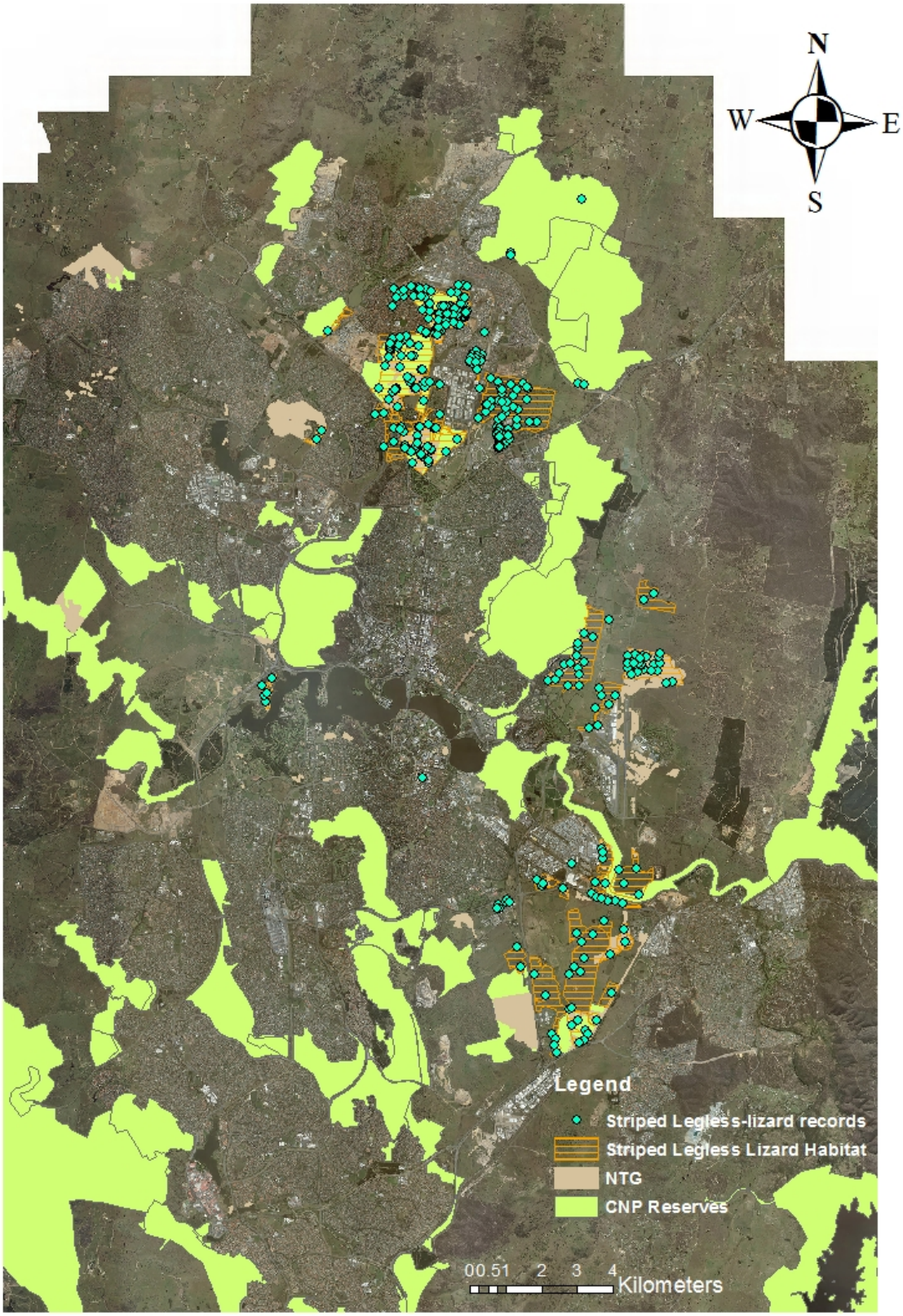


Figure 40. Current known distribution of SLL in relation to CNP reserves and NTG.



C5.3 Golden Sun Moth (*Synemon plana*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Most ACT locations only have Golden Sun Moths (GSM) count records from one or two years of surveys, over which large variation in counts occur. On ACT estate, regular monitoring of GSM populations has only occurred in environmental offset areas. Data confidence for most population surveys is low due to high fluctuations in numbers between years and changes in survey methods. A standardised monitoring program covering ACT reserves and offsets is recommended. Monitoring needs to account for the relationship between GSM count and habitat covariates.

Metric Assessment: This metric assess both GSM populations and habitat. The condition and extent of GSM habitat should be monitored annually at five sites (including reserves and offsets) (% cover of *Austrostipa* and *Rytidosperma* species). Population monitoring if GSM should be trialled and assessed whether viable in the long term.

Class: Mandate	**Category:** Statutory – Threatened species	
Primary drivers context: Data sourced from 2015-2016 which were very warm years with average rainfall. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C5. Native Fauna, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: Golden Sun Moth is an endangered species in the ACT (*Nature Conservation Act 2014*) and critically endangered under Commonwealth legislation (*EPBC Act 1999*). GSM populations across the ACT are severely fragmented due to recent anthropogenic changes and are significantly threatened by urban development and declining habitat quality.

Projects contributing to metric: CR long-term monitoring, Offsets grassland monitoring, ACT Government grassland Restoration Project, CR/UC translocation projects.

Sampling periodicity: Annually at selected sites from 2017. (Action Plan No. 7).

Baseline: Distribution, population estimates and habitat assessment at sites in 2017.

Reference condition: Original distribution unknown but likely former extent of NTG. The EPBC status of the GSM in the ACT is Endangered.

Target condition: The current approach to retain the viability of GSM within the ACT is to protect and enhance populations by maintaining/restoring areas of habitat (Action Plan No. 7).

Trigger point for management: No trigger point at this time. A trigger point in relation to counts is difficult to estimate due to high variability between years; a habitat condition criteria needs to be established.

Qualitative input: There have been no regular surveys for GSM on reserve estate.

Future research questions, management directions, knowledge gaps and recommendations: Annual, coordinated surveys with standardised methods and sites need to be established, with monitoring of relevant habitat variables at the same sites. Research needed on GSMs includes: the use of Chilean Needlegrass by GSM, the response of GSM to weed control, burning, grazing and slashing (currently underway) and the impact of habitat fragmentation on dispersal of GSM. Initial presence /absence surveys for GSM needs to occur in unsurveyed grassland areas as listed. Increased knowledge of life history, demographics, habitat requirements and conservation genetics of GSM would enable better informed management.

Data Analysis

Mulvaney (2012) suggested that estimating the size of GSM populations is problematic due to a rapid turnover of individuals; timing of emergence of adults and because only male GSMs are readily observed. Maximum counts are likely to reflect abundance under good emergence conditions, so methods must be standardised to such. Data analysis needs to account for impacts of weather conditions and ratio of males to females within population estimates (Mulvaney, 2012).

A long term monitoring program for GSM with standardised transect or point counts has been suggested, which includes coordinated surveys conducted on suitable emergence days (at least four days over a week's interval), under clearly specified survey conditions (DEWHA, 2009). Five sites have been suggested for long term monitoring of GSM: Jerrabomberra East, Jarramalee/WestMcGregor (currently slashed and grazed by cattle), Jerrabomberra West (currently ungrazed but may be burnt and grazed in the near future), Crace (grazed by native herbivores) and Woolshed Creek. Sites that may be monitored less frequently include: Lands End (LDA), Throsby (heal and neck extensions), Kinleyside and West Majura. Other potential monitoring sites include Dunlop, Mulanggari and Bonner. Yarralumla Equestrian Park and Lawson are currently monitored externally (Mulvaney, 2012).

Monitoring of key habitat variables is recommended including grass height, biomass, thatch, and percent bare ground. The percent cover of Stipa (*Austrostipa* sp.) and Wallaby Grass (*Rytidosperma* sp.) also needs to be mapped to demonstrate any improvements to habitat through management interventions. The target percentage cover of these species at these sites is currently > 40% (Gibbons and Reid, 2013).

To determine the full extent of GSM in the ACT, a survey of previously unsurveyed grasslands with good quality habitat needs to be prioritised, and presence or absence of the species established at these sites (Figure 41). Mulvaney (2012) suggested presence/absence surveys to be conducted within the Newline area, west of Jarramalee, South Jerrabomberra, between Dunlop grasslands and Hall, the vicinity of Yarralumla woolshed, North Curtin ovals / Royal Golf Course, to the west of the Monaro Highway, in the vicinity of Royalla and the grassland flats above the Murrumbidgee from Tharwa downriver to the back of Weston Creek (Mulvaney, 2012).

The University of Canberra conducted research on translocating GSM larvae in 2012-2013. Outcomes of the study showed that larvae can be readily transported with little or no mortality. Survival of larvae in captivity exceeded 75%, however the percentage of moths emerging from translocated caterpillars was quite low (< 5%). A more recent translocation of GSM took place from Taylor development area to Kinlyside offset area during 2016. The translocation trialled two methods for GSM translocation: direct larvae and soil translocation. The direct larvae translocation was found to be logistically easier to implement than the soil translocation, although similar levels of emergence were detected (11 pupae cases detected in soil translocation plots compared to 12 pupae cases recorded in direct larvae translocation plots). In addition, soil translocation has the disadvantage of potentially unintentional spread of invasive weeds, with GSM larvae detected in the roots of serrated tussock at Taylor during initial surveys. It has been recommended that translocation plots in Kinleyside be monitored for at least two more seasons to assess long term survival of translocated GSM (Crook and Allen, 2017).

Management actions could aim to restore key habitat or linkage areas. Currently approximately 45% of known and assumed habitat is within existing or proposed nature reserve or offset areas (Figure 42). A further 21% is approved or proposed for clearance (including a significant proportion key habitat areas), while a further 23% of the habitat occurs on Commonwealth land and has an uncertain future (Figure 42). Key habitat areas greater than 100 ha (n=3) are likely to be reduced in area by at least 25% over the next few years, while only four of the fifteen major population or habitat area sites are totally within conservation reserves. Over 20% of the major habitat areas are developed, approved or proposed for development within the next five years.

Figure 41. Map of GSM distribution and potential habitat within and external from ACT reserves.

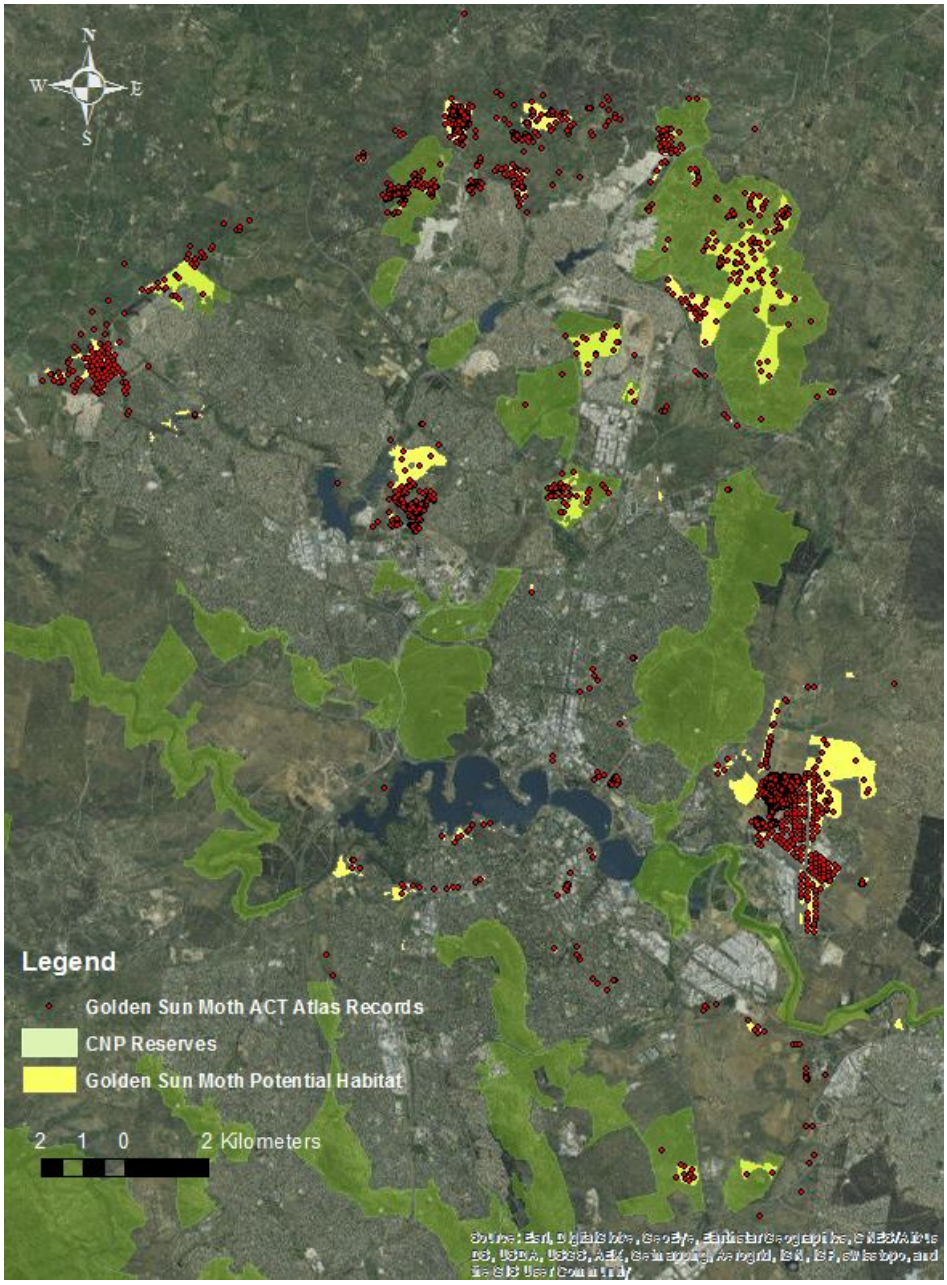
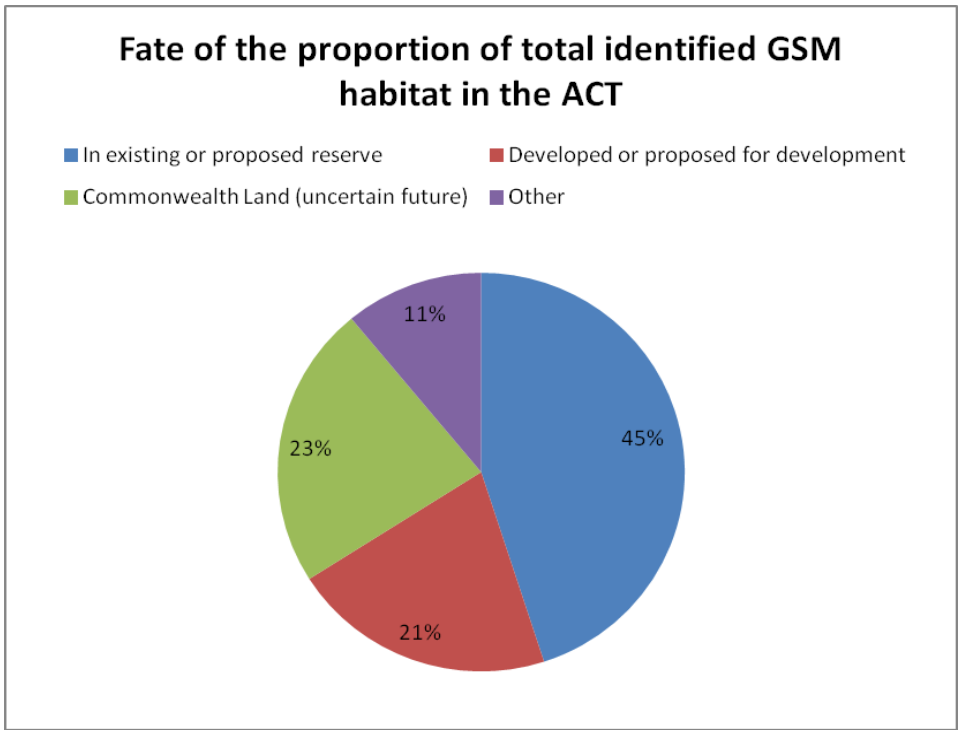


Figure 42. Fate of identified GSM habitat in the ACT (Adapted from Mulvaney (2012)).

