DRAFT ACT NATIVE GRASSLAND CONSERVATION STRATEGY AND ACTION PLANS

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VISION

“Healthy native grasslands supporting a diverse flora and fauna for now and the future”

Native grasslands of the Territory include a rich assemblage of flora and fauna species that combine into a unique ecosystem. These grasslands are a priority for protection and management as they contribute to our natural biodiversity, our history and heritage, and local amenity and community. They also provide opportunities to enhance cultural engagement, education and scientific research.

Since European settlement our native grasslands and grassy woodlands have come under increasing pressure from human settlement, urbanisation and a changing climate. Due to these changes, only 2% to 10% of the lower elevation grasslands in south-eastern Australia remain in high ecological condition, seven grassland species, and one species that occurs in both grasslands and woodlands, are listed as endangered or vulnerable in the ACT. Other plants and animals that occur in grasslands are are also under threat. Temperate grasslands are considered one of the most threatened Australian ecosystems.

The Native Grassland Conservation Strategy aims to build on the successful protection and management of grasslands achieved since the original 2005 Lowland Grassland Conservation Strategy (ACT Government 2005). In the years between the previous strategy and this revised strategy, a number of the native grasslands in the ACT have been protected and a large body of grassland research, monitoring and conservation planning has accumulated.

Building on these significant achievements, this revised strategy provides a Territory-wide approach within a regional context to the conservation and management of native grasslands. It extends to all grassland ecosystems by expanding the scope to include montane and rocky native grasslands. It also shifts the focus from strongly protection-based (recognising the previous success in achieving this) to best-practice conservation management and enhancing the condition of native grasslands in light of a changing climate.

Native grasslands are a unique ecosystem that warrants care and attention. By working together we can conserve these areas for now and the future.

The ACT Government acknowledges the Ngunnawal people as the Traditional Custodians of the land and waters in the ACT and respects their continuing culture and unique contribution they make to the life of our region.

The Ngunnawal people actively managed the landscape over tens of thousands of years and today retain their spiritual and cultural connection to Country.

1. INTRODUCTION

1.1 OVERVIEW

The ACT Native Grassland Strategy provides guidance on the conservation of native grasslands and component species in the ACT consistent with the ACT Nature Conservation Strategy 2013–23 (ACT Government 2013a). Relatively large areas of native grassland in the ACT are now protected within reserves, so the current emphasis of grassland conservation is on management and enhancement of grassland ecosystems. This includes conserving native grassland species and communities by managing threats, maintaining and improving ecological connectivity, ecosystem function and grassland biodiversity, undertaking monitoring and research programs, partnering with the community to support grassland conservation and enhancing the resilience of grasslands to disturbance and climate change.

1.2 STRUCTURE OF THE STRATEGY

This document is divided into seven main strategies with key principles and management guidelines and is structured as follows:

Chapter 1:

This introduction chapter outlines the objectives and scope of the strategy, legislation and policy applying to nature conservation and the links between the strategy and associated action plans.

Chapter 2:

This chapter includes the strategy for protecting native grassland and component species, related protection goals and guidelines, and describes Conservation Significance Categories for grassland sites.

Chapter 3:

This chapter includes the strategy for reducing threats to native grassland biodiversity. It examines the primary threats to biodiversity within local grassland systems including weed infestation, pest vertebrate animals, overgrazing by kangaroos, urbanization and a changing climate, and provides guidelines for managing and minimising the potential impacts of these threats.

Chapter 4:

This chapter includes the strategy for managing native grassland and component species for conservation. It considers adaptive management principles for managing herbage biomass, disturbance regimes and exotic grass as habitat, including species-specific grass structure and herbage biomass management guidelines and how these principles should be implemented at the local scale.

Chapter 5:

This chapter includes the strategy for enhancing ecosystem resilience and function, and improving habitat connectivity, in the context of current and future environmental pressures such as climate change. A framework of options and guidelines for enhancement or restoration is provided for grasslands of varying ecological condition.

Chapter 6:

This chapter includes the strategy for monitoring, research and baseline data collection for native grasslands and component species, and provides an overview of the recently developed Conservation Effectiveness Monitoring Program.

Chapter 7:

This chapter includes the strategy for engaging the community in local native grassland conservation by increasing awareness, supporting and promoting citizen science and engaging with local indigenous communities on traditional ecological knowledge.

Chapter 8:

This chapter provides background information on native grasslands relevant to their conservation, including the history of land-use, their distribution and component species. This chapter also outlines the conservation measures carried out in the last decade, the evidence base drawn on for the strategy and potential climate change effects on grasslands.

1.3 OBJECTIVES OF THE STRATEGY

This ACT Native Grassland Conservation Strategy provides the strategic context for the protection, management and restoration of native grasslands in the ACT. Specifically, the objectives of the strategy are to:

- Provide conservation management guidelines for the protection and enhancement of native grasslands aligned with the strategies outlined in the ACT Nature Conservation Strategy (ACT Government 2013a).
- Provide monitoring and research objectives for the nine native grassland associations found in the ACT.
- Provide strategic context for action plans for threatened grassland flora and fauna, and the Natural Temperate Grassland ecological community.
- Describe the remaining areas of native grassland in the ACT, including a broadening of the scope since the previous strategy, to include native grasslands across the full elevation range of the ACT, and degraded grasslands that may provide habitat or connectivity for grassland flora and fauna.
- Describe the floristic associations found in native grassland areas in the ACT based on current classification methods.
- Provide strategies to increase engagement of the community in native grassland activities and projects.

This strategy is also intended to be a reference document on native grassland for ACT and Australian Government agencies with responsibilities for nature conservation, planning and land management, and for community and other stakeholders with an interest in native grassland conservation.

1.4 SCOPE OF THE STRATEGY

The strategy considers all native grassland ecosystems of the ACT across the full elevation range from lowland Natural Temperate Grassland to the grasslands of the montane and subalpine zones, regardless of tenure and land use. It considers the ecological value and management of degraded native grassland,

Ecological burn at Jerrabomberra West Nature Reserve

including grassland dominated by invasive weeds, some of which provides habitat for threatened grassland fauna.

Derived (or 'secondary') grasslands are included in the ACT Lowland Woodland Conservation Strategy (ACT Government 2004) as they are derived from cleared woodland.

This document supersedes the previous ACT Lowland Grassland Conservation Strategy (ACT Government 2005), and presents updated material relevant to ACT grasslands and their conservation. This document also includes the action plan for Baeuerlen's Gentian, which was not included in the previous strategy and instead was a separate document.

Unlike the previous strategy, this revised strategy covers all grasslands in the ACT, including rocky grasslands and grasslands that occur above 625 metres above sea level.

In contrast to the previous strategy, action plans for the ecological community and associated species, which are declared as threatened under the *Nature Conservation Act 2014* (ACT) (View the Act (PDF, 952Kb)), are included as stand-alone documents to aid identification of specific actions and progress.

1.5 RELEVANT POLICY AND LEGISLATION

1.5.1 International and national context

Management of threatened species and ecological communities is guided by international, national and Territory agreements, policy and laws.

The United Nations Convention on Biological Diversity is an international legal instrument for the conservation and sustainable use of biological diversity. Australia ratified the Convention in 1993 and, in line with the Convention, prepared the National Strategy for the Conservation of Australia's Biological Diversity (1996). This strategy was reviewed and replaced by Australia's Biodiversity Conservation Strategy 2010–2030 and the Strategy for Australia's National Reserve System 2009–2030, which provide frameworks for protecting biological diversity and maintaining ecological processes and systems.

The International Union for the Conservation of Nature (IUCN) establishes criteria for assessing the conservation status of species. Assessment of species in the ACT by the Scientific Committee (a statutory committee under the *Nature Conservation Act 2014*) is generally consistent with the IUCN criteria and conservation categories.

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the protection of 'matters of national environmental significance' (MNES) and includes criteria for environmental impact assessment. A number of threatened grassland flora and fauna and the Natural Temperate Grassland ecological community are listed as MNES.

1.5.2 ACT legislation

The *Nature Conservation Act 2014* (NC Act) provides for the protection and management of native plants and animals in the ACT and the identification and management of threatened species and ecological communities. The NC Act requires a nature conservation strategy be prepared and implemented. The NC Act outlines the processes for developing action plans for listed species and ecological communities and also creates key statutory positions: the Conservator of Flora and Fauna, Conservation Officers and the Parks and Conservation Service. Under the NC Act, updates to action plans for threatened species and ecological communities must explicitly consider the implications of climate change.

The *Planning and Development Act 2007* has provisions for sustainable development and includes requirements for environmental impact assessment for any proposal that may have a significant adverse impact on a threatened species or ecological community. See Section 1.5.4 on Environmental Offsets.

The *Heritage Act 2004* establishes a system for the recognition, registration and conservation of natural and cultural heritage places and values in the ACT. The ACT Heritage Register is used to identify heritage sites that might be impacted by proposed activities or development works. The *Heritage Act 2004* also provides for the preparation of conservation management plans and heritage guidelines for the protection of sites of heritage significance. While some places and objects in ACT grasslands are included on the ACT Heritage Register, many more (particularly Aboriginal artefacts) are likely to be unidentified.

The *Pest Plants and Animals Act 2005* lists pest plants and animals and provides for development of pest animal and pest plant management plans.

The *Emergencies Act 2004* requires the development of a Strategic Bushfire Management Plan which guides the management of fire risk in the ACT.

The *Human Rights Act 2004* outlines the obligations on public authorities to act and make decisions compatibly with human rights, including the cultural rights of Aboriginals and Torres Straight Islanders.

For more information on ACT legislation, view the Human Rights Act 2004 (PDF, 150Kb).

1.5.3 ACT policy on nature conservation and climate adaptation

The *ACT Nature Conservation Strategy 2013–23* establishes a policy framework for conservation of biodiversity across all tenures in the ACT. The strategy emphasises more resilient landscapes by restoring priority landscapes and enhancing connectivity to enable species and ecosystems to better adapt to climate change. The *ACT Biosecurity Strategy 2015–25* further addresses how to manage key threats (weeds, pest animals, disease) across both conservation and production landscapes.

The *ACT Climate Change Adaptation Strategy* (ACT Government 2016) aims to guide collective efforts in adapting to climate change.

The Climate Change Adaptation Strategy identifies 'natural resources and ecosystems' as one of five priority sectors. The strategy identifies two priority actions:

- Support landscape scale conservation by identifying, protecting and strengthening: potential climate wildlife refuges (biodiversity refugia) and adaptive capacity of ecosystems in our bioregion.
- Care for land and water through education about climate change impacts and adaptation actions, control of pest animals and weeds that may become more critical under climate change, and monitor impacts on ecosystems.

The ACT participates in regional and national initiatives such as CSIRO AdaptNRM (Visit the AdaptNRM website) to inform best practice management and enhance collaboration in helping biodiversity adapt to climate change.

1.5.4 ACT policy on environmental offsets

Environmental offsets are part of Commonwealth and ACT environmental approvals processes and aim to conserve 'matters of national environmental significance' (MNES) and 'ACT protected matters' through conservation actions to compensate for significant adverse environmental impacts. The primary objectives of the *ACT Environmental Offsets Policy* (ACT Government 2015a) are to ensure:

- Impacts on areas of high conservation value or irreplaceable assets are avoided or mitigated. Environmental offsets are to be considered only after feasible and appropriate avoidance and mitigation measures have been undertaken.
- Impacts from the loss of ecological communities and habitat are offset by commensurate gains in extent or quality elsewhere.

The *Planning and Development Act 2007* covers the requirements for environmental offsets in the ACT, including the *ACT Environmental Offsets Policy*. The policy outlines how environmental compensation may be made to offset the impact of developments or other activities that have a significant adverse environmental impact on protected matters. The policy gives careful consideration to whether an impact is acceptable, and therefore able to be offset.

The *ACT Environmental Offsets Policy* is supported by an environmental offsets calculator, which determines whether a protected matter will be subject to a significant adverse environmental impact and the minimum acceptable environmental offset required. The calculator also identifies when the impact on a species or ecological community requires the Conservator of Flora and Fauna to consider whether offsets are appropriate. For more information on the ACT Offsets Policy, visit the Environment website for more info.

1.6 ACTION PLANS

1.6.1 Overview

Action plans for threatened species and threatened ecological communities are statutory documents under the *Nature Conservation Act 2014* (NC Act). The Conservator of Flora and Fauna is responsible for preparing a draft action plan (or in some cases, conservation advice) for each species listed as threatened under the NC Act. Action plans are prepared with expert input from the Scientific Committee, which is a statutory committee established under the NC Act.

Action plans associated with this strategy are included in Part B of this document, and include an action plan for the threatened grassland ecological community and action plans for each of the seven threatened species that are dependent on native grassland in the ACT. Each action plan provides a detailed description of the community or species, its conservation status, ecology, key threats, and outlines the major conservation objectives and intended management actions. Conservation objectives, management actions and performance indicators in action plans are arranged into five core objectives of Protect, Manage, Increase, Knowledge, Awareness.