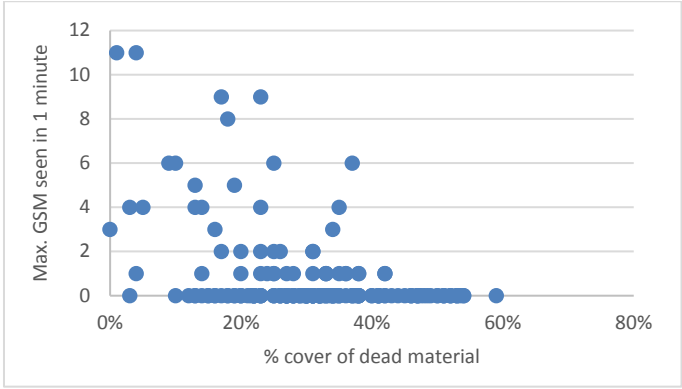


Mulvaney (2012) suggested priority areas for restoration of habitat and linkages as the grassland area between Dunlop, West Macgregor and Jaramalee (potentially in both NSW and ACT); the grasslands that link Cookanalla, Harman and East Jerrabomberra sites; unoccupied grassland on Crace nature reserve; and the Royal Canberra Golf Club extension area, Dudley St and Yarralumla Woolshed. Fragments of habitats that could be improved by weed control, plantings or other restoration work include south Lawson and the Belconnen Naval Transmission Station and the north and south ends of Jerrabomberra valley.

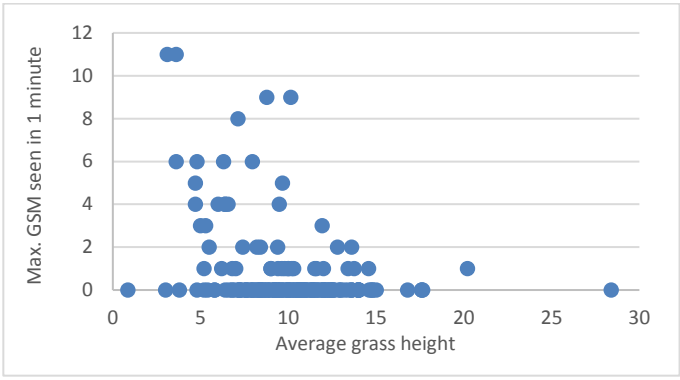
Inter-tussock spaces are considered important in assisting patrolling males to locate females displaying from a sedentary position (Gilmore and Mueck, 2010). Biomass management is therefore essential to maintain high quality habitat. Management of biomass may be through grazing with domestic stock or kangaroos, slashing or controlled burning. GSM are known to occur in areas where each of these methods has been regularly undertaken (Gilmore and Mueck, 2010).

As part of the ACT Government Grassland Restoration Project, preliminary results from GSM habitat surveys show that the percent cover of dead material has a negative relationship with the maximum number of GSM counted in one minute (Figure 43a). Average grass height for the highest counts of GSM within one minute was found to be between 5-12cm (Figure 43b) while results for the relationship between maximum GSM seen in one minute and bare ground were less clear (Figure 43c). Further analysis of these results needs to be conducted, considering the covariate of flying conditions as an interaction term and plot as random term as some plots would be inherently higher in GSM numbers due to surrounding source populations.

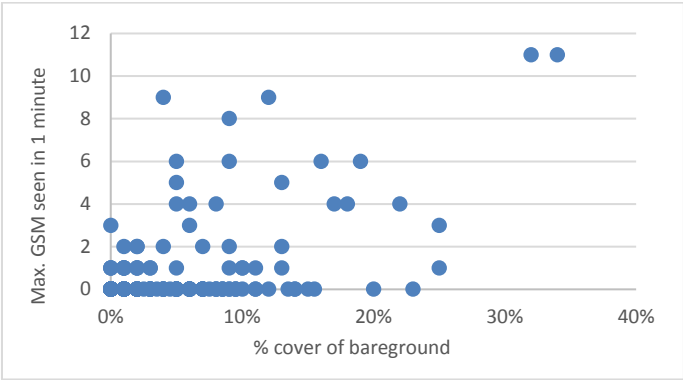
Figure 43 (a-c). Maximum GSM counts in relation to environmental variables.



(a)



(b)



(c)

On larger sites and rural sites, invasion by weeds and inappropriate fire management are the major concerns, while management by mowing or grazing can maintain low grassland structure by controlling tall species. The effects of fire on GSM remain largely unstudied. In theory GSM larvae should be resistant to fire, however there are observations suggesting that populations may fall in the years following a fire before increasing again. GSM larvae feed on the underground reserves of plants and these reserves are mobilised following a fire and may reduce food availability to the larvae. As a precautionary measure, due to the limited mobility of GSM, care should be taken with fire used as a management tool so that only a small proportion of any site is burnt at any one time.

C5.4 Pink-tailed Worm-lizard (*Aprasia parapulchella*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST ECOLOGICAL TARGET	

Summary: At present information is only available for the current known distribution of the Pink-tailed Worm-lizard (PTWL) within the ACT, and mapped potential habitat areas. There are still potential habitat areas that require mapping, with high priority given to mapping of the Murrumbidgee River Corridor (MRC). The connection of large tracts of suitable habitat should be a priority for management of the species within the ACT, including the connectivity between key habitat areas in reserve lands and across rural lease areas. NRM projects are currently working on a draft proposal that addresses some of these gaps. PCS is currently conducting research into rock supplementation for PTWL habitat restoration in addition to trialling a new, non-invasive method for survey of the species which will also benefit monitoring of other reptiles. Results of these trials should be available next CEMP plan.

Metric Assessment: This metric reviews current knowledge of the distribution of Pink-tailed Worm-lizards (PTWL s) in the ACT and potential habitat surveys. A new low-impact survey method for PTWL is currently being trialled (PCS) and may provide a robust measure of PTWL abundance at sites in the future.

Class: Minor	**Category:** Statutory – Threatened species habitat	
Primary drivers context: No data used in this assessment for primary driver context.	**Associated indicators:** C1. NTG C2. Native Flora, general C5. Native Fauna, general	**Associated stressors**: S1. Herbivore pressure S2. Fire regime S3. Invasive weeds

Rationale: The PTWL is listed as a vulnerable species in the ACT (*Nature Conservation Act 2014*) and nationally (*EPBC Act 1999*). It is a species with little known information due to difficulties in detection, and has specialised habitat requirements that may provide habitat and monitoring protocols for other reptile species not currently captured in current monitoring programs (see metric C4.1 in this document).

Projects contributing to metric: PCS research including vegetation condition monitoring and trialling of a new low-impact survey method for PTWL. Current mapping of habitat and priority restoration sites (NRM projects – draft proposal), PTWL habitat restoration.

Sampling periodicity: 1-5 years (to be determined from outcomes of new method)

Baseline: Current known distribution. First sampling results once method has been established.

Reference condition: Estimated distribution of suitable natural rocky areas in grasslands prior to large scale recent anthropogenic disturbances is unknown. The EPBC status of the Pink-tailed Worm-lizard in the ACT is Vulnerable.

Target Condition: The current approach to retain the viability of PTWL within the ACT is to protect, maintain and enhance areas of suitable rocky habitat. Mapped areas should be retained and enhanced if research findings show enhancement programs (rock supplementation) are suitable and connectivity between identified priority areas increased.

Trigger point for management: No trigger point at this time.

Qualitative input: Advice and input into this metric was sort from Dr Will Osborne.

Future research questions, management directions, knowledge gaps and recommendations: Research on best practice for abundance estimation, habitat improvement and increasing connectivity of habitat is currently under way (PCS/NRM). The invasion of exotic weed species into key habitat, in particular African lovegrass (*Eragrostis curvula*), is of concern.

Data Analysis

Early research (Barrer, 1992; Jones, 1999; Osborne et al., 1991) found that well-drained sites with a cover of partially embedded rocks provide suitable habitat for Pink-tailed Worm-lizards (PTWLs). More recently there has been extensive mapping of the potential distribution of the PTWLs in the ACT using known preferred habitat as an indicator of distribution (Wong and Osborne, 2010).

The species is found in partially embedded rocky areas of lowland native grasslands, with the highest quality sites considered to be those dominated by native grasses (e.g. *Themeda* spp.). The species can be present at sites with some level of invasion of exotic species however appears to be absent from fully pasture improved sites (Jones, 1999; Osborne and McKergow, 1993). This being so, native vegetation retention or restoration is important in addition to the retention of partially embedded rocks of a suitable size in ensuring protection of PTWL habitat within reserves.

PTWLs shelter in ant burrows and feed on the brood of a number of small ant species. The traditional method for survey of rock turning and searching is problematic because of the likely disturbance to the ant burrows, therefore impacting on their viability as habitat. The ACT Government is currently undertaking research into the development of a low-impact monitoring technique for the Pink-tailed Worm-lizard using artificial shelters (clay bricks). The trial commenced in 2014 and be conducted at three study sites known to support high densities of PTWL along the Molonglo River Corridor.

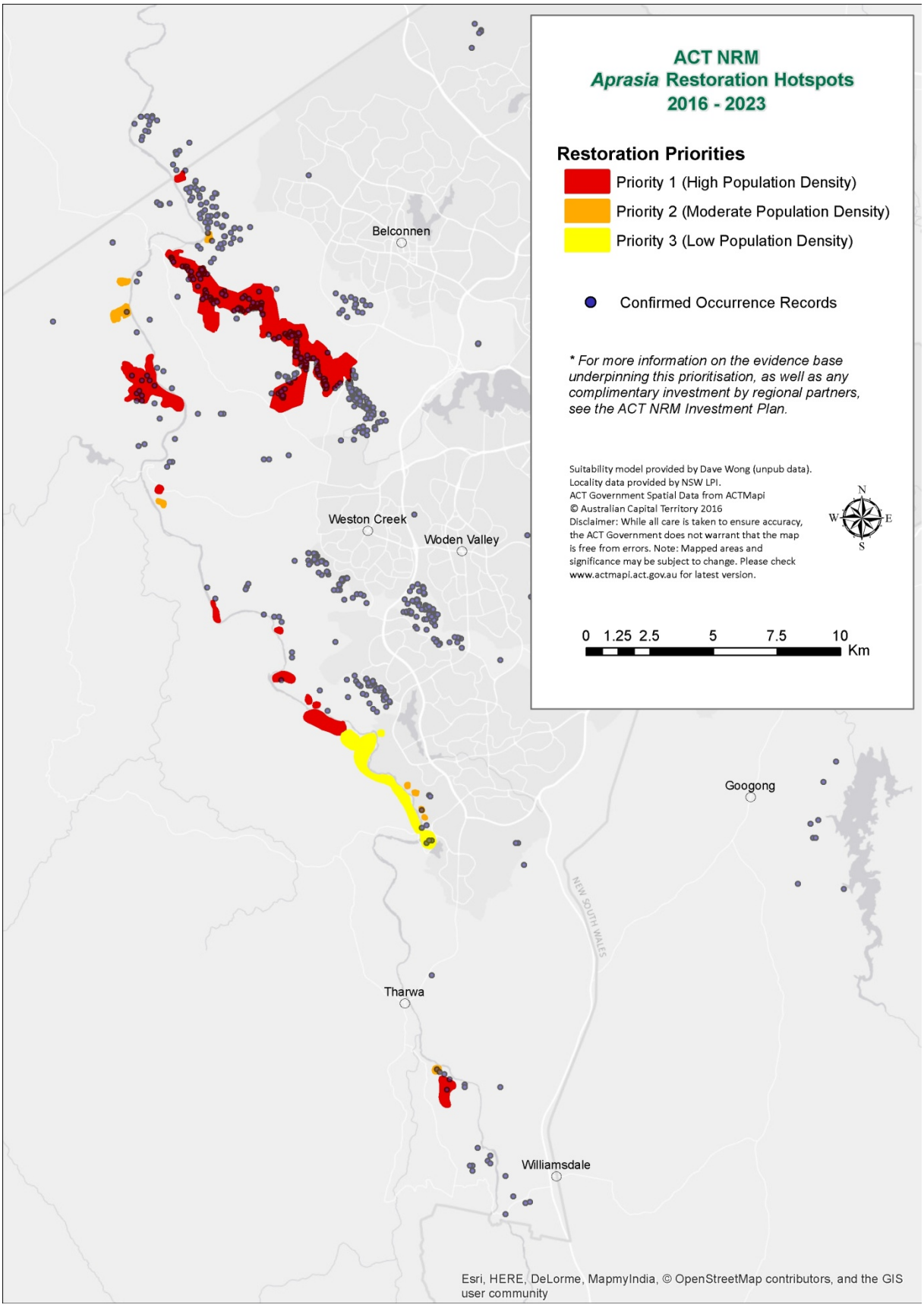
In addition to the artificial shelter trial, PCS has undertaken research into the development of a method for restoring PTWL habitat. The outcomes of this study have been used to guide large scale restoration works, including rock placement, grass tubestock planting and weed control in 2015, 2016 and 2017 (2.8 ha in total). PTWLs have been detected across a number of the restoration sites.

The restoration of rocky habitats within grasslands through PTWL habitat restoration project is likely to benefit a range of reptile species, invertebrates and potentially even plants that occupy habitats associated with PTWL. Rocky grassland habitats (more recently termed 'rocky grasslands') occupied by PTWL have been found to support a diverse plant community and are home to up to 19 other species of reptile (Osborne and McKergow, 1993). Thus conservation efforts aimed at PTWLs have broader outcomes in terms of protection of biodiversity. In addition, the inclusion of PTWL monitoring will provide a more robust measure of reptile diversity for CEMP, as the monitoring of rocky habitats in grasslands is not currently included.

The recovery plan for the PTWL in the ACT (Osborne and Jones, 1995) identifies three areas of national conservation significance: Mount Taylor; the Molonglo River Corridor from Coombs peninsular to the junction with the Murrumbidgee River and several nature reserves within the MRC. There is need for further mapping of potential PTWL where mapping has not yet been completed, with high priority given to mapping of the MRC. The MRC provides a continuous corridor connecting habitat to NSW on both sides of the ACT, so is likely to provide valuable connected habitat for the species. The connection of large tracts of suitable habitat should be a priority for management of the species within the ACT, including the connectivity between habitats in reserve lands and across rural lease areas.

Rehabilitation and restoration of habitat could be undertaken at several key locations to increase the viability of these populations across the region. NRM projects are currently working on a draft proposal that addresses some of these gaps; identifying high, medium and low priority restoration for the species mapped against confirmed records and potential habitat (Figure 44).

Figure 44. Draft map of proposed priority areas for PTWL habitat restoration (NRM projects).



MONITORING OF ECOSYSTEM STRESSORS

S1. HERBIVORE PRESSURE

S2. FIRE REGIMES

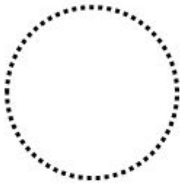
S3. INVASIVE WEEDS

S4. INTRODUCED PREDATORS

Eastern Grey Kangaroos at sunset – Little Mulligans. Photo credit Melissa Snape

1: HERBIVORE PRESSURE

S1.1 Eastern Grey Kangaroo (*Macropus giganteus*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Eastern Grey Kangaroo (EGK) density fluctuates around the target of 1 EGK/ha at most of the monitored sites, with Googong and Jerrabomberra East and West containing densities higher than the target condition range. Jerrabomberra West is currently under-grazed so this is a conscious management decision for this site. Jerrabomberra East has had very high densities of EGKs, ranging from 3-6.5 EGKs/ha since 2013. Logistical issues have delayed culling at this site. Conversely, two sites bordering leasehold land (Kama and Dunlop) may have lower than desired densities of EGKs as populations are controlled outside reserve areas on neighbouring lands.

Metric Assessment: This metric uses change in EGK density at 10 grassland sites that have been monitored annually since 2009 using standard density assessment methods including direct counts, walk line transects and sweep counts. Not all sites are monitored every year.

Class: Core	**Category:** Non-statutory	
Primary drivers context: Data sourced from years 2009-2016; Millennium drought 2001- 2009. , followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S2. Fire regime S3. Invasive weeds S4. Introduced predators

Rationale: Macropod grazing is an integral part of lowland native grasslands ecology. Changes to land use in the ACT due to pastoral improvement, installation of permanent water sources, loss of predators and urban expansion has impacted on EGK densities, sometimes resulting in overgrazing or under-grazing leading to loss of flora diversity and fauna habitat.

Projects contributing to metric: CR Kangaroo monitoring program

Sampling periodicity: Annually at selected sites (KMUs) as required.

Reference condition: Estimated natural density range for EGKs in grasslands prior to large scale recent anthropogenic disturbances is unknown.

Baseline: First year of sampling (2009 for most sites)

Target condition: Target density 1EGK/ha (optimal range of 0.6-1.5 EGK/ha) (Fletcher, 2006). Adjusted for climatic conditions, other land management activities and site priorities.

Trigger point for management: Upper limit of target density and priority site status.

Qualitative input: Research is currently underway to investigate reserve specific target densities dependant on grass associations and the needs of priority species (such as endangered or vulnerable reptile populations). Ecologists advise priority sites for culling.

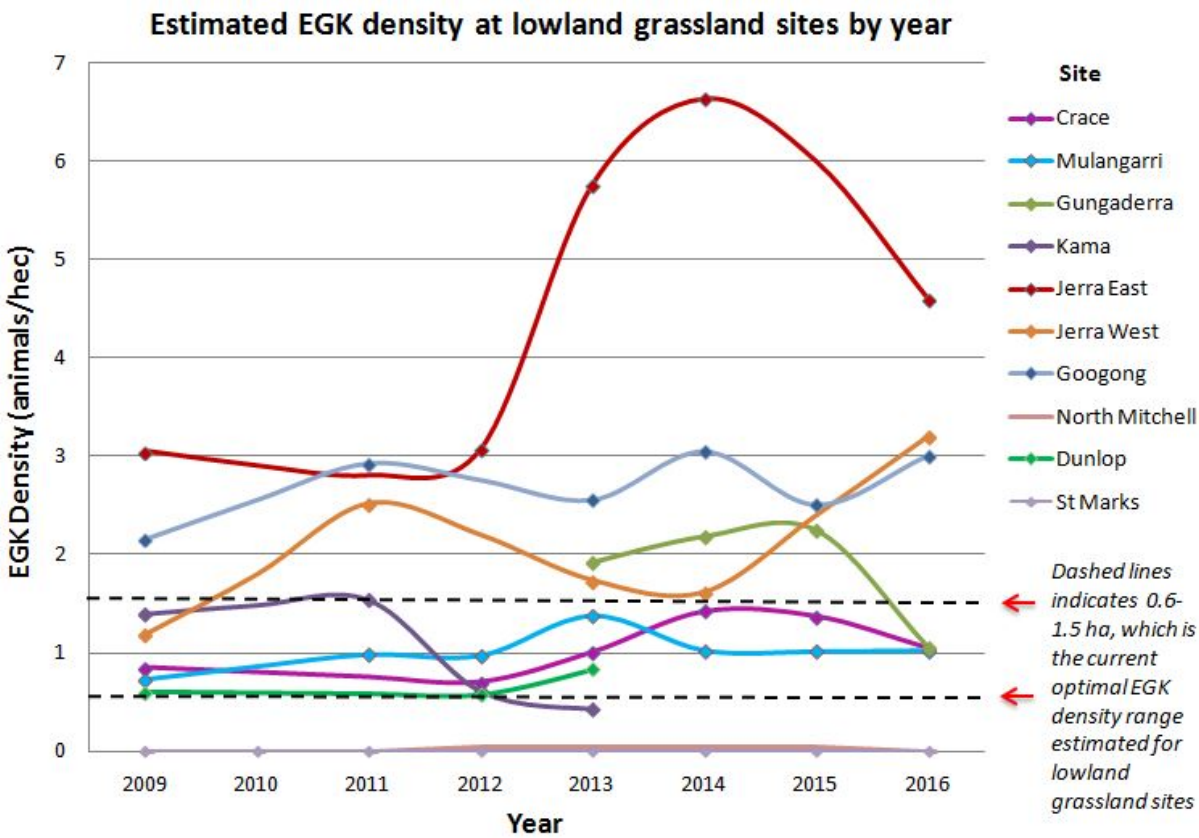
Future research questions, management directions, knowledge gaps and recommendations: Current research (CR) is examining how the recommended density may differ in response to climatic variations (e.g. drought, following very wet years) and grass associations. In addition, target kangaroo density in reserves may be dependent on habitat preferences of priority species at that site. The results of this study will be addressed in the next CEMP plan. Mapping of grass associations across CNP will enhance management decision making.

Data Analysis

Kangaroo density is not monitored at all reserves; rather monitoring sites are based on priority areas where kangaroo numbers are too high for optimal conservation outcomes and may need to be controlled (Figure 45). Different, standardised methods are used for estimating kangaroo density, with the method chosen dependant on the size and structural complexity of the site. Methods include direct counts; walk line transects and sweep counts. It has been recommended that spotlighting be adopted as a consistent survey method for collecting kangaroo abundance indices across all reserves. Direct counts and other methods used for more accurate abundance counts are time consuming and costly and are therefore not effective methods for abundance estimates in the long term.

Areas counted are referred to as Kangaroo Management Units (KMUs; refer to the Eastern Grey Kangaroo: controlled native species management plan) (ACT Government, 2017b). The number of kangaroos culled from a site is calculated using procedures outlined in the Calculation of the numbers of kangaroos to cull document. Some sites such as Kama, Jerrabomberra East and Dunlop have large variation in counts and are difficult to manage as they are bordered by rural landholders which may mange EGK populations separately. Kangaroo populations in Kama and Dunlop NR in particular may have lower than desired EGK densities as neighbouring landholders cull EGKs on rural lease lands.

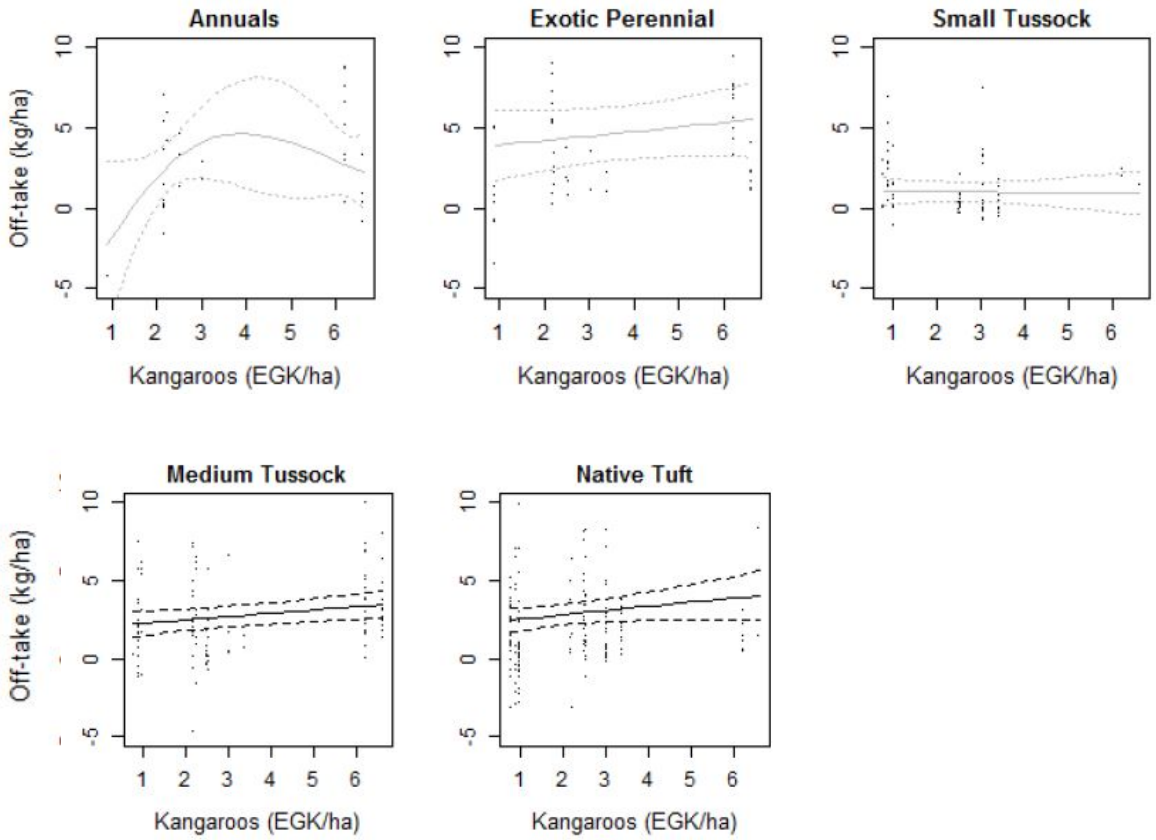
Figure 45. Kangaroo density over time at 10 grassland sites. Data for most sites have been collected since 2009, with the exception of Gungaderra. Not all sites are sampled every year. The dashed line indicates the long-term target density of 0.6-1.5 EGK/ha in grasslands.



Off-take monitoring tracks changes in pasture growth relative to changes in EGK density to determine the impact on grassland productivity. It is generally thought that grassland flora and fauna require a grazing regime which promotes a mosaic grassland structure to ensure enough inter-tussock space to provide bare ground for reproduction and regeneration of native species, but also a diversity of structure to provide suitable fauna habitat for a wide range of species.

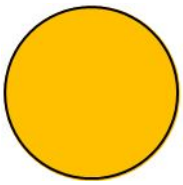
Recent research has shown that different grazing pressures are required in different grass associations (Snape et al., in review). For example, the impact of kangaroo density on the amount of grass eaten (off-take) was depended on grass type (association) with higher off-take recorded for medium tussock and native tuft grassland associations (Figure 46). This could indicate higher palatability or a preference for these grass types. Other factors that were important in determining off-take were pasture growth (determined by climate), current standing crop, and season (Snape et al., in review).

Figure 46. The relationship between kangaroo density and pasture off-take for different grass associations. Sourced from Snape et al. (in review).



Future research will re-assess relationships between herbivore densities and off-take under different climatic conditions to enable climate and site sensitive kangaroo management to be undertaken.

S1.2 European Rabbit (*Oryctolagus cuniculus)*

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: The target density for management of rabbits (0.5 rabbits/spotlight km) is evident at five of the six monitored sites. Rabbit densities were higher at Jerrabomberra East in 2013/2014, but have recently declined to less than 0.5 rabbits/spotlight km. One site, Jerrabomberra West, has very high and increasing rabbit densities, growing from an estimated 4 rabbits/km in 2013 to 6 rabbits/km in 2016. These warrens are in woodland on neighbouring leasehold lands and not on reserve estate, therefore are not managed by ACT government. There is a need to monitor conservation outcomes of rabbit control (such as vegetation response) and to gain better understanding of trigger points for management, which may be site-specific.

Metric Assessment: A relative measure of rabbits calculated from an index of activity (rabbits seen/spotlight km) using spotlighting counts at six sites. Additional sites (including offset areas and additional grassland sites) will come into the next CEMP plan.

Class: Minor	**Category:** Non-statutory	
Primary drivers context: Data sourced from years 2013-2016, which very warm years with average rainfall. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora	**Associated stressors**: S3. Invasive weeds S4. Introduced predators

Rationale: Rabbits are an introduced pest that has cause significant soil disturbance and grazing pressure in grassland reserves. Land degradation by rabbits is listed as a key threatening process under the *EPBC Act 1999* and under the *NSW Threatened Species Conservation Act 1995*, but is not currently listed in the ACT.

Projects contributing to metric: PCS spotlight counts, Offsets grassland monitoring.

Sampling periodicity: Biannual spotlight sampling – needs to be standardised as autumn/spring counts across all of PCS and environmental offsets.

Baseline: First year of sampling for each site.

Reference condition: Estimated rabbit density of zero.

Target condition: Current desired density of 0.5 rabbits per km.

Trigger point for management: Currently when populations exceed 3-4 rabbits per hectare at a site (upper and lower limits of this range may be site dependant).

Qualitative input: The density/damage relationship for rabbits in grasslands is currently unknown, so target condition densities are based on expert opinion derived from observation of what the landscape looks like under different rabbit densities. The current target densities for management are where there are no warrens in open ground, no major visual evidence of populations (bare ground, digs, scats), and flora survival and recruitment is good.

Future research questions, management directions, knowledge gaps and recommendations: A future recommendation is for research to focus on quantifying the optimal and achievable densities for rabbits in grasslands. There is little information on how rabbits may change grassland structure or species richness through selective grazing pressure. Current monitoring is focused on measurement of the threat without measuring conservation outcome of control; vegetation response to rabbit removal should be monitored following large control programs.

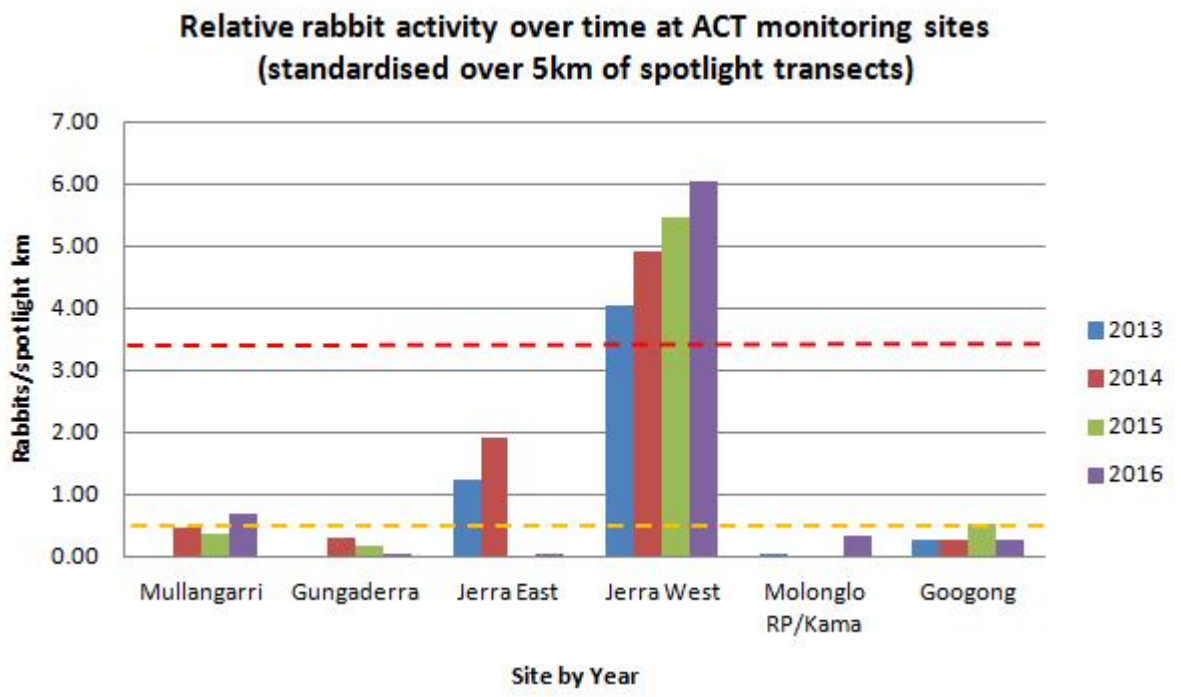
Data Analysis

Figure 47 shows trends in rabbit activity along current spotlighting transects in grasslands. Relative rabbit activity is shown without adjusting for the influence of covariates (such as moon phase and weather) on counts. Only three years of data are available for Mulanggari and Gungaderra transects, and transects at Molonglo River Corridor changed locations in 2016, influencing counts for these sites.