The action plans associated with this strategy include:

One ecological community

- Natural Temperate Grassland

Four animal species

- Grassland Earless Dragon (*Tympanocryptis pinguicolla*)
- Golden Sun Moth (*Synemon plana*)
- Striped Legless Lizard (*Delma impar*)
- Perunga Grasshopper (*Perunga orachea*)

Three plant species

- Button Wrinklewort (*Rutidosis leptorrhynchoides*)
- Ginninderra Peppercress (*Lepidium ginninderrense*)
- Baeuerlen's Gentian (*Gentiana baeuerlenii*)

All of these threatened species are grassland specialists. The Pink-tailed Worm-lizard (*Aprasia parapulchella*) (listed as Vulnerable) is associated with both grasslands and grassy woodlands, and therefore the Action Plan for this species has not been included in this Grassland Strategy document and instead is a separate document. However, many of the objectives and guidelines in this strategy are directly relevant to the protection and management of Pink-tailed Worm-lizard habitat.

Table 1 shows a summary of the conservation objectives for each action plan.

1.6.2 Links between this strategy and action plans

Action plans provide guidance for undertaking actions to benefit individual threatened species and the threatened grassland community.

This ACT Native Grassland Conservation Strategy provides overarching conservation goals and principles on which to base these actions. It also provides a framework for planning and prioritising actions across the range of grassland sites in the ACT, including actions for sites where there are multiple threatened species present and multiple (sometimes competing) conservation objectives.

Where relevant, specific goals or actions from the action plans have been reproduced in the strategy section (Part A) of this document to assist readers to cross-reference between the strategy and the action plans (Part B). The objectives from each of the action plans are shown in Table 1.

1.6.3 Development, implementation and review of action plans

Action plans have been developed and implemented for all of the threatened species that are found in the native grasslands of the ACT, and for the grassland ecological community itself. Since the previous strategy reviews have been undertaken for all of these action plans and provided to the ACT Scientific Committee for assessment. The Committee's assessment is based on objectives and performance indicators in action plans, and progress that can reasonably be expected within the review timeframe. Review of action plans is also the primary means for assessing progress towards the goals of this strategy.

The ACT Government will continue to develop and implement action plans (or conservation advice where appropriate) for threatened species and threatened ecological communities, and will regularly review progress towards achieving their conservation objectives.

Table 1. Summary of objectives from each of the action plans, grouped by the five core objectives of Protect, Manage, Increase, Knowledge and Awareness. Note that 'unintended impacts' are those not already considered through an environmental assessment or other statutory process.

Objective	Action Plan
PROTECT	
Conserve all remaining Conservation Significance Category 1 NTG sites in the ACT. Protect Conservation Significance Category 2 NTG sites in the ACT from unintended impacts.	Natural Temperate Grassland
Conserve all large and medium size populations in the ACT. Protect small populations from unintended impacts.	Button Wrinklewort Striped Legless Lizard Pink-tailed Worm-lizard
Conserve all ACT populations.	Ginninderra Peppercress Grassland Earless Dragon Baeuerlan's Gentian
Conserve large populations in the ACT. Protect other ACT populations from unintended impacts.	Golden Sun Moth
Protect native grassland sites where the species occurs from unintended impacts.	Perunga Grasshopper
MANAGE	
Manage Natural Temperate Grasslands to: • maintain and improve grassland structure, function and diversity • reduce the impacts of threats • conserve grassland biodiversity	Natural Temperate Grassland
Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	All Species
INCREASE	
Enhance the long-term viability of Natural Temperate Grassland by restoring priority grassland sites.	Natural Temperate Grassland
Enhance the long-term viability of populations through management of adjacent grassland to facilitate expansion of populations into suitable habitat. Establish new populations.	All Species
KNOWLEDGE	
Improved understanding of the ecology, habitat and threats to the species/community.	All
AWARENESS	
Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species/community.	All

2. STRATEGY: PROTECT NATIVE GRASSLAND AND COMPONENT SPECIES

Button wrinklewort and natural temperate grasslands at Majura training area

2.1 OVERVIEW

Natural Temperate Grassland is one of Australia's most threatened ecosystems. The native grasslands of the ACT provide critical habitat for several species of threatened plants and animals. In this context, the conservation of the remaining areas of native grassland (including Natural Temperate Grassland) makes an important contribution to national biodiversity conservation. Protection of threatened species and ecological communities is a requirement under the ACT *Nature Conservation Act 2014* with statutory action plans providing the framework for implementation and evaluation of conservation actions. Protection of nationally listed threatened species and ecological communities is also required under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The ACT contains significant remnants of the current extent of Natural Temperate Grassland in the region. These grassland remnants occur on lands that are under a range of tenures and levels of protection, including nature reserve, urban open space (generally public land under the Territory Plan), Territory land under rural leasehold, unleased Territory land, Commonwealth-owned and managed 'National Land', privately-leased Commonwealth land, and 'Designated' land (land owned by either the Territory or the Commonwealth that is under the planning control of the National Capital Authority).

Substantial areas of the remaining native grasslands are now contained within nature reserve or other areas where land management goals focus on conservation. However, the small size and fragmented nature of the remaining grassland areas and the significant development pressures on land in and around existing urban areas due to Canberra's growth pose particular difficulties for protection and management of grassland sites. A number of high conservation-value grassland sites outside of nature reserves (including on Commonwealth land) are subject to infrastructure development proposals, and other grassland sites (including those within nature reserves), are subject to urban edge effects (weed invasion, recreation pressures, increased predation of grassland fauna by foxes and cats).

The size, number, connectivity and ecological condition of remnant grasslands are major determinants of the long-term viability of the native grassland ecological community. Generally, larger remnants:

- Contain a greater diversity of habitats and species.
- Have larger (more genetically viable) populations of plants and animals.
- Are more likely to maintain their ecological condition in the long term (particularly if buffered from incompatible adjacent land-use).
- Are more resilient to environmental disturbance (drought, fire etc.) and edge effects.

In particular, the maintenance of natural-patch-dynamic processes in fragmented landscapes is critically dependent on the presence of areas of sufficient size to sustain a mosaic of habitats that correspond to different ecological states (Bennett 1999). A greater number of patches is more likely to encompass different plant associations, habitats and species (all of which tend to vary across the landscape) or multiple populations of the same species (important for genetic diversity), and provides replication of conservation areas as a precaution against catastrophe and/or unpredictable local extinction. Connectivity improves long-term viability by facilitating dispersal of individuals between patches, hence avoiding genetic problems and enabling re-colonisation following population decline or local extinction.

For some sites, the combination of small size, isolation and the impacts of adjacent land uses may preclude or severely limit long-term viability, irrespective of protection and other conservation measures.

Adequate protection and management of native grassland sites in the ACT, including those that may not meet the criteria for a threatened grassland community but are important fauna habitat, is critical to attaining the goals of this strategy.

The Conservation Significance Categories outlined in this chapter provide guidance for protection and management priorities for individual grassland sites. Principles and guidelines for the protection of grassland sites are outlined in this chapter, whereas the conservation management of grasslands is detailed in Chapter 4. Achieving the protection goals in this strategy will depend upon encouraging protection of grassland sites on land owned by other jurisdictions.

2.2 PROTECTION GOAL

Conserve all remaining areas of native grassland in the ACT that are in moderate to high ecological condition.

Conserve viable wild populations of native grassland flora and fauna species in the ACT, and support local, regional and national efforts towards conservation of these species.

2.3 KEY PRINCIPLES

The long-term viability of native grasslands in the ACT will be maximised by:

- Conserving the remaining extent of native grassland (including the number of sites and their size), which will involve encouraging other jurisdictions to conserve native grasslands on their lands.
- Protecting native grassland patches from further fragmentation or modification due to urban infrastructure developments, agricultural practices or urban edge effects.
- Actively managing grasslands sites to enhance condition.
- Enhancing connectivity between grassland patches and to other vegetation types.

2.4 CONSERVATION SIGNIFICANCE CATEGORIES

2.4.1 Floristic Value Score

For the purposes of protecting and managing the remaining native grasslands in the ACT, each known site has been assessed and identified as falling into a Conservation Significance Category (Figure 1 and **Figure 2**). Since the previous strategy, the ACT Government has adopted the use of the Floristic Value Score (FVS) to quantify native grassland ecological condition (or 'quality') (Rehwinkel 2007, 2014). Grasslands in higher condition have higher native plant diversity and lower levels of disturbance or modification and fewer weeds. This relatively recently developed measure is widely-used for assessing grassland condition, with sites measuring 5 or more being considered to have a floristic value sufficient to be identified as part of the Natural Temperate Grassland Endangered Ecological Community under the EPBC Act (Commonwealth of Australia 2016, Rehwinkel 2007, 2014).

The FVS plays a key role in allowing an area of native grassland to be assigned to the most appropriate Conservation Significance Category. In addition to the condition of a grassland, the measures that determine the Conservation Significance Category of a grassland patch are its value as habitat for threatened species. Note that the minimum patch size considered to contain native grassland under the EPBC Act 1999 is 0.1 ha (patches smaller than this area are not considered to be native grassland) (Commonwealth of Australia 2016).

The FVS has been undertaken for grasslands known to be in high ecological condition (from previous grassland surveys and assessments using other methods). These high condition grasslands meet the criteria for Conservation Significance Category 1 grasslands. The Floristic Value Score has not been undertaken for all grassland sites in the ACT in moderate or low condition, and so these grasslands have not been assigned to either Category 2 or Category 3 in this strategy. Determining whether a grassland site is Category 2 or Category 3 will depend on detailed site inspections to assess the Floristic Value Score.

2.4.2 Key threatened species habitat

In this strategy, an area of habitat that is likely to be crucial to the conservation of a threatened species in the ACT is considered to be 'key' habitat. Equally, loss of 'key' habitat is likely to severely jeopardise the long-term conservation of a threatened species in the ACT. Key habitat will usually be large in area, contain the largest populations of threatened species in the ACT, be in moderate to good ecological condition and most likely contain habitat for multiple threatened species.

2.5 CONSERVATION SIGNIFICANCE CATEGORY 1 SITES

Sites in this category meet the following criteria:

- high ecological condition (Floristic Value Score >20), or
- key threatened species habitat

Sites in the ACT assessed as meeting these criteria total approximately 4516 hectares (ha) and include:

- Majura Valley East (Majura Training Area, Airport Beacon paddock, Canberra International Airport)
- Majura Valley West (Majura West grasslands, Campbell Park)
- Jerrabomberra Valley East ('Cookanalla', HMAS Harman, 'Bonshaw', Jerrabomberra East grassland conservation area)
- Jerrabomberra Valley West (Jerrabomberra West Nature Reserve, Callum Brae)
- Lawson Grasslands (former Belconnen Naval Station)
- Gungahlin Grasslands (Mulangarri, Gungaderra and Crace Reserves and Kenny and North Mitchell grasslands)
- Molonglo River Corridor
- Namadgi National Park (Orroral Valley, Grassy Creek, Long Flat)
- Dunlop Grasslands Reserve

These sites represent the largest remaining areas of good (in some cases best) quality Natural Temperate Grassland and key habitat for threatened grassland species. This core group of sites warrants formal protection to ensure conservation in the long term. These sites should also be given priority for management actions that maintain or improve ecological condition or their value as threatened species habitat.

Five smaller sites (totalling 13 ha) are included in this category because they are in very good condition (high FVS). These sites occur at Caswell Drive and Glenloch Interchange, St Mark's Cathedral (Barton), Tennant St (Fyshwick), Tuggeranong Grassland and Isabella Pond (Tuggeranong).

Refer to the ACTmapi website for locations of Grasslands listed as the Natural Temperate Endangered Ecological Community, other native grasslands and distributions of threatened grassland fauna.

2.5.1 Protection guidelines for CSC 1 grassland sites

For Territory-owned land, the appropriate level of protection for Conservation Significance Category 1 sites is nature reserve under the *Planning and Development Act 2007* or similar formal protection. Some Conservation Significance Category 1 sites are already protected in reserves, and others are protected as urban open space and are managed for conservation. For land that is not owned by the Territory (such as National Land), the ACT Government will encourage other landowners/agencies to conserve CSC 1 sites on their lands. The EPBC Act already provides a level of protection for threatened grasslands located on Commonwealth land (including land managed by the Commonwealth and privately leased Commonwealth land such as Canberra International Airport). In addition to the EPBC Act, statutory reservation (under Commonwealth legislation) is also desirable for Commonwealth-owned and managed land to ensure conservation in the long term.

Wallaby Grass, Common Everlasting Daisy, Natural Temperate Grassland

2.6 CONSERVATION SIGNIFICANCE CATEGORY 2 SITES

Sites in this category meet the following criteria:

- moderate condition (Floristic Value Score between 10 and 20), or
- threatened species habitat in native grassland (i.e. grassland dominated by native perennial grasses)

Conservation Significance Category 2 grassland sites are those with a history of greater modification (e.g. exhibiting reduced plant species diversity, loss of disturbance-sensitive species and an increase in disturbance tolerant species, and greater weediness). These sites are generally in moderate condition and are likely to be viable in the medium term but their long-term viability may be limited by virtue of their size, low area to perimeter ratio and/or impacts from surrounding land uses. These sites may provide habitat for threatened species and may complement Conservation Significance Category 1 grassland sites by providing connectivity to adjacent habitat or act as a buffer to adjacent incompatible land uses. For some of these sites, management actions might result in significant improvement in the ecological condition and therefore each site needs to be assessed for management priority based on expected benefit (improvement in ecological condition, improvement in habitat quality etc.) for the resources expended.

Refer to the ACTmapi website for locations of Grasslands listed as the Natural Temperate Endangered Ecological Community, other native grasslands and distributions of threatened grassland fauna

2.6.1 Protection guidelines for CSC 2 grassland sites

Conservation of Conservation Significance Category 2 sites on Territory Land may be achieved through Public Land categories of the Territory Plan including nature reserve, urban open space and special purpose reserve. Activities permitted in these land use categories may be compatible with the conservation of native grasslands, provided that appropriate conservation management is in place. In these cases maintenance of the conservation values of the site is the responsibility of the relevant ACT Government agency. Other similar land uses include road reserves and powerline easements. For National Land, Memoranda of Understanding with Australian Government agencies may be an appropriate mechanism.

2.7 CONSERVATION SIGNIFICANCE CATEGORY 3 SITES

Sites in this category meet the following criteria:

- low condition native grassland (Floristic Value Score ≥5 and <10 and dominated by native perennial grasses), or
- threatened species habitat in exotic grassland, or
- native grassland that forms an important buffer or connection to higher quality grasslands

Conservation Significance Category 3 grassland sites have a lower conservation value, but may still contribute to conservation of grassland biodiversity. Typically, these sites include small patches (<10 ha) of native grassland in poor to moderate condition, or include threatened species habitat that is dominated by exotic grasses (such as Phalaris (*Phalaris aquatica*) and Chilean Needle Grass (*Nasella neesiana*)). Many of these sites occur on small and very small urban sites and on rural leases, and/or are severely fragmented and have reduced viability as a grassland community. Category 3 sites also include grasslands that are important as buffers between higher quality grasslands and adjacent incompatible land uses, or are important connections between higher conservation value sites. Category 3 sites may also include grasslands that are landscape features within the urban fabric, or that provide opportunities for education or research (such as rehabilitation trials). Populations of threatened species occurring in Category 3 sites are either small (and may be in marginal or fragmented habitat) or occur in exotic grassland that supports few other native grassland plants or animals.

2.7.1 Protection guidelines for CSC 3 grassland sites

Where possible, Conservation Significance Category 3 sites should be retained for their value as threatened species habitat or for their buffer/connectivity function and appropriately managed until their long-term future is determined. Each site needs to be assessed as part of the outline planning, environmental assessment and development approval process. Planning and management arrangements may include agreements with non-government landholders, property management agreements with rural lessees and protection of sites within the urban fabric. These arrangements provide a means to continue the primary land use while accommodating the conservation values of these sites.

2.8 LOCAL, REGIONAL AND NATIONAL COOPERATION

Conservation of grassland sites across all tenures will involve cooperation between government agencies and other landholders within the ACT and region. The ACT Government will work with Commonwealth agencies (particularly the Department of Defence and the National Capital Authority), NSW Government and other landholders (such as Canberra International Airport) to encourage:

- Formal protection of Conservation Significance Category 1 grassland sites.
- Actions and land uses compatible with the conservation of Conservation Significance Category 2 and 3 sites.
- Maintaining or improving ecological connectivity of Natural Temperate Grassland.

The ACT Government will also maintain links with, and participate in, regional and national recovery efforts for native grasslands and threatened grassland species.

Figure 1. Map of native grasslands in the north of the ACT showing Conservation Significance Category 1 grasslands and other grasslands (which include CSC 2 and 3 grasslands, and exotic grasslands).

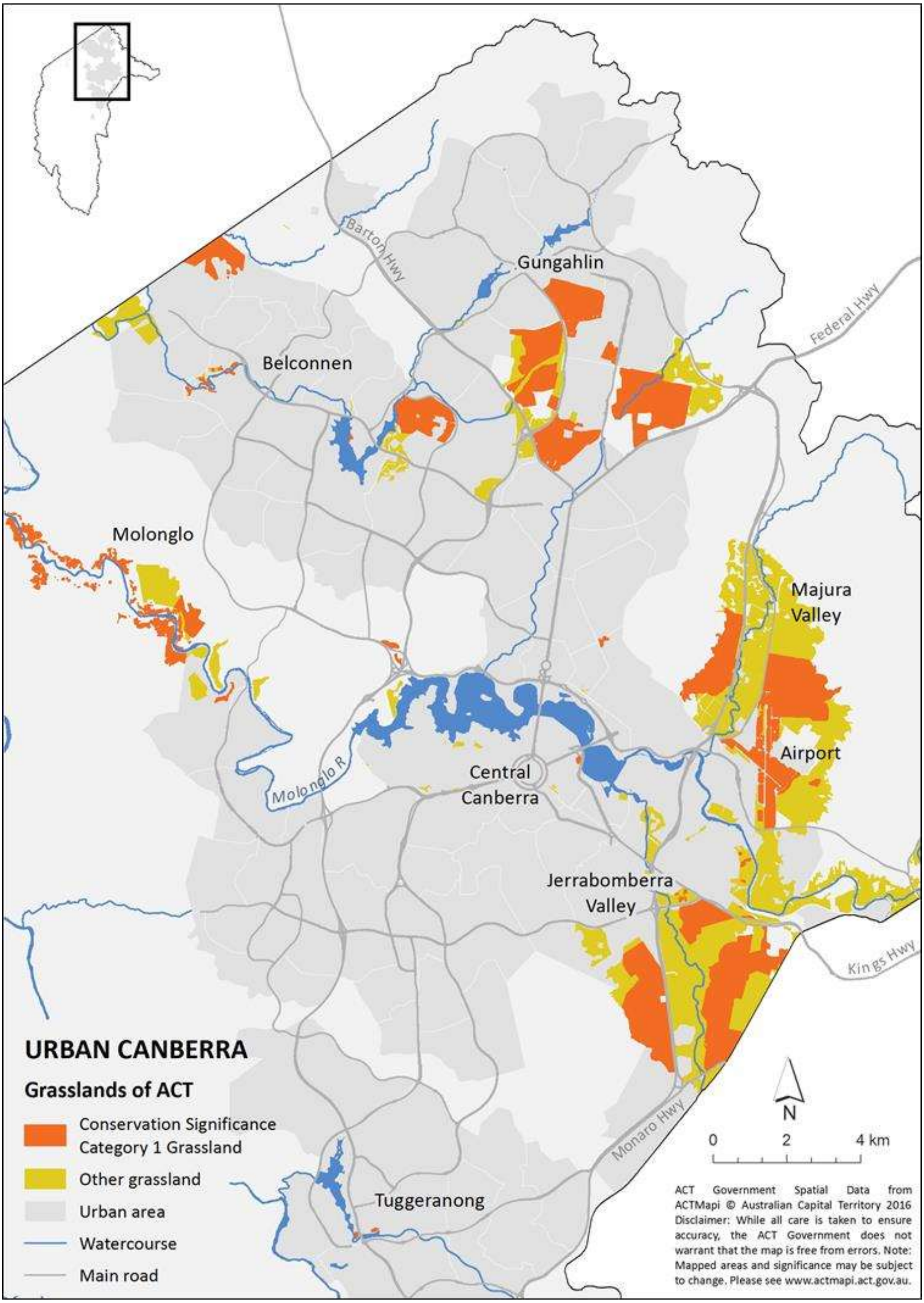
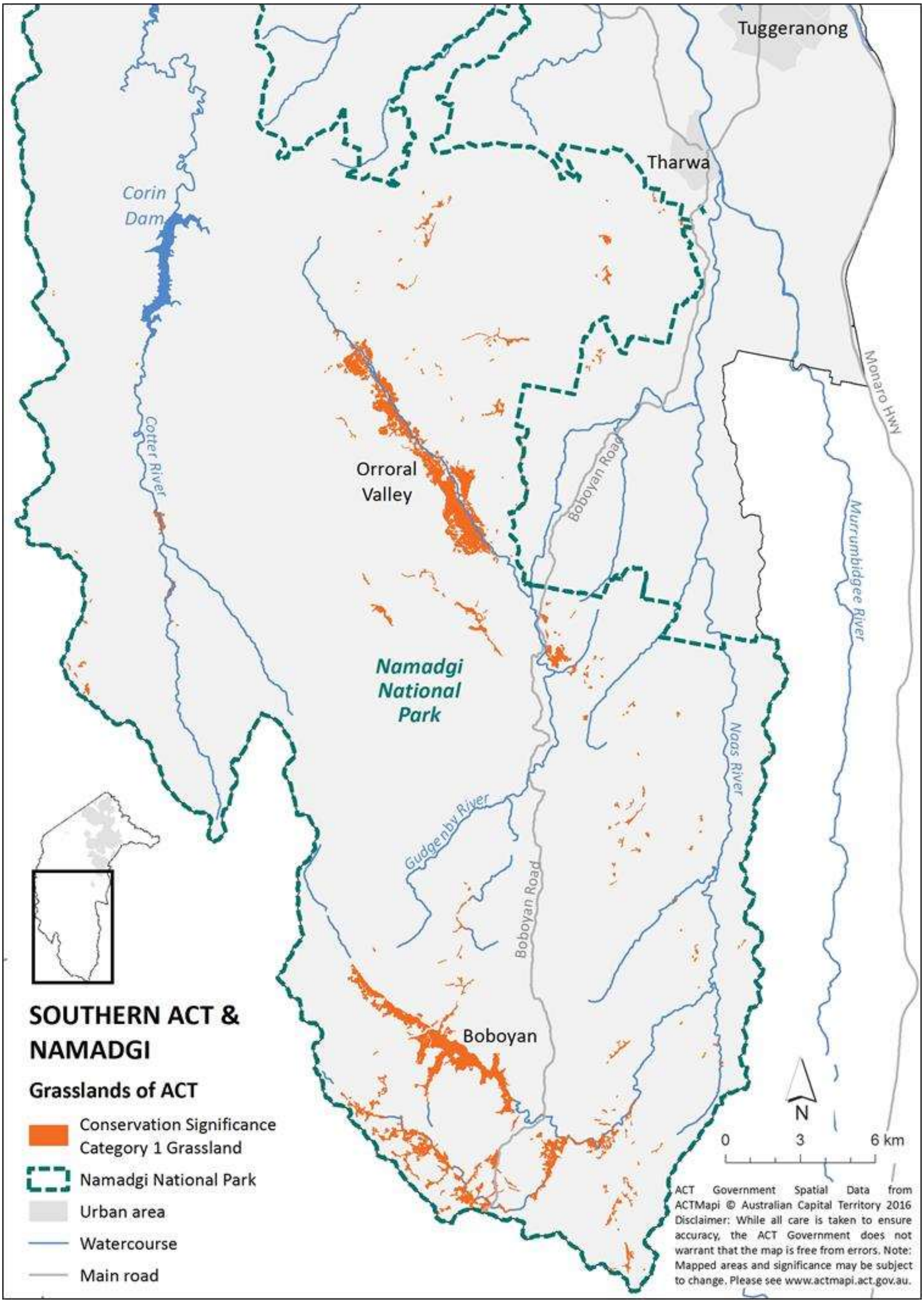


Figure 2. Map of native grasslands in the south of the ACT.



Pale Sundew (photo M. Beddingfield)

3. STRATEGY: REDUCE THREATS TO NATIVE GRASSLAND BIODIVERSITY

3.1 OVERVIEW

Native grasslands in south-eastern Australia are recognised as one of the continent's most threatened ecological communities (Gilfedder *et al.* 2008). Land use change, land management practices and introduced species are major contributing factors to native grassland decline and have resulted in a broad range of threats to native grassland biodiversity. These threats include factors and processes such as changes to grazing and fire regimes, invasion of pest animal and plant species, changes to grass biomass and grassland habitat structure, changes in native flora and fauna populations and ultimately the loss of native biodiversity. The consequences of climate change are likely to result in exacerbation of current threats and new threats. Managing threats is a key strategy in conserving and restoring grasslands in the ACT.

Grazing and fire regimes are key ecological processes in native grassland ecosystems and can profoundly affect (both positively and negatively) the condition, vegetation structure and species composition of native grasslands, both in the short and longer term. Consequently, the changes that have occurred to grazing and fire regimes since European settlement are one of the primary causes of modification of native grasslands (Eddy 2002). In particular, the ecological consequences of either overgrazing or undergrazing by native herbivores are a key management issue for native grasslands. Whilst inappropriate grazing and fire regimes are threats to native grasslands, these threats can be mitigated by implementing appropriate regimes. Guidelines for appropriate grazing and fire regimes for conservation of native grasslands are outlined in Chapter 4 of this strategy.

3.2 THREAT MANAGEMENT GOAL

Prevent or manage the impacts of threatening processes to maintain or improve the ecological condition and biodiversity of native grasslands, with particular attention to threatened species.