Rabbit numbers appear generally stable and within the target condition at most sites (Figure 47). High rabbit numbers at Jerrabomberra West are a result of a large warren in close proximity to the spot light transect but located on neighbouring leasehold land, therefore not under PCS management. There are some limitations with the spotlight method, in particular the location of tracks and accessibility to vehicles determines sampling locations, so that not all rabbit prone areas within a reserve may be sampled.

Monitoring of any active warrens was formerly used as a method to monitor rabbit activity in some reserves. There is still some monitoring of rabbit warrens conducted in Gungaderra NR and Mulanggari NR grasslands. Active warrens are mapped within Collector app and categorised as open (active) or closed with number of holes at the warren recorded. Active warrens are treated by contractors in spring and autumn, and then revisited periodically post treatment to monitor for reactivation and success of treatment. The method could be expanded to other reserves with the involvement of ParkCare and other volunteer groups. Checking for rabbit activity will form part of the quarterly reserve 'health check' and this information will feed into this metric next CEMP plan. The success of any rabbit management needs to be monitored through vegetation response.

Figure 47. Spring (Sept-Nov) spotlight counts for rabbits at six grassland sites. Data are averaged over 3 nights and standardised for 5km of transect.



S1.3 Grazing by domestic stock

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Grazing trials with domestic livestock (conservation grazing) as part of the ACT Government Grasslands Restoration Project are expected to commence 2017 at Crace NR, Gungaderra NR, Mulanggari NR and Jerrabomberra West. Currently reserve grazing plans prescribe stocking levels and rotations for each reserve, however actual stocking levels may be restricted by available stock and may not meet these prescriptions. There is a need for better records to be kept and monitoring to be undertaken when stock are used opportunistically in grassland reserves and offset areas. This may be best achieved by the formation of 'land management units' identifying areas and specifying associated grazing histories. This will greatly assist PCS in quantifying and gaining a better understanding of the impacts and benefits of stock grazing on priority species and ecosystems. Grazing may be used as an initial tool to reduce biomass prior to ecological burning (see section S2: Fire Regimes).

Metric Assessment: Floristic and biomass data will be compared before and after grazing takes place. In addition, records of number and type of stock in a given area (DSE), and dates of grazing (length of grazing time/season) needs to be recorded for all grazing events.

Class: Minor	**Category:** Non-statutory	
Primary drivers context: No data used in this assessment for primary driver context.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S3. Invasive weeds S4. Introduced predators

Rationale: Stock are used in grassland reserves to maintain grassland structure, and to lower biomass in areas dominated by exotic grasses that are under grazed by native herbivores.

Projects contributing to metric: PCS grazing trials

Sampling periodicity: Opportunistic whenever grazing is used as a management tool.

Baseline: Condition of grassland site prior to grazing (or first grazing event where attainable).

Reference condition: Estimated natural density range for EGKs in grasslands (natural grazing regime) prior to large scale recent anthropogenic disturbances is unknown.

Target condition: An increase in structural heterogeneity and native plant species richness at the site, a decrease in exotic plant species and a reduction in biomass to a suitable level for target priority species and to encourage a diversity of native fauna.

Trigger point for management: A defined biomass level for different grass associations to be established so that grazing as a management action at these sites can be implemented.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: There is a dire need for accurate and consistent record keeping and data collection whenever stock are used for biomass control in reserves. Information such as prior condition, biomass and species dominance at each site, season and duration of grazing, stock type and amount per unit area (DSE) should be recorded, as well as follow up information on conservation gains, so recommendations of conservation grazing as the optimal method to improve/maintain floristic diversity and faunal habitat can be assessed. One possible way of improving record keeping of grazing activities in addition to tying in historical grazing to other datasets would be the use of land management units.

Data Analysis

The use of domestic stock for increasing natural values in grassland ecosystems is termed conservation grazing. Historically the use of grazing grassland in reserves has primarily been to control fire risk, however the purpose of conservation grazing is to maintain grassland structure and composition, control problem weed species and to lower biomass in areas dominated by exotic grasses (particularly phalaris and wild oats) that are under-grazed by native herbivores. Historically there has been little or no recording of ad-hoc grazing activities conducted within ACT reserves. In the future, basic data on location, timing and amount of grazing (DSE), in addition to other covariates where possible, needs to be recorded for any grazing activity conducted on reserve lands so that information on grazing history is available to contextualise changes in ecosystem condition. This may be best achieved by the formation of 'land management units' within grassland reserves, which can identify areas of land at the paddock scale and specify associated grazing histories.

Conservation objectives, exotic species, and biomass measurements should be used to trigger the use of conservation grazing, coupled with an assessment of thatch depth. Grazing may be used as an initial tool to reduce biomass prior to ecological burning when thatch coverage and depth is high (see section S2: Fire Regimes). A management response to initiate or withdraw grazing at a reserve should be determined by the capacity to use ecological burning (where grazing is implemented at sites where ecological burning capacity is low), and follow predetermined estimations of biomass and proportion of bare ground, in addition to other considerations such as reserve location, stock availability, fencing suitability and exotic vs. native pasture dominance. Reserve grazing plans will identify conservation objectives for each paddock and from this define required timing of grazing and stock rotations for each reserve. Issues beyond the control of PCS, such as availability of livestock stock, complicate the use of this management tool for biomass control.

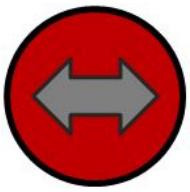
A simple snap-shot tool for estimating biomass in the field is the golf ball method (Morgan, 2015). The golf ball method enables a quick estimation of biomass and structure at the plot level, which can then, with sufficient sample size in representative vegetation types and grass associations, be used to estimate biomass loads across a reserve or even at a site level within a reserve. A manual for the use of the gold ball method to estimate biomass in ACT reserves, included standardised methods for assessment, is currently under construction. An estimation of biomass using the gold ball method may be incorporated into the periodic 'health checks of ACT grassland reserves.

The monitoring of biomass levels periodically across grassland reserves to assess the need for management intervention could alternatively be captured using remote sensing imagery through technology such as drones. Information on biomass levels could then be coupled with standardised procedures outlined in a document compiling current information on biomass thresholds for species and communities to make more informed management decisions.

While livestock have been used as a biomass management tool for some time, use has been sporadic and poorly documented, so that there were no data available for this metric at this time. As part of the ACT Government Grasslands Restoration Project, grazing trials are expected to commence at two locations (Crace NR, Gungaderra NR, Mulanggari NR and Jerrabomberra West) in 2017. There is a need for better records to be kept and monitoring to be undertaken when stock are used opportunistically in grassland reserves. Better record keeping in addition to outcomes from livestock grazing trials will greatly assist PCS in quantifying and gaining a better understanding of the impacts and benefits of stock grazing on priority species and ecosystems.

S2: FIRE REGIMES

S2.1 Fire frequency within recommended ecological thresholds

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Less than 20% of the area of NTG lies within tolerable fire intervals for this ecosystem, and for lowland native grasslands (not including NTG) and exotic grasslands this proportion is much lower. These results highlight a need to increase fire frequency to maintain native species diversity, although impacts on many fauna species remain unknown.

Metric Assessment: Ecological fire thresholds were used to define the upper and lower limits of time since fire (TSF) intervals, outside of which changes in the composition and structure of lowland native grassland ecosystems are likely. The current age class distribution was compared to the ideal distribution based on minimum and maximum tolerable fire intervals (TFI's). The percentage of areas that has been burn below, within and above the calculated TFI was then calculated. These percentages can be used to track status over time.

Class: Core	**Category:** Non-statutory	
Primary drivers context: Data sourced from available historical fire records (from 1900). Contrasting landform and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S3. Invasive weeds

Rationale: Minimum and maximum inter-fire intervals have been defined for all ecological communities in the ACT. Burning or outside of these intervals is likely to have adverse impacts on conservation values within communities. *Themeda* dominated grasslands are generally well adapted to fire, however the response of C3 dominated grasslands is less clear. Much of the lowland native grasslands are no longer burnt as often as would have occurred historically due to risk of loss of surrounding assets.

Projects contributing to metric: CR Fire Ecology Program

Sampling periodicity: Annually

Baseline: Assessment for this CEMP plan.

Reference condition: Ecological fire threshold for lowland native grassland vegetation communities have been defined. The ideal TSF interval calculated for the maintenance of lowland native grasslands is 3-12 years.

Target condition: Grasslands managed within maximum/minimum recommended ecological thresholds (TFI) for fire frequency.

Trigger point for management: No trigger point at this time. Above maximum desirable threshold in addition to assessment of biomass, thatch cover/depth and native species persistence at the site need to be considered to define trigger point for management.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: Fire history requires improved data capture protocols to ensure consistency of data and accuracy of interpretation. There is a need to revise current ecological thresholds (TFIs) to include responses of different grass associations and fauna fire response. There is a need to research fire impacts in C3 dominated grasslands (this may be currently underway externally by Ginninderra Catchment Group) and improve knowledge of ecosystem dynamics under different fire frequencies, intensities, and seasonality.

Data Analysis

Ecological thresholds, also known as Tolerable Fire Intervals (TFI) define the upper and lower limits of the inter fire interval for ecosystems outside of which repeated fire events are likely to change the composition and structure of ecosystems and reduce biodiversity conservation values. The current time since fire (TSF) age class distribution can be statistically and graphically compared with an 'ideal' age class distribution based on the minimum and maximum ecological threshold (TFI) of a particular ecosystem. The ideal age class distribution can be estimated as normally distributed (shaded grey on Figure 48a-c) with a mean equal to the mid-point between the min and max TFI and a standard deviation such that 95% of values fall between the min and max TFI.

For this metric we estimated the ideal age class distribution for lowland native grasslands. The ideal age class distribution can then be compared to the known age class distribution for that ecosystem by calculating the percentage of area that had been burn below, within and above the calculated TFI. These percentages can then be used to track condition or status over time. The Kolmogorov-Smirnov test was then used to determine the statistical difference between the actual and ideal age class distributions. This provides a comparative measure of deviation of the actual time since fire (TSF) distribution from the ideal distribution (Table 11).

Results indicate a severe lack of burning in lowland native grasslands. The ideal fire frequency for maintenance of healthy and diverse lowland native grassland ecosystems is thought to be 3-12 year fire intervals. Data shows that more than half of the lowland native grasslands have not been burnt for in excess of 100 years (Table 11; Figure 48a-c). In Natural Temperate Grasslands there has been a larger proportion of area burn within the last 20 years than within non-NTG lowland native grasslands (excluding NTG) and exotic grasslands, however this still only represents less than 20% of the area of NTG within recommended TFI, and much less than this in grasslands dominated by native pasture or exotic species (Table 11; Figure 48a-c).

For sites that have high biomass, a good native seed bank and a deep layer of thatch, fire may be the best management option for grassland restoration and for the maintenance of grassland ecosystem health. In addition to the monitoring of biomass (see metric S1.3 of this document), there is a need to conduct regular monitoring of thatch cover and depth in grassland reserves. The monitoring of thatch cover and depth periodically along set transects is recommended to be incorporated into regular 'health checks' within ACT lowland grassland reserves.

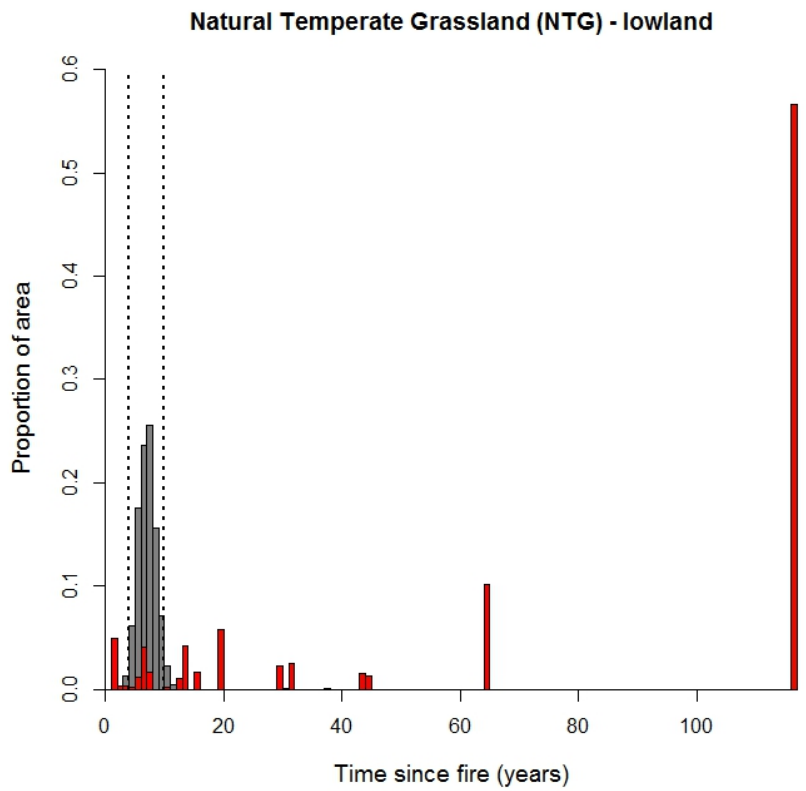
Table 11: Kolmogorov-Smirnov test ('D' statistic) indicating dispersion of actual time-since-fire (TSF) distribution from ideal distribution for lowland native grasslands. Results are shown separately for NTG, lowlands native grasslands (other than NTG) and exotic grasslands. P values indicate if the difference between actual and desired distribution is statistically significant.

	Min TFI	Max TFI	Mean TSF	SD TSF	Median TSF	% below min	% within range	% above max	D Stat	*p* -value
NTG	4	10	78.4	46.7	117	5.3	7.1	87.3	0.871	<0.001
LNG	4	10	93.4	39.1	117	0.9	0.4	98.6	0.986	<0.001
Exotic	4	10	97.6	38.2	117	0.6	1.9	97.5	0.972	<0.001

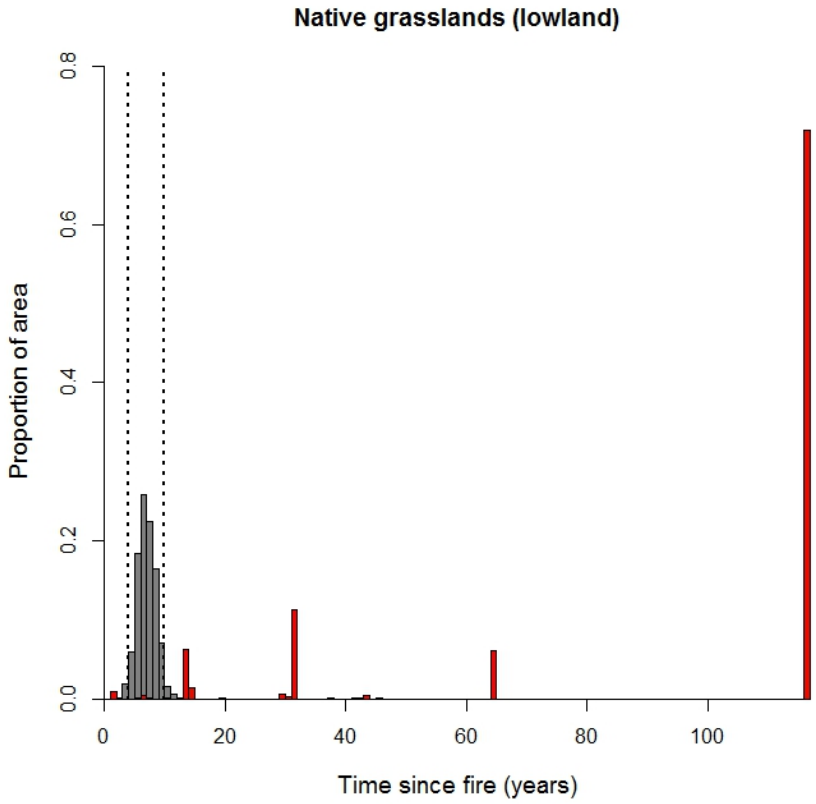
There is a need for a trigger point to be established that combines assessment of biomass accumulation, thatch cover/depth and persistence of native species at a site in order to initiate management actions prior to thatch and biomass becoming constraining factors for flora diversity and fauna species. This trigger point needs further clarification and is likely to be site-specific, relating to dominate grass associations and the presence of threatened species. Other relevant research that may assist management includes investigations into optimal patch size and fire intensity as well as the impact of fire frequency on fauna species; findings from which all may be relevant to determine future TFIs within lowland native grassland ecosystems.