3.3 KEY PRINCIPLES

- Land management activities can affect the level of a threat (such as fire regime and potential for weed incursion) and so a 'whole of system approach' is required to mitigate threats.
- Most biological systems are complex and our knowledge of them is imperfect. The nature of threats is often imprecise and the outcomes of actions to mitigate threats may be uncertain. Priorities and allocation of resources to mitigate threats therefore requires a risk management and systems approach.
- Management programs should strategically target actual, rather than perceived, threats.
- Prevention, and early detection and intervention, are the most cost-effective techniques.
- Management of weeds and pest animals should be based on minimising the level of damage or potential for damage caused, rather than simply aiming to reduce abundance of weeds and pest animals.
- Monitoring and evaluation is required to ensure the benefits obtained exceed the risks and cost of management activities.
- An adaptive management approach is required to achieve continuous improvement.

- Impact of the urban edge on grasslands (and ongoing conservation management costs) can be reduced at the planning stage (e.g. by allowing adequate buffers and not permitting housing on the outer edge of perimeter roads).

3.4 MANAGE WEEDS

Weeds are widespread in native grasslands, including high quality grasslands. The ecological impact of weed species varies considerably, from those that have little impact on grasslands such as small ephemerals, to those that can significantly alter grassland structure and composition such as large woody weeds and stipoid tussock grasses (Robinson 2015). Once established, invasive plants can become dominant, resulting in large and dense monocultures that outcompete and eventually exclude other native grassland plants (Faithfull *et al.* 2010; Robinson 2015). Invasive grassland plants can also alter soil characteristics, such as reducing soil moisture availability (Faithfull *et al.* 2010).

Many weeds are so widespread in native grassland communities of the ACT that it is now largely impossible to control or manage them. These include species such as Catsear (*Hypochaeris radicata*), Sorrel (*Acetosella vulgaris*) and Dandelion (*Taraxacum officinale*) and many annual grasses such as Brome Grass (*Bromus* spp.), Quaking Grass (*Briza* spp.), Hairgrass (*Aira* spp.) and Fescue (*Vulpia* spp.).

Weeds in native grasslands have invaded and spread through a variety of mechanisms, including deliberate introductions for pasture improvement, as contaminants in animal feed, changes to soil nutrient levels and drainage, disturbances and the opening up of inter-tussock space. In grasslands of higher elevation areas, weeds are often more prevalent in the areas around the homesteads, alongside roads, and in areas that were historically used for grazing (Helman and Gilmour 1985; Godfree *et al.* 2004). Many invasive plants in native grasslands have long-lived seed banks that can persist for years (Snell *et al.* 2007; Briese *et al.* 2000), making control and eradication a long term process.

Weed species of particular concern in ACT's native grasslands are those listed as Weeds of National Significance (Visit the Federal Government Environment website), and those listed as pest plants under the Pest Plants and Animals Act 2005, as these species require particular actions. Woody weeds are particularly problematic in grasslands as they can disproportionally alter grassland structure and function because of their size and life form, and should be a focus of control and eradication in native grasslands (Robinson 2015).

3.4.1 Guidelines to manage weeds

- Follow current best practice strategies for weed management as provided in the ACT Weeds Strategy (ACT Government 2009).
- The four most serious weeds that should receive priority for control are the perennial grass species African Lovegrass (*Eragrostis curvula*), Chilean Needle Grass (*Nassella neesiana*) and Serrated Tussock (*Nassella trichotoma*), and the perennial forb St John's Wort (*Hypericum perforatum*).
- Two species have been highlighted as potentially becoming major weeds in high elevation grasslands: Orange Hawkweed (*Leucanthemum vulgare*) and Oxeye Daisy (*Hieracium aurantiacum*) (Rowland 2012; Doherty, Wright and McDougall 2015). It is particularly important to report any sightings of these two species.
- Other weeds that require attention for control and eradication include Sweet Vernal Grass (*Anthoxanthum odoratum*), the annual grass Wild Oats (*Avena* spp.) (depending on rainfall), the forbs Saffron Thistle (*Carthamus lanatus*) and Paterson's Curse (*Echium plantagineum*), and woody weeds such as African Boxthorn (*Lycium ferocissimum*), Sweet Briar (*Rosa rubiginosa*), Hawthorn (*Crataegus monogyna*) and Firethorns (*Pyracantha* sp.).
- Mowing/Slashing is a major cause of weed spread. Best practice slashing/mowing hygiene should be followed. To minimise spread, a protocol such as the 'Stop, Inspect, Protect' (NSW DPI) should be made standard for all slashing, both within and outside reserves:
  - **Stop**: do not slash invasive grass in seed and do not mow infested areas before clean areas.

- **Inspect** and thoroughly wash down slashers between sites.
- **Protect** native vegetation by reporting new invasive grass infestations as they are found.

- When applying control methods for a particular weed, care should be taken to prevent a 'weed-shaped hole' that allows the invasion of a second weed (Firn, House and Buckley 2010).
- Drifting of herbicides from spraying weeds onto surrounding native vegetation should be avoided.
- Appropriate action should be taken for weeds that are declared as pest plants under the *Pest Plants and Animals Act 2005* (View the Act (PDF, 167Kb)) For example, if a pest plant has been declared as notifiable, its presence must be notified to the chief executive of the relevant government agency. If a plant has been declared as prohibited, its importation, propagation, commercial supply and disposal is controlled. A declaration can also be made requiring that a pest plant must be suppressed or contained. Many of these pest plants are found in ACT native grasslands.
- Any records of weeds on the list of New Weeds, Alert Weeds and Sleeper Weeds should be reported to the Parks and Conservation Service Senior Weed Management Officer.

3.5 MANAGE INTRODUCED PEST ANIMALS

Introduced pest animals have a range of deleterious impacts on native grasslands in the ACT. The main pest animal species include introduced grazers such as the European Rabbit and Brown Hare, predators such as the feral cat and European Red Fox, and the European Wasp. In higher elevation grasslands, several additional pest animal species can be found, including the feral pig, feral horse and several species of deer (Fallow, Red and Sambar).

Introduced grazers impact native grasslands in a range of ways, including altering natural grazing regimes and grassland biomass and structure, as well as causing soil disturbance, soil fertility changes, altered drainage, trampling, and direct consumption of vulnerable species such as native forbs, lilies and orchids.

Grazing by rabbits may have played an even greater role in altering native grasslands than livestock grazing (Eddy 2002). Rabbits are widespread in grasslands across the altitudinal gradient. For example, research by Leigh *et al.* (1987) found that rabbit grazing in subalpine grasslands had significant impacts on native forb cover and diversity.

Introduced rodents such as House Mice occur in Natural Temperate Grassland, where they fill the niche of many small marsupials and native rodents that are now rare or extinct.

In the higher elevation grasslands, one of the more significant threats is the feral pig. Pigs have caused significant damage to the grasslands, as well as bogs and wetlands, in Namadgi National Park by wallowing and digging for food such as tubers of *Hypoxis hygrometrica*, *Bulbine* sp., *Gastrodia* sp., *Chiloglottis* sp. and *Arthropodium milleflorum* (Helman and Gilmour 1985; Hone 2002). Pig rooting can result in areas of bare (turned over) soil, facilitating weed establishment.

Feral horses are widespread in many Australian ecosystems, including subalpine environments. Feral horses are abundant in areas near the ACT, including Kosciusko National Park and on occasion have crossed the border into Namadgi

National Park, where they are controlled. There are many documented impacts of feral horses, including soil compaction, erosion, trampling, track formation, loss of vegetation cover, weed dispersal, and species composition change in grassy areas due to grazing (ACT Government 2007; Nimmo and Miller 2007).

Feral deer are browsers, and can potentially impact native grasslands in the ACT by wallowing and track formation, and are considered to be a particular risk for subalpine wetland areas (ACT Government 2012b).

Predation by introduced predators, including foxes and both feral and domestic cats, can potentially have a large impact on native fauna populations in grasslands, such as birds, small mammals and reptiles. Foxes in south-eastern Australia are known to predate on small mammals, lizards and insects (Saunders et al. 2004). Diets of domestic cats in Canberra have been found to include a range of native and introduced fauna, including grassland species such as the Olive Legless Lizard (*Delma inornata*) (Barrat 1997; Eyles and Mulvaney 2014).

European Wasps are found throughout the ACT and have expanded to the remote areas of Namadgi National Park (ACT Government 2012b). In rural areas away from urbanisation, European Wasps usually nest in underground holes dug in the soil (Ward, Honan and Lefoe 2002). Their impacts include reducing populations of other insects, as well as potentially attacking and stinging people and animals, particularly when defending nests (ACT Government 2012b).

Wild dogs (mostly dingoes that have hybridised with domestic dogs) are present in remote areas of the ACT including Namadgi National Park where montane grasslands occur. Although wild dogs are considered to be pests by graziers due to their impacts on sheep, they have been performing the beneficial role of higher order predator in Australian ecosystems for around 4000 years (Corbett 2008). Wild dogs prey on species such as kangaroos, wallabies and rabbits, and may help suppress other predators such as the introduced Red Fox and cat, thus playing a role in maintaining biodiversity (Letnic *et al.* 2013). Wild dogs are controlled in areas adjoining rural properties to protect livestock. However, in core areas of Namadgi National Park such as the Gudgenby Valley (including montane grasslands), they are protected. For further information, visit the [ACT Environment PCS website.]

Serrated Tussock

3.5.1 Guidelines to manage introduced pest animals

- For native grasslands in the ACT, the major pest animals requiring management are the European Rabbit, European Red Fox, feral cat, Brown Hare, and the European Wasp. In the higher elevation grasslands several additional pest species also require management: feral pigs, feral horses, and deer (Fallow, Red and Sambar).
- Follow current best practice strategies for pest animal management in the ACT, which are provided in the *ACT Pest Animal Management Strategy 2012–2022* (ACT Government 2012b) and *Best Practice Management Guide for Rabbits in the ACT* (ACT Government 2015c).
- Feral horse management should be guided by the *Namadgi National Park Feral Horse Management Plan 2007* (ACT Government 2007).
- Wild dog management in montane grasslands should be guided by ACT Government Wild Dog management policies, and the *Namadgi National Park Plan of Management 2010*.

3.6 ECOLOGICALLY INAPPROPRIATE DISTURBANCE REGIMES

Natural disturbance regimes, such as fire and grazing, are critical processes in Natural Temperate Grassland. Appropriate levels of disturbance in grasslands will regulate grass biomass and inter-tussock space (Lunt *et al.* 2012; Tremont and McIntyre 1994), ensuring habitat for flora and fauna, and thus biodiversity, is maintained. Disturbance regimes that are either too frequent or too few will result in simplification of grassland structure and loss of flora and fauna diversity.

Generally, lowland *Themeda triandra*-dominated Natural Temperate Grassland has suffered declines in condition because of a reduction in disturbance frequency, particularly fire, resulting in the accumulation of grass biomass and declines in inter-tussock space (Morgan 2015). This situation is further exacerbated in many of the ACT's smaller urban remnants that have very few, if any, native grazers (i.e. kangaroos) to control grass biomass. Under-grazing of native grasslands results in the accumulation of very high plant biomass which is undesirable due to the reduction in grassland ecological condition and biodiversity (many forbs cannot survive or reproduce when grass is very long and dense), and the decline in habitat quality for threatened grassland species.

In other Natural Temperate Grassland communities, overgrazing has occurred as a result of (a) inappropriate stocking densities (sheep and cattle), (b) high numbers introduced grazers such as rabbits, and (c) in some instances by relatively high densities of kangaroos (see section 3.7). Over-grazing can result in the simplification of grassland structural complexity, and changes in plant species composition through grazing selectivity (Morgan 2015). Unlike fire, which is indiscriminate in herbage mass removal, grazers have preferences for grazing some species over others. For example, *Themeda triandra* is palatable to stock, and in south-eastern Australia, *T. triandra*-dominated grasslands can be converted to dominance by other species under persistent livestock grazing (Lunt *et al.* 2007).

Native forbs can also be reduced or lost from the plant community if they are more palatable and are grazed preferentially, or if they are generally intolerant to exogenous disturbances (Tremont and McIntyre 1994; McIntyre and Lavorel 1994). Stock and other introduced grazers can cause physical degradation by trampling, increased nutrient inputs from animal droppings, increased weed invasion through the creation of bare ground and weed seed dispersal, soil erosion, and compaction. These impacts can be exacerbated during times of drought, leading to increased risk of drought-induced mortality for plants and soil erosion (Hodgkinson 2009).

See section 4.6 for guidelines to implement ecologically appropriate disturbance regimes.

3.7 MANAGE GRAZING BY KANGAROOS

Grazing by native herbivores is an integral ecological process in native grasslands. Eastern

Grey Kangaroos are the most abundant native mammalian herbivore in grasslands and are considered to be an 'ecosystem engineer' in the ACT and region due to their dominant influence on grassland structure and resource availability for other species (ACT Government, 2010; Howland *et al.* 2014). Kangaroo densities can fluctuate depending on influences such as the creation of artificial watering points, predator removal, fencing and habitat fragmentation.

In the ACT high kangaroo densities in urban grassland and woodlands have resulted in overgrazing in some areas, increasing the cover of short (<10 cm) vegetation, particularly during drought years (ACT Government 2010; Vivian and Godfree 2014). The resulting lack of variation in grass tussock structure and consequent loss of plant cover reduces the diversity of fauna species that depend on tussocks for habitat (ACT Government, 2010; Antos and Williams, 2015; Howland *et al.* 2014).

Livestock grazing or fire are alternative methods for managing grass biomass, particularly in circumstances where grazing by kangaroos is unable to achieve grass herbage mass management goals. Further information on managing herbage mass though grazing is given in chapter 4.

3.7.1 Guidelines to avoid overgrazing by kangaroos

- Kangaroos are the preferred grazers for managing grass biomass and structure in native grasslands in the ACT (Chapter 4).
- Populations of kangaroos in the ACT are to be maintained as a significant part of the fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory. To prevent overgrazing by kangaroos, Eastern Grey Kangaroo populations are to be managed according to the ACT Kangaroo Management Plan (ACT Government 2010) and subsidiary policy instruments.

3.8 MANAGE IMPACTS OF URBANISATION

Urban grasslands face a different suite of pressures compared to those in rural or semi-rural areas. For example, in urban areas, pressures on grasslands commonly include dumping (of rubbish, building rubble and garden waste), high nutrient inputs, microclimate modification, trampling, trail bike riding, rock removal and roaming domestic cats, while natural disturbance regimes such as fire are often severely modified.

Typical weeds tend to be garden escapees and species from waste areas (Cilliers, Williams and Barnard 2008). Grasslands in urban areas tend

Eastern Grey Kangaroos

to have higher rates of plant population extinction than those in semi-rural and rural areas. The risk of plant population extinction increases with factors such as fragmentation (e.g. due to higher road density) and reduction in natural disturbances (e.g. longer intervals between fires) (Williams *et al.* 2005a, 2005b). A thorough discussion of design and planning principles for native grasslands in urban areas can be read in Marshall (2015).

3.8.1 Guidelines to minimise impacts of urbanisation

- During the planning stages of new developments, design urban edges that minimise impacts of the urban edge on adjacent native grasslands (including provision of adequate buffer areas and creation of hard urban edges such as roads to minimise incursions of garden weeds and domestic animals).
- Fire fuel reduction zones that are intensively managed to protect urban assets from fire (i.e. Inner Asset Protection Zones) are incorporated into the development area and not adjacent protected areas. For example, planning to have a sealed road between a suburb and the adjacent nature reserve provides a desirable hard edge and also serves as part of the Inner Asset Protection Zone (which may also include the nature strip in front of houses and 10-20 m wide mown area between the road and the nature reserve fence which can be used for cycle paths and recreational activities such as walking dogs).
- Sites adjacent to grassland remnants in urban areas are managed to avoid adverse effects, such as reducing run-off, weed invasion, trampling and pest animals.
- In small urban grassland remnants, avoid shading from nearby planted trees or buildings (Marshall 2015). Trees should not be planted in native grasslands set aside for conservation.
- Avoid impacts from infrastructure developments in high conservation urban grassland remnants, such as laying of pipelines and hard-surface paths. Where services (cables, pipelines etc) are necessary they should be installed by tunnelling under the surface, not trenching, wherever possible.
- Implement measures aimed at preventing urban-edge disturbances and their impact on grassland remnants in urban areas, such as rock removal, soil compaction, topsoil removal, stockpiling or dumping of materials such as gravel and soil, fertiliser use, and activities that result in soil erosion. If disturbance is necessary, follow-up rehabilitation should be undertaken including levelling, weed removal and encouraging the establishment of native plant species from the adjacent vegetation (Eddy 2002).
- Any new residential areas developed in the vicinity of a Natural Temperate Grassland Reserve, or threatened grassland fauna habitat, should be declared cat containment areas.
- Ongoing protection and management of grassland reserves in urban areas can be enhanced by including the local community in grassland conservation and educational activities, such as through urban Landcare and ParkCare groups.

3.9 MANAGE THE CONSEQUENCES OF CLIMATE CHANGE

Maintaining biodiversity under climate change involves the acceptance that ecological change is inevitable, and implementing actions to influence the trajectories of ecological change toward desirable long-term conservation goals. To help species adapt to climate change, the ACT Government recommends adopting national best practices developed by CSIRO's AdaptNRM (Visit the AdaptNRM website) Recommendations from AdaptNRM are largely consistent with existing best practices in the management of grasslands in the ACT region; for example, enhancing ecosystem resilience to change, improving landscape habitat connectivity and building adaptive capacity within agencies and the community.

Climate change is expected to exacerbate many existing threats to grasslands. Management guidelines under climate change have therefore been incorporated into relevant sections throughout this strategy. A key recommendation from AdaptNRM is to implement 'climate-ready best practices' that make sense to pursue regardless how the future unfolds (i.e. 'no-regrets' actions) and more 'intensive options' under potentially extreme changes in climate.

Best practices for managing grasslands to be 'climate-ready' include:

- Minimising human induced non-climate stressors, and encouraging positive land use change with benefits for biodiversity (see Chapter 3).
- Protecting large areas of habitat and maintaining large populations, promoting species-level genetic diversity, and enhancing connectivity to support migration and range shifts (see Chapters 2 and 5).
- Monitoring and accepting change (see Chapters 5 and 6).

More intensive management options to help safeguard native grasslands and constituent species under potentially extreme changes in climate include landscape engineering, captive breeding, seed banking and translocations, as well as identification of potential climate refugia and the creation of reserves with hard boundaries such as roads.

More detailed information on the effects of climate change and guidelines to assist ecosystems to adapt can be found in Chapter 5.

3.9.1 Guidelines to manage the consequences of climate change

- Apply the 'precautionary principle': take action now, despite future uncertainty.
- Explore plausible future scenarios for the ACT region, as well as appropriate adaptation responses, by building the capacity of land managers, policy makers, researchers and community volunteers in both scenario planning and development of 'adaptation pathways'.
- Participate in national and regional initiatives such as AdaptNRM to promote best practice.

4. STRATEGY: MANAGE NATIVE GRASSLAND AND COMPONENT SPECIES FOR CONSERVATION

Natural grasslands require active management to maintain their ecological condition, to provide habitat for component species, to promote recovery of threatened species and to reduce threats to the ecological community (such as weed infestation). Grass (or more correctly, herbage) biomass and grassland structure are key drivers of vegetation and fauna dynamics in native grasslands (Morgan 2015) and hence grassland biodiversity.

Some grasslands in the ACT are not managed primarily for livestock (such as those in reserves) and in these areas Eastern Grey Kangaroos may be responsible for most of the herbivory. The interaction between seasonal conditions (grass growth) and kangaroo abundance (grazing) can strongly influence seasonal grass biomass and structure. Manipulating (or managing) kangaroo abundance can therefore potentially have profound effects on grassland biomass and structure. Other methods used to manage herbage mass and structure in grasslands include grazing by introduced herbivores, burning, and mowing or slashing. There is limited knowledge of the long-term effects of some of these management practices on grassland structure, composition and biodiversity.

There is some evidence to suggest optimal habitat for one threatened grassland species may not be optimal for another. Managing grasslands to conserve a range of species is likely to be dependent on maintaining a patchy, heterogeneous sward structure (i.e. patches of longer, dense grass mixed with patches of shorter, more open sward) to provide a range of habitat niches. In some grasslands, differing topography and soils may provide the opportunity to manage these areas to maintain different sward structure. For example, higher areas with shallower soils are likely to have a naturally shorter and more open sward than lower areas on deeper, moister soils. For some smaller grassland fragments and at a small scale it may not be possible to maintain habitat heterogeneity to meet the requirements for all threatened species or for multiple ecological values.

Many grassland sites encompass areas of Natural Temperate Grassland, native grassland (in varying condition) and exotic grassland, some or all of which may be used as habitat by threatened species. The sometimes conflicting conservation goals (such as controlling exotic grasses versus their value as threatened species habitat) arising in these situations can lead to difficult management decisions.

A key aim of this strategy is to provide a strong focus on conservation management of the remaining grassland sites in the ACT. This chapter provides goals, principles and guidelines for the management of native grasslands and threatened species habitat.

The specific nature and detail of some management guidelines in this chapter (such as management of grass biomass and grassland structure) are more typical of guidelines in a management plan, and have been included in this strategy because of their crucial role in maintaining the condition of grasslands and biodiversity. Their inclusion in this strategy aims to:

i) provide land managers with a convenient reference for grassland management guidelines (where relevant, management guidelines have been compiled from the individual action plans), and

ii) assist the development of detailed site-specific management and/or operational plans.

4.2 MANAGEMENT GOAL

Manage native grassland in the ACT across all tenures to maintain or improve ecological condition and biodiversity, with particular attention to grassland habitat of threatened species.

4.3 KEY PRINCIPLES

- Best practice management involves applying an 'adaptive management' approach linking research and monitoring to management.
- Conservation of an intact grassland ecological community and healthy ecosystem function is preferable to conserving an area for a single species, though priority may be given to managing habitat for a particular threatened species, which can act as a 'flagship' or 'umbrella' species.
- Structurally complex grasslands (i.e. grasslands that have a mix of short, medium and long grasses with inter-tussock spaces) increase the probability of a range of plant and animal species persisting and reproducing in a grassland remnant by providing a variety of habitat and resources (Wong and Morgan 2007; Stevens *et al.* 2010; Howland *et al.* 2014; Morgan 2015).
- A heterogeneous, patchy sward structure of mostly intermediate grass biomass with inter-tussock spaces is an appropriate management goal given imperfect knowledge of the habitat requirements for many component species and of the long-term effects of management activities.
- Disturbance regimes, particularly fire and grazing, are a key ecological process in native grassland ecosystems because of their role in altering grass biomass and inter-tussock space and promoting plant reproduction and biodiversity.
- Where grazing is used to manage grass biomass and structure in native grasslands the preferred approach is the use of native herbivores.

4.4 APPLY BEST PRACTICE WITHIN AN ADAPTIVE MANAGEMENT FRAMEWORK

Though there have been significant advances in knowledge of native grassland in south-eastern Australia over the last three decades, many aspects remain uncertain. Within an overall objective of maintaining and improving grassland biodiversity, an appropriate response to this uncertainty is to apply 'adaptive management' (Nichols and Williams 2006).

Adaptive management allows for the testing of management practices in-situ to determine if they are achieving the desired outcomes, and adapting them as required. Adaptive management requires clearly defined objectives be developed based on current knowledge of the vegetation community, associated species and their responses to management. The results of the management regime must be monitored so its effectiveness can be assessed and management practices modified as required.

Monitoring assists in distinguishing between seasonal effects and long-term changes to species and site characteristics.

An important part of this adaptive management approach is the recognition that flexibility is required in the management techniques applied to particular grasslands. Grassland structure and composition differ dramatically between sites in different locations, and between sites with different soils and management histories in the same area. Consequently, no single management regime will be suitable for all species and all sites. There is now widespread acceptance by grassland ecologists of the need to adopt site-specific management approaches within the more general theoretical and empirical framework of native grassland management.

Management that is regarded by experts in a particular field to be of the highest standards at the time is termed 'best practice management'. In the context of biodiversity conservation, best practice management is that which promotes biodiversity and healthy ecosystem function.

The ACT Government will encourage best practice conservation management actions for native grasslands to be undertaken in an adaptive framework and facilitate the

Dry tussock grassland at Cotter Flats

incorporation of monitoring and research results into management of grasslands and component species.

4.5 MANAGE GRASS BIOMASS AND STRUCTURE

One of the fundamental principles of grassland conservation and maintenance of grassland biodiversity is the management of grass biomass and the space among the grass tussocks—the 'inter-tussock space' (Wong and Morgan 2007; Morgan 2015). This principle is based on the essential role of native grasses in maintaining the structure and function of healthy native grassland ecosystems, particularly through the provision of habitat and resources for grassland animals. Grass biomass in turn is controlled by factors such as disturbance regimes (e.g. fire and native animal grazing), site productivity and seasonal conditions such as rainfall and temperature. In modified grassland communities, particularly where herbivores and/or their predators have been removed, the natural processes that influence grass biomass levels are usually disrupted and, as a result, grass biomass levels can become too high, too low, or too homogeneous to support a diverse grassland community. Grass structure and biomass are related; both 'overgrazed' and 'undergrazed' areas tend to be too structurally homogeneous to support a diverse range of organisms.

For native grassland forbs, inter-tussock spaces are a critical microhabitat for germination, establishment and growth (Morgan 1998; Morgan 1997; Tremont and McIntyre 1994). If grass biomass levels become too high, the inter-tussock spaces decrease in size and number and become shaded by the tussock grasses, which can monopolise resources. This reduces forb seed germination, emergence from below-ground organs, growth, flowering rates, seed production and seedling establishment (Lunt and Morgan 2002), as well as persistence of the biological crust (O'Bryan *et al.* 2009).

Maintenance of a healthy biological crust (a layer of algae and cryptogams that form a protective covering on top of the soil) as part of the grassland ‘structure’ is important in reducing erosion and loss of nutrients (Sharp et al. 2015). The biological crust can be damaged by disturbance, including vehicles and trampling by people and animals with hard hooves (stock).

Native grassland fauna can also be affected by changes to grass biomass, with many species having specific habitat requirements (Figure 3). For example, the Eastern Three-toed Earless Skink is associated with habitats containing relatively tall grass with large amounts of grass biomass and grass cover, whereas the Striped Legless Lizard is associated with habitats containing intermediate (Howland *et al.* 2014) to moderately high (Biosis 2012) grass biomass and cover.