Fire may be a management tool that is used in conjunction with other biomass control techniques. For example, livestock grazing may be implemented prior to burning to assist in lowering biomass and grass height initially and aid in breaking up thatch layers (see section S1.3), thus reducing fire severity when burns are conducted. The widespread lack of recent fire in lowland native grassland ecosystems is likely to be a primary constraint in maintaining native species dominated grasslands. As a result there appears to be an abundance of opportunities across reserves to conduct burning activities that may compliment or enhance other management objectives, such as threatened species conservation, in addition to adding to the current body knowledge on preferred fire intervals in grassland ecosystems. There have been recent efforts to increase the extent of burning in grassland reserves, including the use of cultural burns and this will be continued in the future.

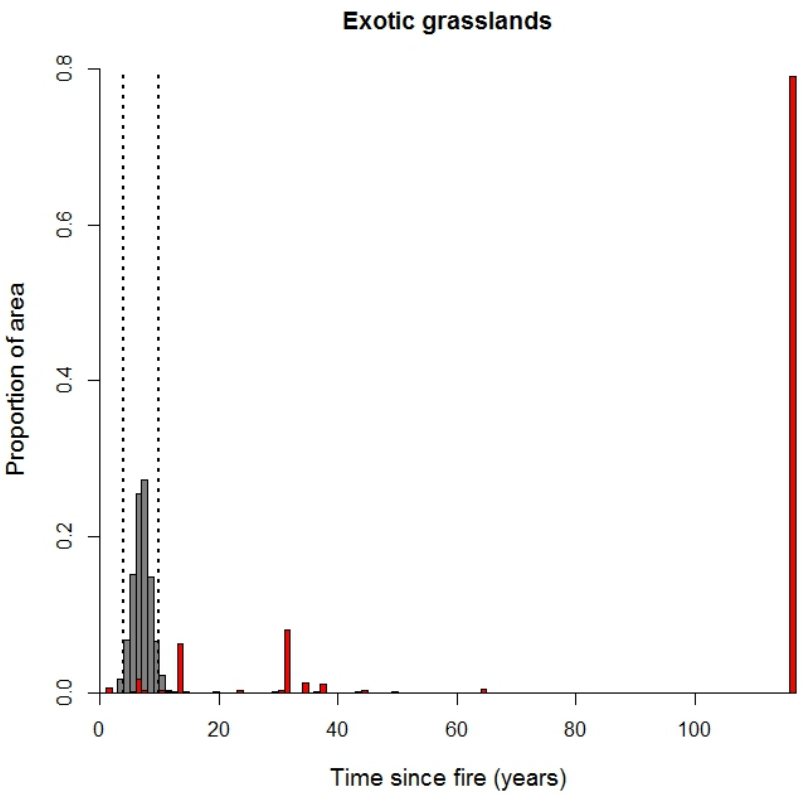
Figure 48 (a-c). The estimated proportion of (a) NTG, (b) other lowland native grasslands (i.e. native pasture) and (c) exotic grasslands in each time since fire (TSF) age class. Dotted lines on each graph indicate the minimum and maximum threshold for the desirable fire interval for this ecosystem, grey bars indicate the ideal TSF distribution and red bars indicate actual TSF distribution.



(a)

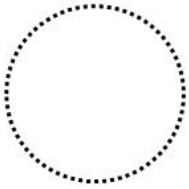
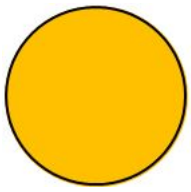

Native grasslands (lowland)
Proportion of area
0.0
0.2
0.4
0.6
0.8
0
20
40
60
80
100
Time since fire (years)

(b)


Exotic grasslands
Proportion of area
0.0
0.2
0.4
0.6
0.8
0
20
40
60
80
100
Time since fire (years)

(c)

S2.2 Fire seasonality within recommended ecological guidelines

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Less than 2% of any of the lowland native grassland habitats identified for threatened species have been burnt in the past four years. Of this 2%, most burns were conducted within recommended guidelines for season; however, no burning is recommended in GED habitat so all burns conducted in this habitat were out of season. Currently research is examining the impact of seasonal burns on native flora and some threatened fauna species. The recommended guidelines for seasonality of burns need to be reviewed as more knowledge of the impact of season of fire on grass associations and faunal species is gained.

Metric Assessment: This metric assessment estimates the proportion of habitat or known populations for threatened flora and fauna species for which recent burns fall within and outside the recommended burn season. The metric uses the PCS fire history spatial layer intersected with habitat and point data for threaten species. Current limitations include the lack of fire seasonality data in the fire history layer and lack of records for burns off reserve.

Class: Core	**Category:** Non-statutory	
Primary drivers context: Data sourced from 4 years of historical fire records (from 2013-2017). Contrasting landform and grazing regimes occur between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S3. Invasive weeds

Rationale: The timing of fire in relation to life cycles of plants and fauna in grasslands can impact on conservation values. Burning at crucial reproductive phases is thought to reduce the diversity and abundance of grassland flora and fauna (Morgan, 1999a). The ACT Government has developed ecological guidelines for implementation at planning and operational levels of fire management. These guidelines define seasons that areas containing certain ecological assets can be burnt to minimise any impact.

Projects contributing to metric: CR Fire Ecology Program, ACT Government Grassland Restoration Project

Sampling periodicity: Fire history layer updated annually.

Baseline: Assessment for this CEMP plan.

Reference condition: Unknown

Target condition: 100% of grasslands managed within maximum/minimum recommended ecological thresholds for fire season

Trigger point for management: No trigger point at this time but all proposed prescribed burns are reviewed against Ecological Thresholds including fire seasonality.

Qualitative input: Nil.

Future research questions, management directions, knowledge gaps and recommendations: Current recommended burning seasons in grasslands are mostly based around fauna conservation needs (particularly for reptiles which are less active in cooler months) rather than flora /habitat enhancement. These guidelines need to be reviewed for a more holistic approach to management of lowland native grasslands. There is an information gap where burning that occurs outside PCS managed lands currently is not recorded in the fire history layer.

Data Analysis

This metric estimates the proportion of habitat or known locations for both threatened flora and fauna species that has burnt within and outside the recommended burning season. Both planned (prescribed) fire and wildfire are included in the analysis. Button Wrinklewort is the only plant species for which the proportion of known points was used for fire seasonality analysis. For this species some points represent populations of as many as 1000 plants while others points represented less than five individuals. A further limitation to the analysis was that fire seasonality was only recorded consistently in the fire history layer back to 2013 and consequently this metric was only calculated for the past three years.

Current ecological guidelines for season of burning for listed taxa in lowland native grasslands are given in Table 12. No burning is currently recommended in GED habitat, although recent research has conducted burns at some sites with preliminary success (ACT Government Grassland Restoration Projects). In PTWL habitat, current advice identifies a suitable burning window between mid-winter and mid-spring (mid-July to October), although August and September are preferred burning months. Burning of SLL should be restricted to early spring (September/October) prior to the summer breeding season, or alternatively conducted during early autumn (March/April) to ensure sufficient regrowth of habitat before winter. In GSM, burns are advised to be conducted only between March and October to avoid the summer adult flying season. Finally, for Button Wrinklewort burns should be conducted between April and November to avoid summer flowering and fruiting (Table 12).

Table 12. Current ecological guidelines for season of burning for listed taxa. Green cells indicate acceptable months for low intensity patchy burning.

Listed Taxa	Burning window											
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Grassland Earless Dragon												
Pink-tailed Worm Lizard												
Striped Legless Lizard												
Golden Sun Moth												
Button Wrinklewort												

The outcome of the analysis showed that less than 2% of any of the habitats identified for threatened species had been burnt in the past four years (also see metric S2.1 above). Most burns occurred within recommended guidelines for season with the exception of one fire in GSM habitat in 2013, one fire in SLL habitat in 2016. In additional and all burns conducted in GED habitat were outside of current guidelines but these were implemented as prescribed ecological experiments (Table 13).

Currently research (ACT Government Grassland Restoration Project) is examining the impact of seasonality of burns on native flora and some threatened fauna species. Preliminary results show a preference for the use of autumn fires in lower quality sites without heavy thatch, while spring fires

at heavy thatched sites with good native seed bank appear optimal. In addition, the seasonality of fires and site specific needs requires further research. For example, dominant grasses (whether C3 or C4) may require different seasonal burning regimes and tolerable fire intervals (see metric S2.1). External research by Ginninderra Catchment Group is also examining the impacts of seasonal burning on different grassland associations and initial condition states, findings from which could be incorporated into future guidelines. It is likely that the above recommended guidelines (Table 12) will be updated as more knowledge of the impact of fire seasonality on grass associations and faunal species is gained.

Table 13. The proportion of planned fires and wildfires that occurred in and out of seasonal guidelines for threatened species since 2013.

Species	Year	Total area burnt	Total % habitat burnt	% habitat burnt IN	% habitat burnt OUT	No. Burns IN season	No. Burns OUT season
GSM	2013	11.7	0.62	0.53	0.09	2	1
	2014	0.2	0.01	0.01	0	1	0
	2015	17.8	0.94	0.94	0	6	0
	2016	16.7	0.88	0.88	0	4	0
GED	2013	0.2	0.02	0	0.02	0	1
	2014	2.1	0.20	0	0.20	0	1
	2015	13.5	1.29	0	1.29	0	2
	2016	18.8	1.79	0	1.79	0	1
SLL	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	0.6	0.03	0.03	0	1	0
	2016	29.2	1.54	1.53	0.01	3	2

A final limitation to this analysis is that not all fires are recorded in the fire history GIS spatial layer used in this analysis. Burns that are not conducted by PCS (i.e. burns conducted on leasehold, private or federal lands) and wildfire outside of PCS managed land are often not recorded, resulting in inaccuracies of burn histories. This information gap needs to be addressed by implementing more effective recording processes that enable more thorough and accurate data to be captured.

S3: INVASIVE WEEDS

S3.1 Change in priority weed distribution and density

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: There have been large improvements in weeds data capture since 2014 using mobile applications for weed mapping and increased follow up weed control activity; however standardised methods for estimating density are needed. Improved information is needed on what weeds are detected but not treated, a measurement of effort is needed and more follow up measurements on the improvement in natural values following weed control should be undertaken for monitoring of effectiveness. Results indicate prioritisation of weed control in NTG is evident and that follow up treatment is important in reducing priority species.

Metric Assessment: This metric examines 1) the change in extent (area) of priority weeds in exotic, native dominated, and NTG grasslands and 2) the proportion of follow up weed control (treatments) in different density categories over time. The effectiveness of different control methods will also be assessed in future plans. Changes in weed distribution mapping and estimation of density means that only data from late 2014 onwards is used in this metric.

Class: Core	**Category:** Non-statutory – Threatening process	
Primary drivers context: Data sourced from years 2014-2017, which were warm years with average rainfall. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime

Rationale: Highly invasive weeds identified for ACT lowland native grasslands include African Lovegrass (*Eragrostis curvula*), Serrated Tussock (*Nassella trichotoma*), Chilean Needlegrass (*Nassella neesiana*) and St John's Wort (*Hypericum perforatum*). These species have the potential to out-compete native species and change the composition, structure and functionality of lowland native grasslands.

Projects contributing to metric: PCS - Weed mapping

Reference condition: Distribution and density of weeds equals zero.

Sampling periodicity: Ongoing throughout the year, seasonal control of some species.

Baseline: Weed mapping data used in this assessment dates back to 2009 for some species.

Reference condition: Zero weeds in grassland ecosystems.

Target condition: Ecological threshold for the density of highly invasive weeds is <1%. In degraded grasslands management may aim to improve condition up to novel ecosystems (not fully native but some and continued improvement in exotic species densities).

Trigger point for management: >1% density for highly invasive weeds.

Qualitative input: Senior Weeds Officer concludes that if a problem weed is removed from an area and replaced with a benign weed this would be an improvement for the ecosystem.

Future research questions, management directions, knowledge gaps and recommendations: There is a need to monitor the response of native flora in response to weed control (i.e. measure cover and diversity of native species before and after treatment) to show measured benefits of weed control. There is a need to standardised density estimation, methods for which are currently being explored. There is also a need to standardise effort through recording of complete searches vs. opportunistic sightings or roadside verge control. These changes will increase the ability to detect changes in weed area and density in response to control activities.

Data Analysis

Changes in extent of four priority weed species (African Lovegrass, Chilean Needlegrass, Serrated Tussock, and St John's Wort) were examined in exotic, native dominated, and NTG grasslands. Changes in extent were compared for areas with repeated weed control treatment to assess the amount of control conducted in priority grassland ecosystems. Areas of control were then adjusted by taking account of the proportion of exotic, native, and natural temperate grasslands across the ACT. Calculations were based on an estimated 2116 ha of exotic pasture, 2963 ha of native pasture and 889 ha of Natural Temperate Grassland within lowland native grasslands in the ACT (CR vegetation mapping 2016).

In grasslands, high priority areas include areas of NTG and areas where threatened species populations occur. Weed risk and prioritisation for control is currently assessed using the triage method (Downey et al., 2010). One consideration is that risk will vary according to both the weed species and community/protected plants present; for example, St John's Wort is a low risk to many communities but a high risk to others. Recent, large improvements in the accuracy of weed distribution mapping and estimation of density meant that only data from late 2014 onwards was used in this metric.

Results show that for the first treatment, larger areas of native grassland are controlled for all four species with the exception of St John's Wort where larger areas of exotic grassland are treated (Figure 49). However, when treated areas are adjusted for the proportion of exotic, native and Natural Temperate Grasslands in lowland native grasslands, results indicate a high prioritisation of control of all four species in NTG areas across all treatment numbers, with prioritisation of NTG particularly evident in early treatments (Figure 49).

In addition to treated area, the number of sites treated for the same four species was examined. Number of sites treated was compared by density category over time (number of treatments). Results show that for all species there were greater amounts of area treated where higher weed densities occurred, and for all species except for St John's Wort, there was an increase in the number of sites in the second treatment, before decreasing to fewer sites in consecutive treatments (Figure 50a-d).

The number of treated sites in different density categories over time demonstrates the importance of follow up control for these highly invasive species. For African lovegrass in particular, the importance of follow-up control is shown with some sites having required seven treatments over the past three years (Figure 50a). In addition to the need for follow up treatment often multiple times a year, there is also an issue of seed bank and germination in areas even when adequate control is conducted. In addition to tracking changes in area and density, it is hoped that future plans will be able to examine the effect of timing of treatments and compare the effectiveness of different chemicals used for control.

Since 2014, weed control data have become more robust, with more accurate mapping of controlled areas and data collection procedures standardised using mobile devices. Accuracy and consistency of data is needed to make useful comparisons before and after weed control treatments over time. With issues of mapping accuracy now addressed, there remains the need to standardise weed density estimation. This might be best achieved with density estimated across a standardised area.

Figure 49. Area of priority weeds controlled by grassland category over time (treatment number).