In contrast, the Golden Sun Moth prefers sparser vegetation with low grass biomass and a relatively large proportion of open inter-tussock space to allow males to locate females after emergence.

Other species such as the Grassland Earless Dragon have been found to prefer a sward of generally low to intermediate grass biomass/cover with well-developed inter-tussock spaces, often with some bare ground. Grassland Earless Dragon habitat often contains patches of short, medium and longer grass sward in a mosaic, which is likely to provide a greater range of shelter, invertebrate food, and thermoregulatory opportunities (Stevens *et al.* 2010).

Pink-tailed Worm-lizards occur in rocky grasslands, with shallowly embedded surface rocks comprising a key structural component of their habitat.

Grasslands that contain a mosaic of sward structures (i.e. patches of mostly medium height sward mixed with patches of shorter more open sward and patches of longer dense grass) are likely to support a diversity of species that have somewhat different habitat requirements, or provide a range of habitats for a species to use on a seasonal basis (e.g. Striped Legless Lizards may use dense grass as a refuge during hot, dry periods, or when adjacent areas are heavily grazed, and use shorter or less dense grass at other times).

The management guidelines below are based on current knowledge and some are likely to be modified within the life of this strategy in light of new knowledge. More detail on management actions for threatened species are included in the respective action plans.

4.5.1 Definition of grass height

Grass height (or length) is defined in this document as the height of the grass leaves, not the longer culms that bear seedheads, which are often taller than the grass leaves. The grass leaf height is defined as the height of the denser part of the tussock or grass sward, and does not include the few longer grass leaves that often extend higher than the ‘bulk’ of the grass leaves

Striped Legless Lizard in Kangaroo Grass (photo by M. Evans)

in the tussock or sward. Therefore, the height of a tussock is measured from the ground up to where the denser (or leafier) part of the tussock thins out to become relatively few grass leaves (these relatively few grass leaves and seedhead culms may extend much higher).

4.5.2 Guidelines for managing grass biomass and structure

General guidelines for grass biomass and structure

- As a general rule, aim to maintain a grassland that has intermediate levels of grass biomass, which will promote a grass structure suitable for many grassland species, including threatened species. Such grassland will usually have well-defined tussocks mostly ranging in height between 5 cm and 20 cm, and inter-tussock spaces composed of shorter grasses and forbs with perhaps some bare ground. Avoid removing most of the grass biomass as this creates a very short grassland. Short grassland has grass mostly <5 cm high and usually a high proportion of bare ground but may also have dead thatch or short forbs. Also avoid maintaining grasslands that have high grass biomass. High biomass grasslands tend to have mostly tall (>20cm) dense grass with very little or no inter-tussock spaces and potentially a large build-up of thatch. See Section 4.5.1 for definition of grass height.
- In addition to maintaining mostly intermediate levels of grass biomass, aim to maintain a heterogeneous, patchy grassland sward. A patchy grassland of intermediate grass biomass has a grass sward of mostly intermediate height and density that is interspersed with patches of shorter, sparser grass and patches of longer, denser grass. Such a patchy grassland structure is often naturally created under grazing (by native or introduced herbivores) where mostly intermediate grass biomass is maintained, but could possibly be created using burning. The uniform height created by slashing or mowing is unlikely to promote patchy grassland structure. However, slashing/mowing may still be useful for managing grass biomass and maintaining inter-tussock spaces.
- Aim to maintain grass biomass at intermediate levels even during productive (high grass growth) years, as this will help maintain inter-tussock gaps to allow for the regeneration of native forb species (Wong and Morgan 2007).
- The three main tools for managing grass biomass are: (a) the manipulation of grazing regimes (including both native and introduced grazers), (b) the manipulation of fire regimes, and (c) mowing/slashing. Each of these techniques has different degrees of impact on plant biomass, as well as on native and introduced plant species (Morgan 2015).
- Where grazing is used to manage grass biomass, the preferred method is to use native herbivores (kangaroos), with grazing by stock used in circumstances where kangaroo grazing is unable to maintain the desired grass biomass/structure at a site.
- If fire is used as a management tool in grasslands with threatened fauna, aim to create a patchy mosaic of burnt and unburnt areas at a fine-scale (burnt and unburnt patches that are tens of metres across rather than hundreds of metres across). In low quality habitat (where abundance of threatened lizards is expected to be low), burns may be required on a broader scale to improve overall habitat quality.
- Slashing/mowing may be required in circumstances where it is not practical to use grazing and/or burning to manage grass biomass.
- Different grassland community types require different frequencies of grass biomass removal because rates of grass biomass accumulation depend on grass growth rates, which in turn will vary according to grass species, soil fertility, and climate, as well as seasonal moisture availability (Morgan 2015; Lunt and Morgan 2002; Schultz, Morgan and Lunt 2011).
    - At sites with high moisture and nutrient availability, such as some high productivity Kangaroo Grass (*Themeda triandra*) dominated grasslands, grass growth is relatively fast and will require more frequent biomass removal (e.g. grassland associations r3 – if dominated by *Themeda*, and r7 (see section 8.1.4)).
    - In lower productivity sites, grass growth is more likely to be limited by lower resource availability and poorer

growing conditions, requiring less grass removed, or less frequent removal. This is likely to be the case in grasslands dominated by Wallaby Grasses (*Rytidosperma* spp.) and Speargrasses (*Austrostipa* spp.) (e.g. grassland associations r3 – if dominated by *Rytidosperma*, r5, r6), and grasslands at higher elevations (e.g. grassland associations a14, a30, r1 and r2) and on poor quality sites (e.g. grassland association r8) (see section 8.1.4).

- The history of past management practices at a site can influence the outcome of different biomass management techniques. For example, implementation of fire in long-unburned grassland may have different outcomes to fire used in regularly-burned grassland due to changes in the dominant grass species over time (Sinclair, Duncan and Bruce 2014). The past management practices at a site should be adopted as an initial guide to the grass biomass management method (Morgan 2015).
- Grass biomass and inter-tussock space can vary seasonally according to moisture availability. The prevailing or expected climatic conditions (e.g. drought or La Niña) should be considered when planning grass biomass/structure management strategies.
- If there is conflict between management of habitat for threatened grassland species and management for overall grassland floristic diversity, priority should be given to management of habitat for the threatened grassland species.
- The management of threatened grassland plants should be given equal importance to the management of threatened grassland animals.

Species priority

- If there is conflict between habitat management for two or more threatened grassland species, the priority for management should be determined on the basis of the threatened species listing category (vulnerable, endangered, critically endangered), how abundant and/or restricted in distribution the remaining populations are, how important the site is to the conservation of the species and the nature of any ongoing threats. In most cases, the order of priority will be Grassland Earless Dragon, Pink-tailed Worm-lizard, Striped Legless Lizard, Golden Sun Moth, Ginninderra Peppercress, Baeuerlens Gentian, Button Wrinklewort and Perunga Grasshopper.

Guidelines for Grassland Earless Dragon habitat

- Aim to maintain grassland that has a well-defined tussock structure (i.e. tussocks with inter-tussock spaces). Tussock leaf heights should mostly be between 5 cm and 15 cm, with inter-tussock spaces composed of shorter grasses, forbs and bare ground. This structure can be promoted by maintaining intermediate levels of grass biomass. Avoid creating a grass sward that is uniformly very short (<5 cm) or uniformly very tall and dense (>15 cm high with very few inter-tussock spaces).
- Suitable habitat for Grassland Earless Dragons typically has a fine-scale mosaic of patches of shorter, medium and longer grass, with patches often being several metres across. Maintaining intermediate grass biomass though grazing and/or small-scale patchy burns will promote a patchy grassland structure.

Refer to the Grassland Earless Dragon Action Plan for more information.

Guidelines for Striped Legless Lizard habitat

- Aim to maintain grassland that has an intermediate grass biomass. Grass leaf height should mostly be between 10 cm and 20 cm. Striped Legless Lizards often occur in tall, dense grass (i.e. high grass biomass), which might be important refugia during times when other parts of the habitat are heavily grazed. However, it is possible that tall, dense grass is not their preferred habitat or meets their requirements for breeding, thus management actions should aim to avoid maintaining a large proportion of high grass biomass in Striped Legless Lizards habitat over the longer term (i.e. several years). Where it is impractical to reduce the grass biomass of patches of tall dense grass (such as exotic Phalaris (*Phalaris aquatica*) in moist drainage lines), aim to provide more suitable habitat patches (intermediate grass biomass) adjacent to the patches of long, dense grass.

Refer to the Striped Legless Lizard Action Plan for more information.

Guidelines for Golden Sun Moth habitat

- Aim to maintain grassland that has an intermediate to moderately low grass biomass, with a grass sward that is generally moderately short to medium height (5 cm to 15 cm), has an intermediate density (cover) of tussocks, low weed cover and tussocks are interspersed with areas of bare ground.
- It is important to avoid long, dense grass in Golden Sun Moth habitat during the spring/summer breeding season (October to December), when flying males are actively searching for non-flying females on the ground. However, Golden Sun Moths are probably relatively tolerant of longer grass outside the breeding season (when the species is present as subterranean larvae amongst the roots of grasses).

Refer to the Golden Sun Moth Action Plan for more information.

Guidelines for Perunga Grasshopper Habitat

- Sighting records of this species suggest Perunga Grasshoppers may prefer a grass sward that is intermediate to moderately short , with inter-tussock spaces for forbs (which the species feeds on), though their detailed habitat requirements is not well understood. In the absence of such detailed knowledge, it is appropriate to follow the general guidelines for managing grass biomass and structure (section 4.5.2), which are to maintain a grassland structure that has intermediate levels of grass biomass and a 'patchy' grassland structure.
- Where Perunga Grasshoppers occur with other threatened grassland animals, the grassland should be managed as habitat for these other threatened species, with the assumption that these other animals will act as 'umbrella' species for Perunga Grasshoppers (i.e. management actions to benefit an umbrella species will also benefit other species with similar conservation requirements).

Refer to the Perunga Grasshopper Action Plan for more information.

Guidelines for Pink-tailed Worm-lizard Habitat

- Aim to maintain grassland that is composed of native grasses (particularly Kangaroo Grass (*Themeda triandra*)) with no or little weed cover (weeds are a key threat to Pink-tailed Worm-lizard habitat).
- Maintain surface rock by implementing management actions that prevent or discourage surface rock removal (shallowly embedded surface rock is a key habitat requirement for the species).
- Avoid disturbance in the species habitat, such as intense grazing, application of fertilizer, trampling, soil earthworks/movement/erosion.
- Moderately frequent fire (every 3–5 years) and light grazing (kangaroos or stock) may assist in maintaining a cover of native grasses such as *Themeda triandra*.

Refer to the Pink-tailed Worm-lizard Action Plan (ACT Government 2016c) for more information (not included in this Grassland Strategy document).

Guidelines for threatened flora habitat

- Aim to maintain grassland that has a well-defined heterogeneous tussock structure (i.e. tussocks with inter-tussock spaces). This structure can be promoted by maintaining intermediate levels of grass biomass through grazing and/or burns. Avoid creating a grass sward that is uniformly very short (<5 cm) or uniformly very tall and dense (>20 cm high with very few inter-tussock spaces).
- Aim to control or prohibit weed species from crowding out threatened flora populations.

Refer to the action plans for Button Wrinklewort, Ginninderra Peppercress or Baeuerlen's Gentian for more information.

4.6 IMPLEMENT ECOLOGICALLY APPROPRIATE DISTURBANCE REGIMES

Disturbance regimes are an important component of managing grassland biomass, structure and ecological function and maintaining biodiversity. A disturbance regime consists of the patterns of a disturbance (such as grazing, burning and mowing/slashing) over time and space, and includes characteristics such as:

- frequency (the number of disturbance events in a given period)
- time since the last disturbance
- intensity
- seasonalityduration
- extent/size/patchiness

Variations in these characteristics can all have a strong influence on grassland ecosystems. An example is fire, which (depending on the regime) can have positive or negative effects on grasslands and component species. Frequent fire can cause the loss of sensitive species, infrequent fire can result in excessive grass biomass, and many plants and animals have times in their life cycles when they are more sensitive to the effects of fire.

4.6.1 Guidelines for implementing appropriate grazing regimes

Where grazing is used to manage grass biomass, preference is to be given to using native herbivores instead of introduced herbivores. However, grazing by introduced herbivores is still a useful tool in circumstances where grazing by native herbivores is unable to achieve the desired grass biomass/structure at a site.

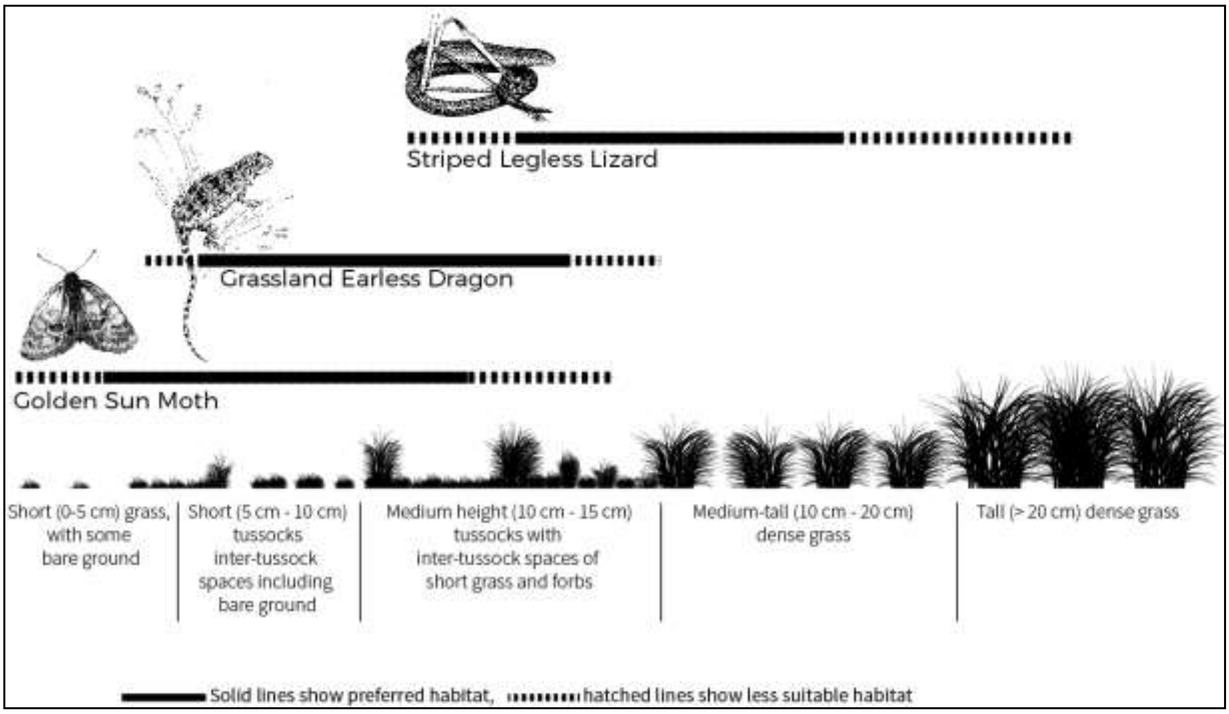
Grazing is most useful as a grassland management tool when the dominant plant species that require biomass management are highly palatable and when the aim is not necessarily to increase native plant biodiversity but to maintain fauna habitat through grass biomass and structure management (Morgan 2015).

Stock grazing as a management tool must be avoided in grasslands with little or no history of stock grazing, due to the likelihood of selective eating of grazing-sensitive forbs, particularly in *Themeda triandra* dominated grasslands (Wong and Morgan 2007; Morgan 2015).

Where stock are used as a management tool, any potential physical impacts should be monitored and minimised, including weed invasion, breaking of soil crusts and damage to the soil surface by hoofs (Wong and Morgan 2007).

In urban lowland grasslands of the ACT, kangaroo densities and their impacts on native vegetation and fauna should be

Figure 3. Diagram of different grass heights and habitat suitability for some threatened grassland fauna.



managed in accordance to ACT Government policies as outlined in the Kangaroo Management Plan (2010) and other subsidiary documents.

4.6.2 Guidelines for implementing appropriate burning, and burning regimes

Conservation management of native grasslands typically aims to promote native plant diversity. To achieve this aim, fires in native grasslands should be implemented in mid to late summer or autumn as this period is outside the major growing season, but before the first autumn rains that can cause resprouting and seed germination (Morgan 2015). Burning of sprouting or germinating plants can impede regeneration of these plants. However, some grassland plants species can be sensitive to summer or autumn burns (Lunt 1994), in which case a late winter or spring burn might be appropriate.

The frequency and timing of fire at a site should consider the life cycles of grassland species present, particularly if the aim is to minimise the immediate impact of prescribed burns on these species. For example, for species such as the Striped Legless Lizard, burning when the animals are most active (i.e. afternoons in September–October or March–April) allows them to move away from fire, whereas burning in Golden Sun Moth habitat in the breeding season or in the month following (October–January) is likely to kill all the eggs laid at the bases of grass tussocks and it is possible the burnt tussocks may not be suitable oviposition sites for females. Where burning is used to maintain or improve habitat quality, the risk of immediate impact to target species from fire needs to be weighed against longer-term habitat benefit.

Grasslands should not be burnt uniformly, but in a heterogeneous (or mosaic) pattern of burnt and unburnt patches to allow a range of refugia and grass structures for species to persist (Wong and Morgan 2007). If threatened grassland animals are present at a site, avoid burning more than a total of 50% of the habitat for these species at the site in any year unless there are good ecological reasons for doing so.

Steps should be taken to reduce the risk of weed invasion after a planned fire. This may involve close monitoring of burnt areas in grasslands of high risk (i.e. close to weed sources, history of weed invasion and a soil seed bank of exotic species) and weed control.

In higher productivity *Themeda triandra* dominated grasslands, frequent burning on an annual to five yearly cycle is considered to be an important ecological process for maintaining floristic diversity and fauna habitat (Morgan 2015). Fire can improve tussock grass health and habitat heterogeneity for fauna and benefit native plant biodiversity by maintaining inter-tussock space (Morgan 2015; Lunt, Prober and Morgan 2012). If fires occur at lower frequencies, the grass canopy has more time to re-establish, and significant reductions in gap size and number can occur after just three years without fire (Morgan 1998). As well as the competitive exclusion of other species, including other vascular plants and the biological soil crust (Morgan 1999; O'Bryan *et al.* 2009), long fire-free periods (even after six years) can lead to declines in the health and vigour of *Themeda triandra* tussocks (Morgan and Lunt 1999). However, these fire frequencies may not be optimal for maintaining plant diversity during periods of drought or La Niña (higher rainfall) or for conserving a priority plant or animal that has a different requirement for fire frequency.

There is currently insufficient evidence to support the frequent use of fire in low productivity grasslands; that is, those grasslands dominated by species other than *Themeda triandra*, and *T. triandra* grasslands in low productivity sites or at higher elevations where the growing season is shorter. There is some evidence to suggest that fire in drier or colder native grasslands does not promote plant diversity (Wong and Morgan 2007) and can even cause grass mortality (Sinclair, Duncan and Bruce 2014). Fire should therefore not be reintroduced into grassland community types that occur on lower productivity sites nor those at higher elevations unless in a carefully designed experimental/research approach to test its impact.

Fire frequency is naturally lower in higher elevation grasslands, with landscape-level fires being a relatively rare event, and the introduction of planned fire is unlikely to be required. After fire, the in-filling of inter-tussock space and production of a litter layer in higher elevation grasslands can take years to occur due to slower plant growth, potentially increasing the risk of soil erosion (Wahren, Papst and Williams 2001).

4.6.3 Guidelines for implementing appropriate mowing/slashing regimes

Mowing/slashing can be a useful grassland management tool in small grassland fragments where burning or grazing is impractical. Mowing/slashing is also useful for managing grass biomass in specific locations for non-conservation purposes, such as along fence-lines and management tracks.

Winter is generally the best time for mowing/slashing to avoid negative impacts to grassland plants, as at other times of the year it can potentially reduce grass reproduction due to its effect on active grass growth and tiller production, flowering and seed production (Morgan 2015).

The height at which grass is slashed is likely to affect fauna habitat, and so the minimum slash height should be regularly reviewed in the light of new information.

Where possible, slashed material should be removed due to the potential for smothering grass tussocks, and creating moist conditions that favour exotic grass growth (Eddy 2002; Morgan 2015).

It is essential that best practice slashing/mowing hygiene is followed (such as detailed in the Parks and Conservation Service Weeds Operation Plan). This will usually involve cleaning mowing equipment with high pressure spray between sites to avoid spreading weed seeds, and may involve spot spraying for invasive weeds at least one month prior to mowing.

See Section 3.4.1 for more information.

4.7 MANAGE FIRE RISK

Native grasslands occur on the urban fringe and within the urban fabric of Canberra. Many of these grasslands are part of Canberra Nature Park, such as the nature reserves of Gungaderra, Mulangarri, Crace and Dunlop, whereas other native grasslands occur on Commonwealth Land, such as the former Belconnen Naval Base. In addition to their role of protecting native species (many of which are threatened), native grasslands in urban areas provide open space, opportunities for recreation and for enjoying nature, and visual amenity.

Grasslands in the urban area, however, can pose a fire risk to residences and urban infrastructure. Managing these urban grasslands involves recognising the goals of conservation and those of reducing the risk of fire to property (houses and other assets). To reduce fire risk, management of urban grasslands involves maintaining low to moderate levels of grass herbage mass (fuel load) within 'Asset Protection Zones' that are located adjacent to urban development through regular burning, grazing or slashing/mowing. 'Fire-wise' planning of the interface between reserves and urban development areas is also important in minimising fire risk, such as using hard surfaces (sealed road) between nature reserves and adjacent urban areas.

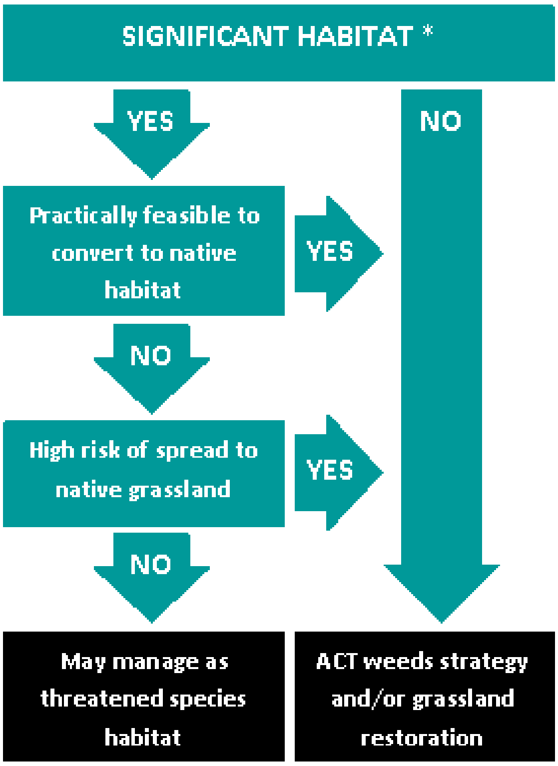
4.8 MANAGE HABITATS THAT INCLUDE EXOTIC GRASSES

Native grasslands, including high quality Natural Temperate Grassland, typically contain a component of exotic grass and other weeds. Some exotic grasses, such as Serrated Tussock (*Nassella trichotoma*), tend to occur as individuals or small clumps of plants dispersed amongst native grasses whereas other species, such as Phalaris (*Phalaris aquatica*), can form large patches within or adjacent to native grasslands. The abundance of exotic grasses is a key contributor to habitat degradation for most plant and animal species dependent on the native grassland community.

However, certain exotic grass species can provide habitat for some fauna species including threatened species. Striped Legless Lizards can be found in patches of Phalaris, Yorkshire Fog (*Holcus lanatus*), Tall Fescue (*Festuca arundinacea*) or Cocksfoot (*Dactylis glomerata*), particularly where adjacent native grassland has been heavily grazed and does not provide adequate cover for these lizards. Because Phalaris usually occurs in moister parts of the landscape and when long and hayed-off is generally unpalatable to stock and kangaroos, patches of this grass can provide refuge for Striped Legless Lizards (and probably other small animals) during drought. Conversion of Phalaris to native grassland is currently difficult and usually not practical, particularly where it occurs in wetter areas (which usually have higher nutrients), along drainage lines and other low-lying moist areas. In situations where Phalaris is unlikely to spread from moist areas, managing the Phalaris as habitat for Striped Legless Lizards might be the best option.

Golden Sun Moth larvae feed on the roots of native grasses including *Rytidosperma* spp. (Wallaby Grasses) and *Austrostipa* spp. (Speargrasses) but are also known to feed on the roots of Chilean Needle Grass (*Nassella neesiana*) and there is some evidence to suggest they can also feed on the roots of Serrated Tussock. Golden Sun Moths can apparently survive in grassland patches composed almost solely of Chilean Needle Grass and there is some evidence the larvae attain greater weights when feeding on this species (Sea and Downey 2014). Where Chilean Needle Grass is used by Golden Sun Moths and the spread of the grass can be contained or poses a relatively low risk to native grasslands, managing the Chilean Needle Grass as Golden Sun Moth habitat might be the best use of the area. Examples of this situation

Figure 4. Flow diagram to assist with decisions on managing habitat that includes exotic grass



*Significant habitat means the removal of the habitat (exotic grass) is likely to significantly negatively affect the short or long term viability of the species at the site.

include the large population of Golden Sun Moth in an extensive area of Chilean Needle Grass in the Macgregor West conservation area, and Chilean Needle Grass used by Golden Sun Moths in large roundabouts, playing fields and median strips.

With the increase in exotic grasses in native grasslands and the lack of techniques and/or resources to reduce the abundance or spread of these grasses, decisions about how to best conserve threatened grassland species must now weigh up the value of exotic grasses as habitat against the risk these grasses pose to further degradation of the remaining native grassland patches.