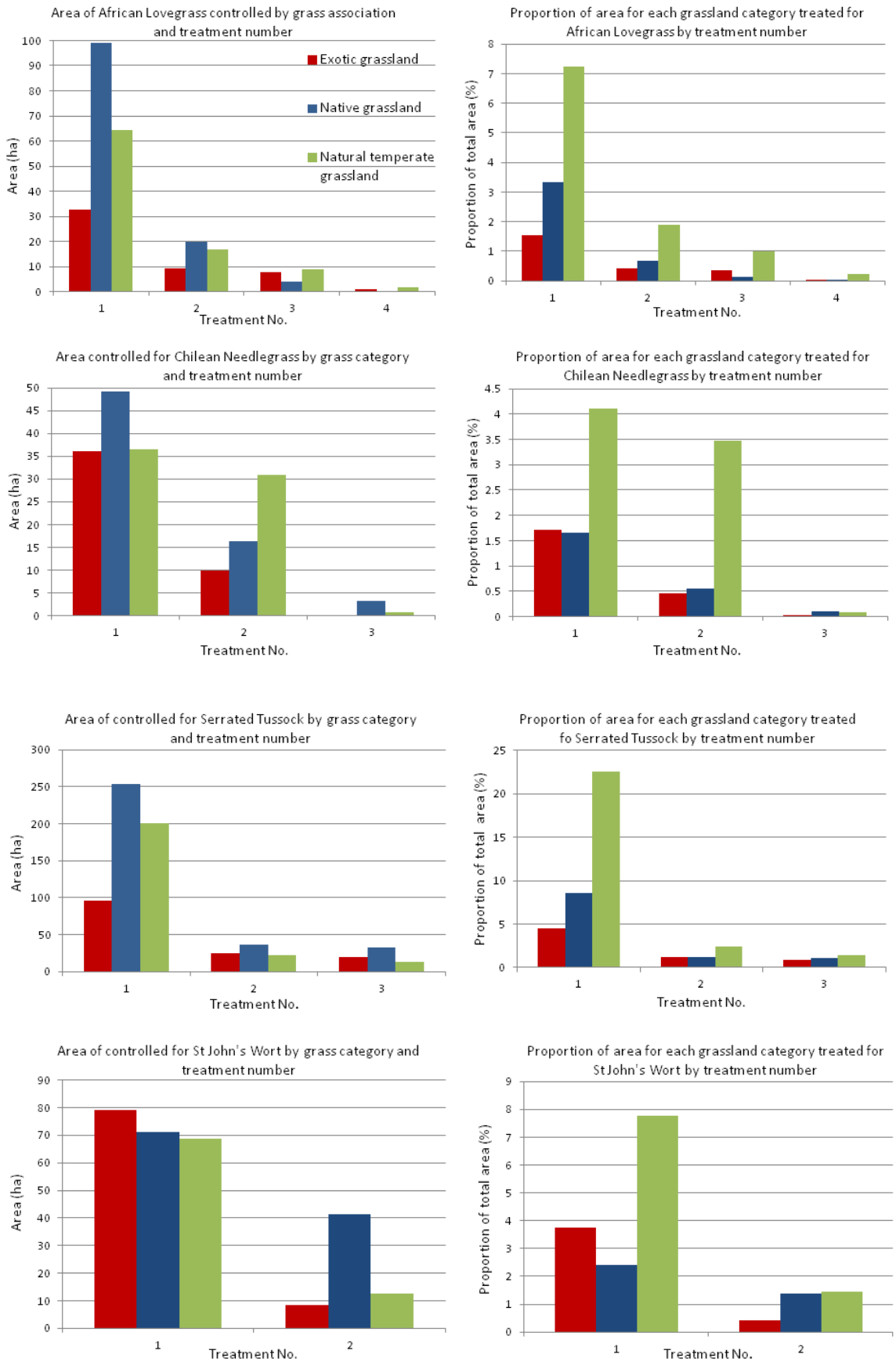
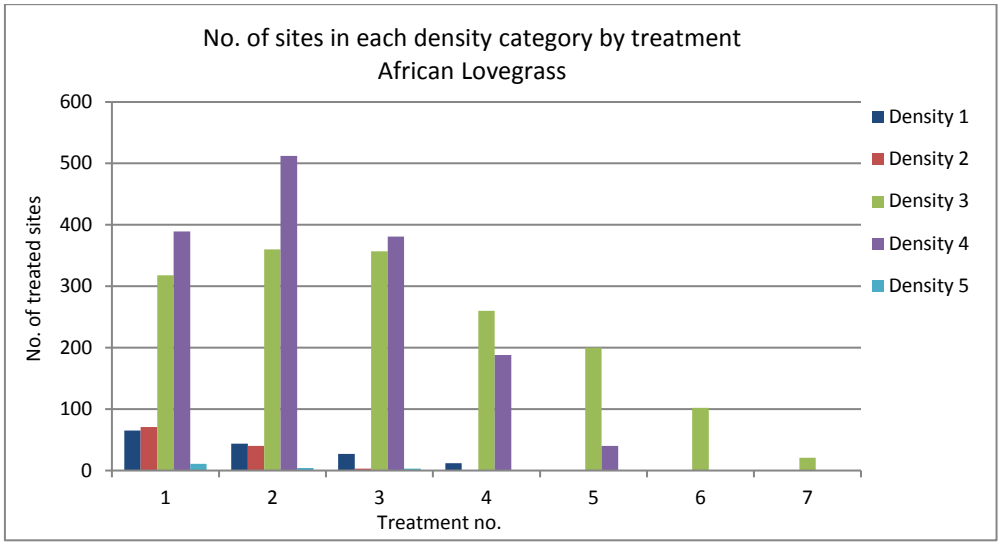
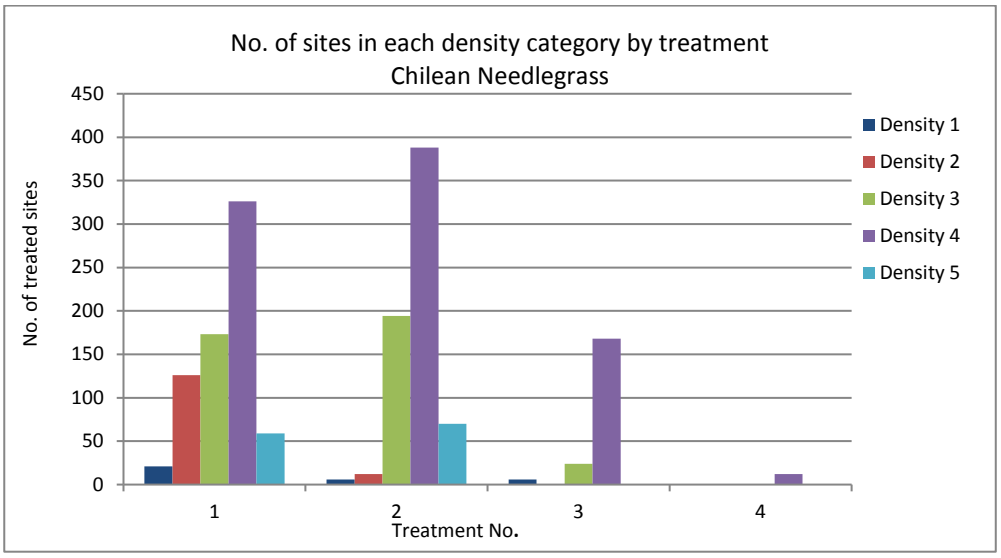


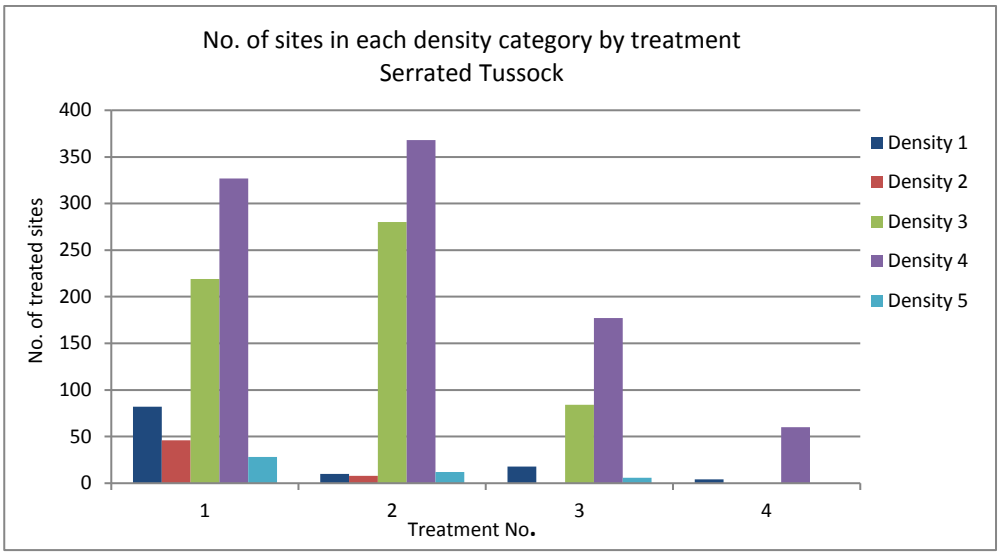
Figure 50(a-d). The number of treated sites in each density category for four priority weeds over time (treatment number). Density categories can be quantified as follows: Category 1 = < 1% ground cover; Category 2 = 1-10% ground cover; Category 3 = 11-25% ground cover; Category 4 = 26-50% ground cover; Category 5 => 50% ground cover.



(a)

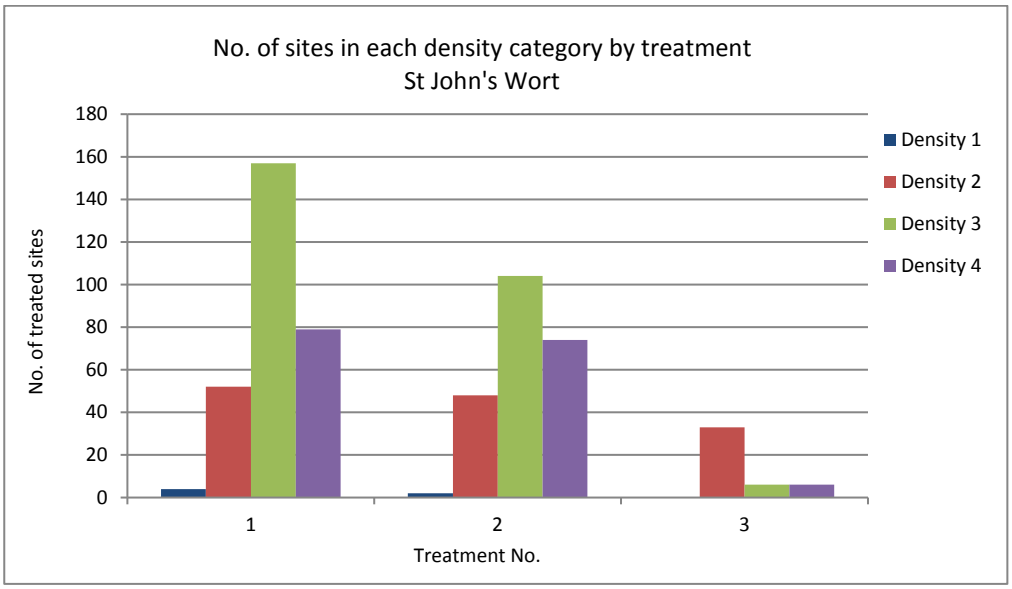


(b)



(c)

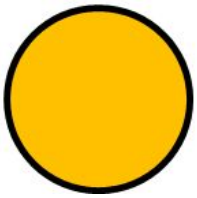
(d)



The extent of both treated and non-treated areas have been mapped since 2015 and this data will provide valuable further assessment of weed control in the next CEMP plan. There is a need to delineate search effort from control effort for all reserves and species. This is so that opportunistic sightings and control works can be separated from areas where a full search has been conducted, and therefore extent and density across the larger area is 'known'. Future records should include mapped areas of all search effort as well as areas where control works have been conducted. This information is easily passed through to rangers, contractors and field staff through ARC GIS online.

Finally, there is a need to record conservation outcomes in treated areas, such as any changes in native species cover or whether the treated weed was replaced with a more benign exotic, even if these areas are not treated again. The weed control spatial mapping layer can be used to target and prioritise areas where post weed control response of native species could be recorded over time. The response of treated patches to control activities may be incorporated into regular 'health checks' within reserves. Alternatively, monitoring of the response of native species post weed control compared with untreated areas may be conducted by community groups. Community monitoring could possibly be extended to the monitoring of higher risk areas such as along roadsides and walking tracks. Additionally, there have been some trial plantings of native species into infestations of Chilean Needle Grass by PCS and these are currently being monitored.

S3.2 New invasive weed incursions

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Incursions of Madagascan Fireweed (*Senecio madagascariensis*) and Mexican Feathergrass (*Nassella tenuissima*) have been successfully controlled at a number of sites. Follow-up treatments of both species have been highly effective at reducing both number of plants and area of infestation. Of critical importance to the success of controlling new infestations is the existence of a dedicated weed control officer (currently located in TCCS) that conducts targeted control works at infestation sites. This has greatly increased efficiency of weed control and has significant positive impacts in the long term. Lack of accurate mapping and missing data prior to 2015 has made comparisons overtime difficult, but these issues have now been addressed and should not be encountered in next CEMP plan.

Metric Assessment: Assessing the amount and distribution of new weeds incursions into previously uninhabited areas, or of new weed species entering the ACT region. Two species that represent a threat to lowland native grasslands were chosen for case studies. Response to new incursions was assessed at sites with repeated treatments. The effectiveness of follow up control and a measure of lack of spread was assessed.

Class: Minor	**Category:** Non-statutory – Threatening process	
Primary drivers context: Data sourced from years 2008-2016. Millennium drought 2001- 2009, followed by very wet years 2010/11 and very warm years with average rainfall during 2012-2016. Contrasting landform, fire and grazing regimes between sites.	**Associated indicators:** C1. NTG C2. Native Flora, general C3. Threatened Flora C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure S2. Fire regime

Rationale: There are many weeds that have not yet made it into the ACT that have the potential to cause significant ecological damage to lowland native grasslands. The ACT Government has biosecurity procedures in place to respond to new emerging outbreaks of invasive weed species and those that are assessed as potential high risk are prioritised for eradication.

Projects contributing to metric: PCS Collector app weed mapping, Canberra Nature Map

Sampling periodicity: Ongoing throughout the year.

Baseline: Status of new incursion at initial assessment.

Reference condition: No new invasive weed incursions.

Target condition: Local eradication of new incursions.

Trigger point for management: New species detected, based on advice from weed experts.

Qualitative input: Advice was sort from Senior ecologist (Vegetation) and Senior Weeds Officer for advice on species selection for this metric.

Future research questions, management directions, knowledge gaps and recommendations: The continuation of a weeds officer position with responsibility for early invader management is critical to the success of controlling new incursions quickly and effectively. Better data recording, the use of Collector app to increase mapping accuracy and more detailed density categories will enable more informative analysis next CEMP plan.

Data Analysis

Two new incursion species that represent a threat to lowland native grassland ecosystems were chosen for case studies in this metric. Madagascan Fireweed (*Senecio madagascariensis*) is highly toxic to livestock and poses a high risk to native grasslands as it will readily colonises inter-tussock spaces and open ground. The second species, Mexican Feathergrass (*Nassella tenuissima*) is highly invasive and is predicted to extend its habitat in the ACT region with climate change.

Madagascan Fireweed incursions have been controlled through manual removal at more than 20 sites since 2011. Most small inclusions of only a handful of plants have successfully been eradicated after the first removal. Larger sites, where the plant has been introduced through contaminated soil and turf (such as in new housing developments) require multiple and ongoing treatments (Figure 51).

Three new housing development sites with incursions of Madagascan Fireweed are Coombs, Crace and Forde. Targeted manual control occurred at these sites over two or more years. Control commenced at Crace in 2011 and at Forde in 2013, however data from years prior to 2015 were not used in this metric due to differences in precision of area estimates. Regardless, data from 2015 and 2016 show that with rigorous and regular removal, weed control has reduced the area of infestation by more than three quarters in just one year at all sites (Figure 52), making eradication an achievable goal. This is further supported when the total number of plants removed over time is examined for the Coombs site which shows a significant decrease from an estimated population of over 300 plants in 2016 to only a handful of plants one year later (Figure 53).

Figure 51. The number of Madagascan Fireweed incursions requiring repeated treatments.

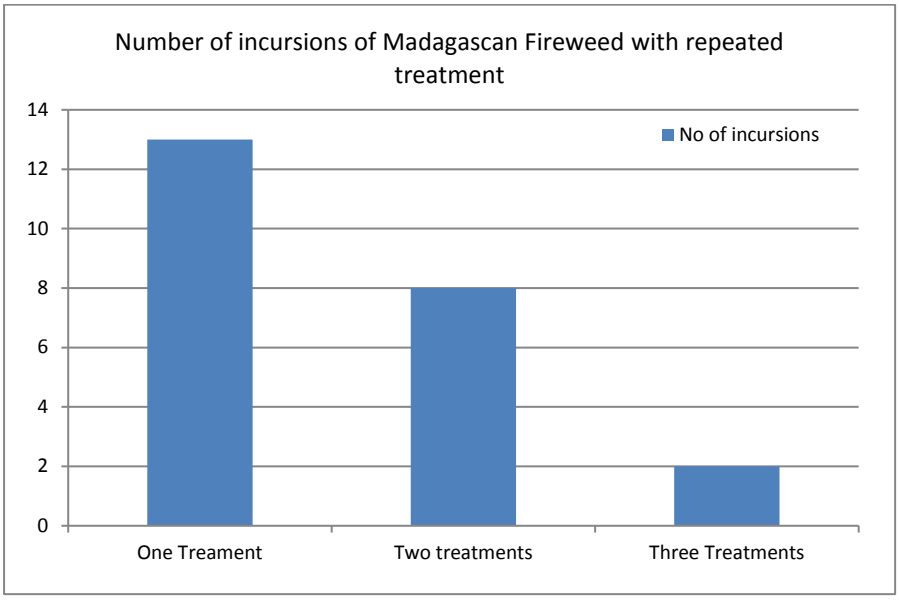


Figure 52. Changes in weed control area for Madagascan Fireweed at three control sites.

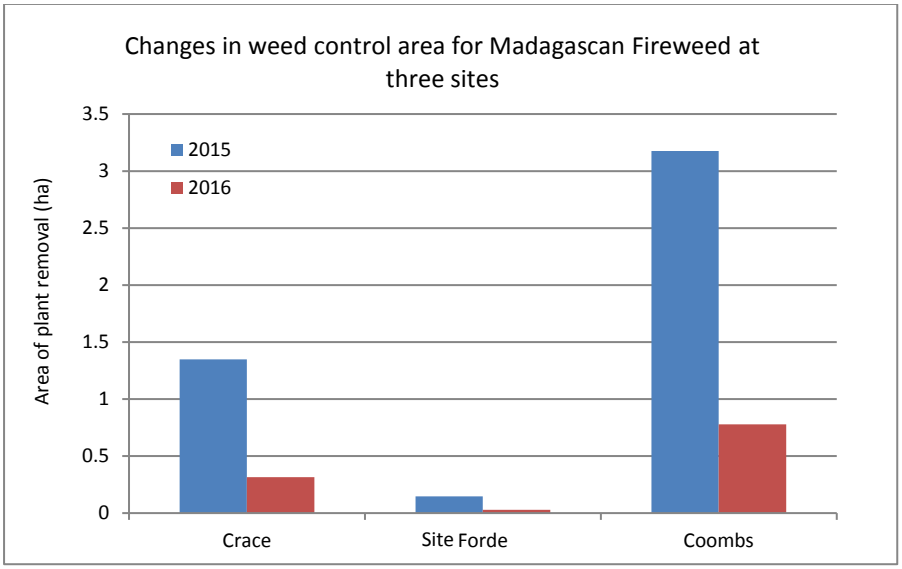
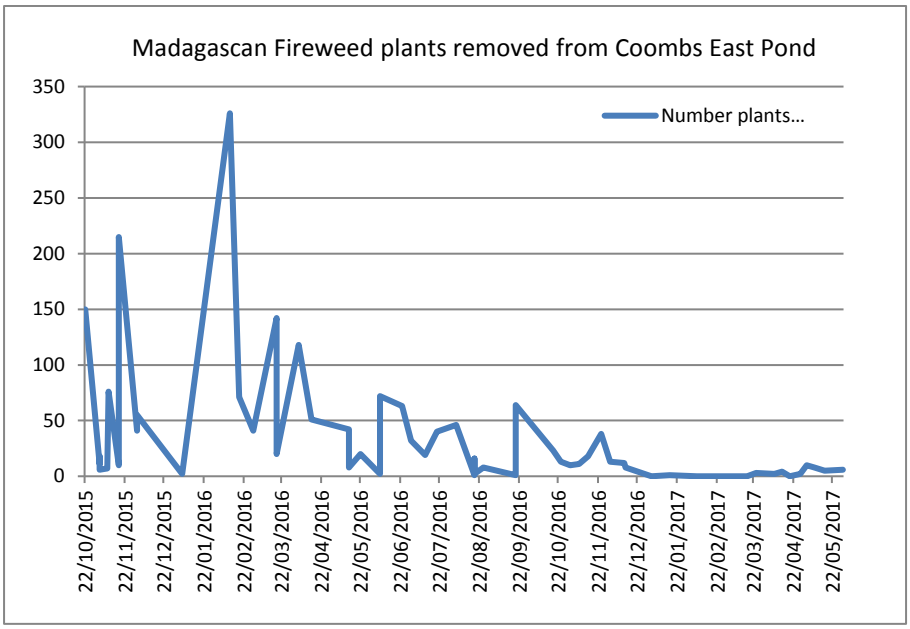


Figure 53. The number of Madagascan Fireweed plants removed from Coombs East Pond since 2015.



Infestations on Mexican Feathergrass commenced control in 2009 at two sites (Figure 54). At the Gordon site eight plants were originally planted in 2008, from which 837 seedlings and mature plants had emerged by the time of control less than a year later. Since 2009, there has been a dramatic reduction in the number of plants at the site, with a sharp then slower decline in the number of plants removed, with very few plants remaining at the site in 2016 (Figure 55). Similarly, the area of the spread has been reduced steadily since 2009 (Figure 54).

Figure 54. Changes in weed control area for Mexican Feathergrass at two control sites.

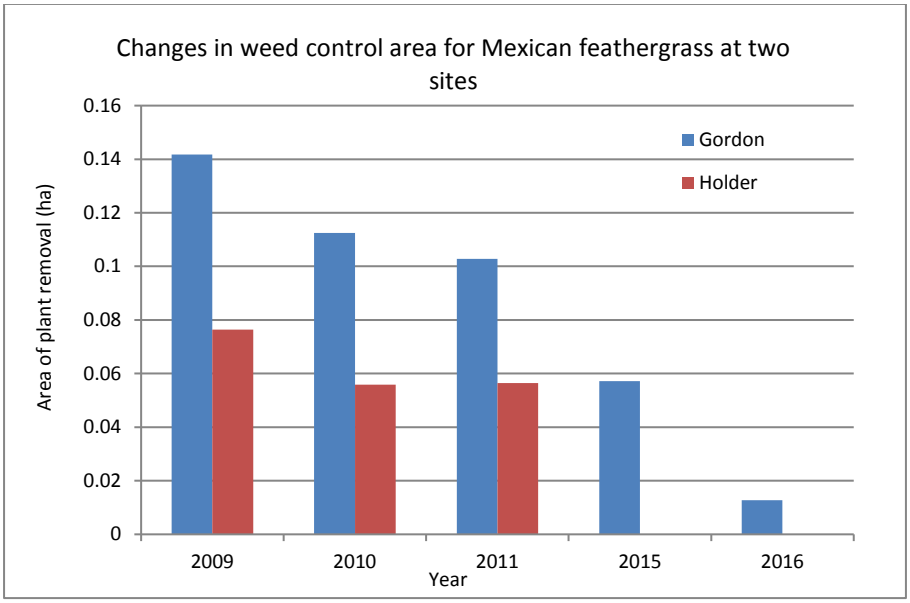
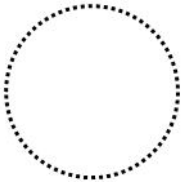


Figure 55. The number of Mexican Feathergrass plants removed from Gordon since 2008.

It has been critically important for halting infestations of new incursions for both species to have the resources/funding for a dedicated weeds officer for early invaders providing rigorous follow up and removal of plants. A dedicated weeds officer in the field has enabled prompt response to incursions, experienced detection of often difficult to see plants and regular and effective monthly follow up to remove new and emerging plants prior to them being able to set seed. This has greatly increased efficiency of weed control and has significant positive impacts in the long term.

S4: INTRODUCED PREDATORS

S4.1 European Fox (*Vulpes vulpes*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: Relative estimates of fox activity using indices from spotlight counts show fluctuation in activity between years, but fox activity has increased at all sites in 2016. Overall fox activity is higher at Jerrabomberra East and Jerrabomberra West compared to other grassland sites. Higher activity of foxes at these two sites coincides with higher estimated densities of rabbits and kangaroos, possibly reflecting more abundant food resources. There is no fox control currently conducted in grasslands. The impact of foxes in grassland reserves is yet to be quantified and needs to be understood in order to validate any management actions.

Metric Assessment: The relative activity of foxes over time is estimated using an index (foxes/spotlight km) calculated using standardised spotlighting counts over 5 km at six sites (Molongo River Park and Kama are combined for this assessment). Additional sites (including offset areas and additional grassland sites) will come into the CEMP plan next plan. This is a convenient, but not ideal, method for estimating fox activity.

Class: Minor	**Category:** Non-statutory – Threatening process	
Primary drivers context: Data sourced 2012-2016 which were very warm years with average rainfall. Contrasting landform, fire and grazing regimes occur between sites.	**Associated indicators:** C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure

Rationale: Fox predation is known impact on populations of native mammals, birds, reptiles and frogs. Fox predation has been listed as a key threatening process under the *EPBC Act 1999*. Currently there are no PCS predator control programs in grasslands.

Projects contributing to metric: PCS spotlight monitoring, Offsets spotlight monitoring

Sampling periodicity: Currently annually or biannually at sites, needs to be made uniform across all sampling areas (occurs concurrently with rabbit population monitoring).

Baseline: First year of spotlighting at each site.

Reference condition: Estimated fox activity / spotlight km of zero.

Target condition: None given – impacts are not quantified at this stage. This needs to be addressed prior to next CEMP plan.

Trigger point for management: No trigger point at this time.

Qualitative input: Nil.

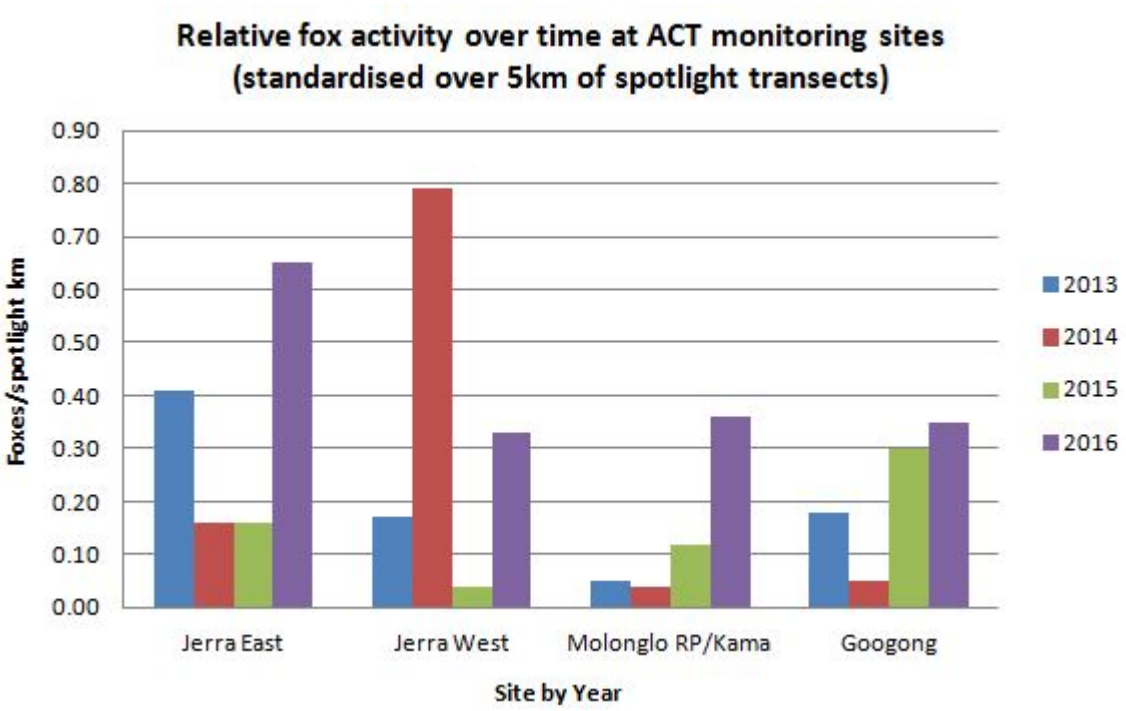
Future research questions, management directions, knowledge gaps and recommendations: There is currently no control of foxes in grassland reserves, and whether foxes are having a significant impact on grassland species and ecosystems is unknown. It is assumed that populations of some native grassland species (such as reptiles and ground nesting birds) may be impacted by fox predation. Little research has been conducted on fox impacts in temperate grassland ecosystems, and whether foxes are having enough of a detrimental impact on grassland fauna to warrant control. Predator control is cost prohibitive, and this large knowledge gap needs to be addressed if fox control is to be validated as a management action in the future.

Data Analysis

The relative density of foxes based on spotlighting activity indices shows that fox populations increased at all monitoring sites in 2016 (Figure 56), likely in response to climatic factors that drive food availability and/or detectability.

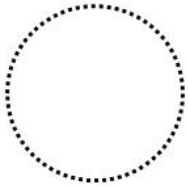
The use of activity indices to estimate populations of predators is not ideal due to the influence of other factors on activity (e.g. season, moon phase, status as a transient of territory holder). A more informative (but also more labour-intensive) monitoring program could include the use of digital cameras (high risk of theft in urban areas) supplemented with alternative methods that can detect both fox and other introduced predators (i.e. feral cats and free-roaming dogs), such as scent stations.

Figure 56. Spring (Sept-Nov) spotlight counts for foxes by site, data averaged over 3 nights and standardised for 5km of transect. The location of spotlight transects at Molonglo River Corridor was changed in 2016.



The impact of foxes on lowland native grassland ecosystems is assumed but has not been determined. Little research has been conducted on fox impacts in temperate grassland ecosystems, and whether foxes are having enough of a detrimental impact on grassland fauna to warrant control is unknown. No target density has been established for this metric as it is unknown at what densities foxes have critical impacts on native fauna. Consequently fox activity has no predetermined trigger point for management. Predator control is expensive and needs to be validated by research prior to its adoption as a regular management action. Understanding the relationship between exotic predator density and impacts on native species, and between control methods and predator numbers would be critical before justifying investment in control efforts.

S4.2 Feral cat (*Felis catus*)

ASSESSMENT AGAINST REFERENCE CONDITION		ASSESSMENT AGAINST TARGET CONDITION	

Summary: There is very little information available on the activity or estimated density of feral cats (including wild and free-roaming domestic cats) in ACT nature reserves. Spotlighting programs occasionally detect feral activity, but are not an optimal method to monitor feral cats. More monitoring and research on the impact of feral cats needs to be conducted in reserves using suitable techniques. There is a large knowledge gap on the impact of feral cats and other introduced predators (i.e. foxes and free-roaming dogs) on grassland fauna and ecosystems in the ACT, and on the efficacy of any potential control methods.

Metric Assessment: Feral cat activity in ACT grassland reserves is currently not estimated as spotlight counts do not detect cat activity well. An alternative survey method, such as scent stations and/or camera traps (difficult in urban reserves due to theft), needs to be incorporated into reserve surveys to monitor cat activity.

Class: Minor	**Category:** Non-statutory – Threatening process	
Primary drivers context: No data used in this assessment for primary driver context.	**Associated indicators:** C4. Native Fauna, general C5. Threatened Fauna	**Associated stressors**: S1. Herbivore pressure

Rationale: Feral cats are known to prey on a range of native fauna in native grasslands in the ACT (Williams and Morgan, 2015), including small mammals, birds, reptiles and frogs. Feral cat predation has been listed as a key threatening process under the *EPBC Act 1999*. The impact of cat predation has not been very well quantified; however it is increasingly evident that some native species are highly vulnerable to cat predation. There is currently no cat control programs conducted in ACT reserves.

Projects contributing to metric: PCS wildlife surveys/spotlight monitoring**,** Environmental Offsets monitoring

Sampling periodicity: None.

Baseline: No data as yet.

Reference condition: Zero cat activity within reserves.

Target condition: None defined

Trigger point for management: No trigger point at this time.

Qualitative input: Nil

Future research questions, management directions, knowledge gaps and recommendations: Spotlighting is not the most effective method for estimating predator activity and/or density within an area however is a good broad method for capturing activity of a range of species. More suitable methods for capturing cat activity and presence would include scent stations and/or camera traps. Feral cats have been implied in the disappearance of native fauna species from reserves, particularly small mammals, and this needs clarification through diet and radio-tracking studies. A review of the effectiveness of cat containment within new suburbs bordering reserves has been highlighted as a priority in the near future.

ADDITIONAL METRICS

There were a number of metrics considered but not included in the current Lowland Native Grasslands Ecosystem Condition Monitoring Plan. These metrics are listed here and reasons for their current omission and/or possible inclusion in future CEMP analysis is discussed.

1. **Small mammals:** Currently small mammals, birds and amphibians are not currently monitored in the Lowland Native Grasslands Ecosystem Condition Monitoring Plan. With the exception of the common dunnart (*Sminthopsis murina*) native small mammal species have largely been replaced by introduced species such as the house mouse (*Mus musculus*) and black rat (*Rattus rattus*). Small mammals occur at very low densities in grasslands therefore gathering informative data on populations is difficult. There are a number of possible student project for small mammal monitoring in targeted reserves or before and after the planned Mulligans Flat/Goorooyaroo fence extension in grassland areas, but at this stage small mammals are not a suitable indicator of overall ecosystem condition.
2. **Grassland birds:** Grassland birds are not currently monitored in the Lowland Native Grasslands Ecosystem Condition Monitoring Plan as there are few species in grasslands and most are typically found at low densities, therefore a large sampling effort would be required to gain useful data. However more common species such as Pipits, Kestrels and Magpies may play key roles in ecosystem dynamics, impacting on both reptile and invertebrate fauna, so their inclusion in future plans may be warranted should research shed light on their functional relationships with other grassland values or stressors. In addition snakes and monitor lizards as primary native predators in grassland ecosystems are an important functional group within the ecosystem. In particular, predation by native predators should be considered where and when habitat manipulation through fire or slashing is to be used as management tools.
3. **Rare species:** In general, 'rare occurrences' of species do not make good metrics as data are few and opportunistic only. However mandated monitoring programs of species that may indicate high quality grasslands may be incorporated as they commence. Potential threatened plant species that may be included as future metrics are the Hoary Sunray (*Leucochrysum albicans*) and Austral Toadflax (*Thesium austral*). These species are EPBC listed species but currently there is no formal monitoring of them in the ACT. Two invertebrate species, the Perunga Grasshopper (*Perunga ochracea*) and the Canberra Raspy Cricket (*Cooraboorama canberrae*) are currently only recorded opportunistically but may be incorporated at a later date if a feasible and repeatable survey method is devised.
4. **Feral deer:** Feral deer have recently been opportunistically recorded in lowland grasslands and this species may become a condition metric in the future, if deer sightings increased.
5. **Soils:** The metric of soils was removed from this Lowland Native Grasslands Ecosystem Condition Monitoring Plan as there is currently little data on soil condition and few practical management options available for soil management. Instead, soil exists in all ecosystem plans as a primary driver. Research has commenced to collect baseline soil data and changes in soil chemistry in response to fire. In addition soils may be a useful indicator to prioritise restoration works in NTG. Soil as a metric may be brought into future CEMP plans as baseline information or alternatively as soil management options become available.

OVERARCHING RECOMMENDATIONS

Listed below are the overarching recommendations that have broad relevance across the ecosystem. A comprehensive list of recommendations resulting from metric analyses is given in Appendix 1.

1. An overall recommendation from this plan is to make long term monitoring programs more robust to statistical analysis, including the formation of a centralised data storage setup to increase accessibility and consistency of data collection across the division.
2. There is a need for accessible and accurate mapping of grassland communities, and possibly other habitat elements (such as biomass), across the spatial extent of native grassland reserves. This mapping could be used to monitor changes over time and help tease out the effects of management and climate on grassland communities.
3. There has been a general lack of fire across much of the extent of lowland native grassland ecosystems over the past 50 years or more. This has likely had significant impacts on species diversity and ecosystem heterogeneity. Reserve managers should consider more widespread use of fire as an ecological tool in lowlands native grasslands. There is also an opportunity to incorporate cultural burns into grassland burning.
4. There is very limited information available on the distribution, abundance or impacts of introduced predators in lowland grassland ecosystems. Whether more active management of introduced predator populations is required has not been verified and is a knowledge gap in this ecosystem.
5. Overall there is a need to increase long-term monitoring of more ecologically representative indicators of grassland fauna such as reptiles diversity and invertebrates (particularly key functional invertebrate species such as burrowers). Such indicators are likely to better represent both ecosystem condition and function than threatened species. This may lead to future management targets becoming more aligned to landscape scale objectives of heterogeneity, minimising habitat fragmentation and loss of connectivity, and understanding the role of keystone species in lowland native grassland ecosystems.
6. Further research is needed into cost effective and achievable restoration techniques to enhance grassland flora diversity and structure that have minimal negative impact on native fauna in this ecosystem. There remains a need for increased understanding of how different flora and fauna communities of lowland grassland ecosystems respond to different biomass management actions, such as burning and grazing. Following this there is an overall need for succinct documentation that captures the biomass needs and management tools available for different grassland associations, biomass and thatch levels and threatened species in lowland native grassland ecosystems. This is likely to be an iterative process as more knowledge on the response of grassland communities to biomass management is gained.
7. For many programs, monitoring of important covariates, increased replication of plots, better data management, recording underlying management histories, the addition of more representative sites, and more consistent field methods would enable much more informative data analysis. Consistency of monitoring methods between projects would also provide larger baseline datasets representative of different management histories and strategies at a landscape scale across reserves.

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APPENDICES: KNOWLEDGE GAPS AND SUMMARY OF RECOMMENDATIONS

Native forbs at Crace Nature Reserve – Photo credit Emma Cook

Appendix 1. Monitoring, research and management knowledge gaps and recommendations identified for condition metrics within the Lowland Native Grassland Ecosystem Condition Monitoring Plan. Recommendations are listed in order by estimated impact level and the complexity of their implementation (high, medium or low).

Monitoring Recommendations

Associated Metric(s)	Recommendation	Impact Level	Complexity of implementation
S1.3 Domestic stock	There is a need for better records to be kept and monitoring to be undertaken when stock are used in grassland reserves and offset areas.	High	Low-Moderate
S2.1 Fire frequency within ecological thresholds	Scale and nature of burn patchiness to promote conservation outcomes need further research and mapping/monitoring	High	High
S3.1 Changes in distribution and abundance of priority weeds	Monitoring of weeds detected but not treated and follow-up monitoring of improvement in natural values after weed control should be undertaken. There is a need to standardised density estimation and effort through recording of complete searches vs. opportunistic sightings or roadside verge control.	High	Moderate
C4.1 Reptiles, general	Annual reptile monitoring needs to be established (grasslands and rocky grasslands). Consistent methods need to be established, collection of data on covariates during monitoring plus recording of management actions at the site.	High	Moderate
C5.2 Striped Legless Lizard	Long-term SLL monitoring needs to be established (see recommendation for reptile monitoring above) with consistent field methods, monitoring of covariates and better data management. Address untested assumptions of the data.	Moderate-High	Moderate
C5.4 Pink-tailed Worm-lizard	Monitoring of PTWL, annual surveys (see recommendation for reptile monitoring above).	Moderate-High	Moderate

C5.3 Golden Sun Moth	Annual, coordinated GSM surveys with standardised methods and sites need to be established, with monitoring of relevant habitat variables.	Moderate-High	Moderate
S1.2 Rabbit	There is a need to monitor conservation outcomes of rabbit control (such as vegetation response) and to gain better understanding of trigger points for management, which may be site-specific.	Moderate-High	Moderate
C4.2 Invertebrates, general	Periodic monitoring of key invertebrates. An effective method for monitoring the vulnerable Perunga Grasshopper needs to be established.	Moderate	Moderate
C2.1 Native plant species richness (NSR) C2.2 Ground cover	Need to establish vegetation monitoring sites which are in poor or moderate condition. Better knowledge of the influence of covariates in determining flora response to management actions is needed. Increased replication at some sites and review of sampling scale (ground cover).	Moderate	Low
C3.2 Ginninderra Peppercress	There is a need to establish a robust and quantifiable survey method to monitor abundance within Ginninderra Peppercress populations. Little is known about what drives large fluctuations in numbers.	Low- Moderate	Low
C5.3 Golden Sun Moth	Initial presence/absence surveys for GSM needs to occur in unsurveyed grassland areas as listed.	Low	Low
C3.1 Button Wrinkelwort	There is a need to establish a more robust survey method to monitor Button Wrinkelwort so that declines in larger populations can be identified and managed.	Low	Low
C2.1 Native plant species richness (NSR)	Need to refine reference condition thresholds to account for intrinsic differences in native plant species richness between grassland communities and define trigger points for management actions.	Low	Low

Management Recommendations

Associated Metric(s)	Recommendation	Impact Level	Complexity of implementation
S2.1 Fire frequency within ecological thresholds	Increase fire frequency to maintain native plant species diversity, although impacts on many C3 grasslands and fauna species remain unknown (see research recommendations).	High	High
C1.1Extent of native vs exotic grasslands in reserves	There is a need for accurate and detailed mapping of grassland communities (and possibly other habitat elements such as biomass) across the spatial extent of native grasslands.	High	Moderate
C5.1 Grassland Earless Dragon	Mapping current distribution of GEDs, ongoing habitat management, restoration of habitat and habitat links between populations and review of strategies for re-introduction of GEDs to identified priority sites.	High	High
C5.4 Pink-tailed Worm-lizard	The connection of large tracts of PTWL habitat, including the connectivity between key habitat areas in reserve lands and across rural lease areas.	High	Moderate -High
C2.1 Native plant species richness (NSR)	Clarification of the best practice for increasing native plant species richness in grasslands, and what management methods to use under which circumstances (grazing, burning, slashing, rock additions).	High	Moderate -High
C4.1 Reptiles, general	Clarification of the best practice for management of reptile fauna in grasslands, and what management methods to use under which circumstances (grazing, burning, slashing, rock additions).	High	Moderate -High
S2.2 Fire season as recommended in ecological guidelines	The recommended guidelines for seasonality of burns need to be reviewed as more knowledge of the impact of season of fire on grass associations and faunal species is gained. Current recommended burning seasons in grasslands are mostly based around fauna conservation needs (particularly for	High	Moderate

	reptiles which are less active in cooler months) rather than flora / habitat enhancement needs.		
S1.3 Domestic stock	Trial the use of land management units to assist with accurate and consistent record keeping when domestic stock grazing is used for biomass control in reserves. Establish a formalised recording format for stock grazing activities.	High	Moderate
S2.1 Fire frequency within ecological thresholds	Fire history requires improved data capture protocols to ensure consistency of data and accuracy of interpretation.	Moderate	Moderate
C5.4 Pink-tailed Worm-lizard	The invasion of exotic weed species into key PTWL habitat, in particular African lovegrass (*Eragrostis curvula*), is of concern.	Moderate	Low
C3.1 Button Wrinkelwort	Introduction of new plants (Button Wrinkelwort) into the St Marks site to enhance genetic diversity.	Moderate	Low
C3.2 Ginninderra Peppercress	Using knowledge gained from initial (unsuccessful) trials of translocation of Ginninderra peppercress, further efforts at translocation should be conducted.	Low- Moderate	Low- Moderate
S2.1 Fire frequency within ecological thresholds S2.2 Fire season as recommended in ecological guidelines	There is an information gap that burning information carried out on non-PCS managed lands currently is not recorded in the burn history layer.	Low	Moderate
S2.2 Fire season as recommended in ecological guidelines	Seasonality of past fires is often missing from fire history layer and could be captured retrospective by reference to burn plans etc.	Low	Low

Research Recommendations

Associated Metric(s)	Recommendation	Impact Level	Complexity of implementation
S2.1 Fire frequency within ecological thresholds	There is a need to research fire impacts in C3 dominated grasslands	High	High
S2.1 Fire frequency within ecological thresholds	Improve knowledge of ecosystem dynamics under different fire frequencies, intensities, and seasonality.	High	High
S2.1 Fire frequency within ecological thresholds	Revise current ecological thresholds (TFIs) to include responses of different grass associations and fauna fire response.	High	High
C1.2 Extent of NTG in reserve areas	Research/review into successful management strategies for restoration of native pasture to NTG status, with a focus on cost effective, non-invasive methods that are not detrimental to fauna.	High	Moderate-High
C1.1Extent of native vs exotic grasslands in reserves	Connectivity analysis for grasslands is required to assist with targeting restoration programs and assist with species/population resilience assessments.	High	Low
C4.2 Invertebrates, general	Research into drives of populations of burrow producing arthropods is required.	High	Moderate
S1.1 Eastern Grey Kangaroo	Continue with research on site-specific recommended EGK densities taking into account climatic variation, grass associations and habitat requirements of priority species.	Moderate-High	Low
S4.1 European Fox	The impact of foxes in grassland reserves is yet to be quantified and needs to be understood in order to validate any management actions.	Moderate-High	Moderate
S4.2 Feral Cat	Research into the impacts of cats on grassland fauna is required to validate the need for more informative monitoring and/or feral cat control.	Moderate-High	High

C5.3 Golden Sun Moth	Research needed on GSMs includes the use of Chilean Needlegrass by GSM, the response of GSM to weed control, burning, grazing and slashing and the impact of habitat fragmentation on dispersal of GSM.	Moderate	Moderate
C5.4 Pink-tailed Worm-lizard	Further survey and mapping of potential PTWL habitat in ACT, with highest priority given to mapping of the Murrumbidgee River Corridor (MRC).	Moderate	Low- Moderate
C3.2 Ginninderra Peppercress	Improved knowledge of the life cycle and ecology of Ginninderra Peppercress to inform best management practice. Further trials of translocation and establishment of ex-situ conservation is needed.	Moderate	Low- Moderate
S1.2 Rabbit	Research into quantifying optimal and achievable densities for rabbits in grasslands and if rabbits change grassland structure or species richness through selective grazing.	Moderate	Low- Moderate
C1.2 Extent of NTG within reserves	Assessment of the relative impacts of urban development and weed invasion over time on the quality and distribution of NTG (and how these impacts can be managed)	Moderate	Low
C5.1 Grassland Earless Dragon	Impacts of predation on GEDs and interactions of predation with management actions (such as burning) are unknown.	Moderate	Moderate
C3.1 Button Wrinkelwort	Research into what factors determine the survival and long term success of translocated Button Wrinklewort populations. Little is known about response to fire or other management actions.	Low-Moderate	Moderate
C4.2 Invertebrates, general	Monitoring of locust populations should be initiated and research into the impacts of high numbers on flora is needed	Low	Moderate
C4.2 Invertebrates, general	Research into a reliable method to monitor Perunga Grasshopper populations at key sites.	Low	Low
C5.3 Golden Sun Moth	Increased knowledge of life history, demographics, habitat requirements and conservation genetics of GSM to better inform management.	Low	Low

C4.2 Invertebrates, general	Preliminary monitoring indicates that preferred habitat of the Canberra Raspy Cricket may be high quality NTG; if so this species may be useful as a future indicator of NTG condition if robust sampling methods can be developed.	Low	Low