4.8.1 Guidelines for managing habitats that include exotic grasses

'Significant habitat' in this section means the removal of the habitat (exotic grass) is likely to significantly negatively affect the short or long-term viability of the species at the site. Figure 4 provides a diagram to assist with decisions on managing habitat that includes exotic grass.

Where exotic grasses do not comprise significant habitat for threatened grassland species, management should be according to the ACT Weeds Strategy 2009 - 2019 (ACT Government 2009).

Where a patch of exotic grass (whether or not it is habitat for threatened species) poses a high risk of spread into high quality native grassland because it cannot be practically contained, management should be according to the ACT Weeds Strategy.

Where exotic grasses comprise significant habitat for threatened grassland species and it is also practically feasible to convert the exotic habitat back to native grassland habitat, the exotic grasses should be managed according to the ACT Weeds Strategy with the aim of restoring native grassland habitat (which is likely to require additional actions to those in the Weeds Strategy, such as restoring native grasses).

Where exotic grasses comprise significant habitat for threatened grassland species and it is not practical to convert the exotic habitat to native habitat, but it is practically feasible to contain the spread or there is a low or acceptable risk of spread into native grassland, management options may include controlling the spread and managing the exotic grass as part of the broader habitat for the threatened species.

4.9 IMPLEMENT MEASURES TO SAFEGUARD POPULATIONS

For some threatened species, preventing extinction in the wild requires significant ex-situ actions such as establishing programs for captive breeding, propagation, seed banks and translocation of individuals. Captive populations of animals or seed banks can provide some insurance against loss of a species if wild populations become extinct, with the aim of using ex-situ populations or seed banks to re-establish wild populations. Captive populations have also been used for undertaking essential conservation research that is impractical on wild populations. Captive breeding, propagation or translocation programs can be useful methods (sometimes the only methods) for promoting the recovery of small extant populations.

There are usually significant risks (both to wild and captive populations) and costs associated with establishing ex-situ populations or undertaking translocations. In general, such ex-situ actions should be used only in exceptional circumstances, such as when in-situ actions have failed and the species' survival is likely to depend on ex-situ actions (which may include essential research).

Experimental captive breeding and release to the wild have been undertaken for the Grassland Earless Dragon as part of a joint project between the ACT Government and the University of Canberra. This project aims to better understand the captive breeding and reintroduction requirements and methods for this species. Experimental translocations of Golden Sun Moths and Striped Legless Lizards have been undertaken to investigate methods to establish new populations of these species. Propagation and translocation has been undertaken for the Ginninderra Peppercress and for the Button Wrinklewort for similar reasons.

Seeds of both the Ginninderra Peppercress and Button Wrinklewort are currently banked in the National Seed Bank. These ex-situ actions are discussed further in the respective action plans for these species.

Genetic rescue (the recovery in the average fitness of individuals through increased gene flow into small populations) may be one key method through which conservation of threatened grassland species can be achieved. Before genetic rescue is undertaken the genetic structure of populations should be considered. Only in exceptional circumstances should genetic rescue be attempted without this knowledge.

4.9.1 Guidelines to safeguard populations

- Establishment of captive threatened animal populations or translocations of threatened animals should only be done in exceptional circumstances, such as when the species' survival is likely to depend on these actions, research critical to the survival of the species cannot be done on individuals in the wild, or where important ecological information can be gained by experimental translocation of 'doomed' individuals (individuals that would otherwise die due to urban infrastructure development).
- Proposals for establishing captive populations or translocations of threatened species are to be approved by the Conservator for Flora and Fauna.
- Development of proposals and implementation of programs to establish captive populations, seedbanks or to translocate threatened species should be done in consultation with the ACT Government research unit.
- Follow current best practice, such as the 'IUCN Guidelines for Reintroductions and other Conservation Translocations' (IUCN/SSC 2013).

4.10 LOCAL AND REGIONAL COOPERATION

Effective conservation management of grassland sites across all tenures in the ACT and region will involve commitment and cooperation between government agencies, other landholders and the community. The ACT Government will work with government agencies (particularly the Department of Defence and the NSW Government), landholders (including rural lessees) and the community (particularly Parkcare groups, and the Conservation Council and its member groups) to encourage and facilitate best practice management of native grassland and its component species. Methods include:

- Liaising with Commonwealth agencies responsible for managing National Land containing native grassland and habitat for threatened species, and seeking cooperative agreements (such as MOUs) with those agencies.
- Having in place management plans (Public Land) or similar arrangements (for other tenures) that reflect commitment to active and effective conservation of Natural Temperate Grassland remnants.
- Encouraging other government agencies to have management plans or similar arrangements that reflect commitment to active and effective conservation of Natural Temperate Grassland on their land.
- Identifying and prioritising management actions for individual native grassland sites, irrespective of tenure.
- Providing up-to-date best practice management guidelines for managers of all land tenures and community groups to apply when undertaking Natural Temperate Grassland management activities.
- Sharing information and knowledge on management of native grasslands and constituent species.

Blue Grass Liley (photo J. Lidner)

5. STRATEGY: ENHANCE RESILIENCE, ECOSYSTEM FUNCTION AND HABITAT CONNECTIVITY

Native grasslands in the ACT and surrounding region were extensive at the time of European settlement (Groves and Williams 1981; Costin 1954). Almost all of the region's lowland grasslands are now lost due to development in valleys and low-lying areas, with the remainder being highly fragmented and usually degraded.

Fragmented and/or degraded grasslands tend to have reduced or disrupted ecosystem function. Ecosystem function is the way in which an ecosystem works, and includes processes such as energy flows, nutrient cycling, food webs, and plant-animal interactions (Prober and Thiele 2005). Enhancing ecosystem function involves enhancing the overall condition of grasslands by repairing degradation, implementing appropriate disturbance regimes (grazing and fire), managing threats and improving ecological connectivity. Some of these actions are outlined elsewhere in this strategy and in the action plans for threatened species.

Evidence over the last decade has shown that ecological change in response to climate change is unavoidable, widespread and substantial (Williams *et al.* 2014). An important strategy for grassland conservation is to improve ecosystem function and connectivity between fragmented grassland habitats (ACT Government 2013a), with the aim of improving the long-term viability of the grassland ecological community and its resilience to climate change and other pressures.

5.2 ECOSYSTEM FUNCTION AND CONNECTIVITY GOAL

Native grasslands in good ecological condition support viable populations of grassland species, are well connected in the landscape and are more resilient, including to climate change.

5.3 KEY PRINCIPLES

- Rather than aim to restore fragmented native grasslands to a pre-European state, a more realistic goal is to enhance ecosystem function and connectivity by improving the ecological condition of grassland remnants and their value as habitat though appropriate management, threat mitigation and maintaining and creating habitat connections between remnants.
- Under a changing climate, characteristics of ecological communities (including native grasslands) will change as the communities seek a new equilibrium with the changing environmental conditions.
- Ecosystems should be viewed and managed as changing entities, with management aiming to facilitate the natural response under a changing climate though enhanced ecosystem resilience and adaptability.
- Areas that are larger, in better ecological condition and more connected in the landscape are generally more resilient and viable in the longer term, and better able to provide conditions for species and ecosystems to adapt to climate change.
- Degraded grasslands, and grasslands that are overgrazed, are more likely to experience reduction or disruption of healthy ecosystem functions.
- Small, fragmented grasslands are more susceptible to disturbance, such as from edge effects.
- Small isolated populations are more susceptible to local extinction and to genetic problems.

5.4 IMPROVE RESILIENCE AND ADAPTABILITY UNDER A CHANGING CLIMATE

The distribution of many species and ecosystems is related to, among other factors, rainfall and temperature regimes. Climate change is predicted to make the ACT region drier and warmer (ACT Government 2012a; Timbal *et al.* 2015). Future rainfall is predicted to be lower than the current average, less evenly distributed and less predictable. Native grasslands (and their distribution) are expected to respond to these changing conditions as they seek a new equilibrium with the changing environmental conditions.

Potential implications of climate change (e.g. shifts in seasonal moisture availability, increased temperatures, increasing fire frequency and intensity) for grasslands include: invasion by woody species, reduced productivity, reduced cover of native grasses and annual forbs and increased soil erosion, as well as increases in invasive weeds (e.g. Chilean Needle Grass (*Nassella neesiana*), Serrated Tussock (*Nassella trichotoma*), African Lovegrass (*Eragrostis curvula*)) (NSW Government, 2011). Invasion by trees and shrubs is likely to reduce the size of individual grassland patches, reducing the overall distribution or extent of the community in the ACT. Under this scenario it is possible that some native grassland patches may become grassy woodlands or grassy shrublands.

Responses of individual flora and fauna species are more difficult to predict, though species able to exist in grassy woodlands (as well as native grasslands) would be expected to be less affected than species dependent solely on native grassland as habitat. Pest animal species (which are often habitat and dietary generalists) may be advantaged by climate change, adding further pressure on native fauna.

5.4.1 Guidelines to improve resilience and adaptability to climate change

Some of these guidelines are recommendations of CSIRO AdaptNRM (Visit the AdaptNRM website):

- Increase the resilience of native grasslands (and other ecological communities) to climate change by maximising the following: size and number of grassland patches, 'round' patch shapes instead of 'linear' patch shapes, quality (or health) of native grasslands.
- Help species adapt to a changing climate by conserving large populations, promoting species-level genetic diversity, maintaining and improving ecological connectivity both between grassland patches and to other vegetation communities, and in particular altitudinal connectivity to facilitate species dispersal along temperature and moisture gradients.
- Increase resilience by controlling or managing 'non-climate change' ecological stressors such as weeds, native and introduced herbivores, introduced predators, urban edge effects.
- Extreme climate change may warrant more intensive (or higher risk) actions that include:
  - i. assisted dispersal
  - ii. more intensively managing fire regimes at site and landscape scales
  - iii. considering landscape engineering solutions
  - iv. intensively managing natural pressures to help conserve highly valued species or ecological communities
  - v. maintaining ex situ populations and breeding programs for iconic species, and
  - vi. creating reserves with hard boundaries then intensively managing within them
- Promote community re-assembly with native species by:
  - i. managing nationally alien species
  - ii. continuing to manage for 'local species' and

Natural Temperate Grassland monitoring site at Cookanalla property

iii. considering introduction of non-local regional species that are adapted to new local conditions

- Identify, manage and protect refugia.
- Manage ecosystems for ecological diversity to promote resilience and monitor what works to inform adaptive management.
- Use comprehensive, adequate and representative (CAR) principles to conserve the full range of regional environmental types.
- Encourage land use changes that favour native grassland biodiversity.
- Maintain adequate grass biomass/cover to help buffer grassland fauna from predicted climatic temperature and rainfall extremes. Grass cover provides shade, reduces evaporation, reduces erosion and moderates hot/cold extremes in soil temperature.

5.5 ENHANCE ECOSYSTEM FUNCTION

The native grasslands of south-eastern Australia, particularly lowland temperate grasslands, are especially degraded and have experienced severe disruption to their natural processes and species composition. As such, rather than complete restoration of ecological condition and ecosystem function to approximate the pre-European state, more realistic and achievable restoration goals commonly include improving the vegetation structure and plant composition of grasslands, improving habitat for fauna, controlling exotic species and enhancing native biodiversity (Prober and Thiele 2005). Although detailed techniques to enhance/restore the ecological condition and ecosystem function of native grasslands are outside the scope of this document, some key considerations and guidelines are given below.

A key step in native grassland restoration is the establishment of a healthy and moderately dense native grassy sward (Prober and Thiele 2005). Restoration of a native grassy sward on degraded grassland sites that lack native grasses will require sufficient seed to be available and adequate soil nutrient content (Gibson-Roy and

Delpratt 2015). Currently, techniques for the restoration of *Themeda triandra* swards are better understood compared to other dominant native grass species (Prober and Thiele 2005; Cole and Lunt 2005). In many cases, it may be preferable to re-introduce native forbs at the same time, even prior to, the native grassy sward (Gibson-Roy and Delpratt 2015).

Native perennial species of south-eastern Australian grasslands tend to lack a persistent seed bank, and so recovery of plant biodiversity, even after short-term disturbance, might not be achievable from the in-situ seed bank and in such cases will depend on reintroducing propagules by planting or direct seeding (Morgan 1989; Lunt 1990; Morgan 2015). In grassland where the native grassy sward is already present, creation of inter-tussock space will be required (see Chapter 4 on grass biomass management) prior to planting or seeding with forbs, with ongoing maintenance required to ensure that the native grasses or weeds do not close the inter-tussock gaps (Gibson-Roy and Delpratt 2015).

Large-scale restoration of the native sward and/or forb component requires correspondingly large amounts of native seed. Current best practice principles related to seed sourcing for grassland restoration include considerations of genetics and provenance, seed viability, methods for collection and/or large-scale seed production, harvesting, processing and storage (further details are given in Delpratt and Gibson-Roy 2015).

In highly degraded sites, particularly those with a history of soil disturbance, sowing and fertilisation, the soil profile is likely to contain a high soil nutrient content and weed load. Techniques for restoration include scalping (removal of the soil to a defined depth), nutrient stripping (planting of species, including *Themeda triandra*, that use large amounts of nutrient for growth), and reverse fertilisation (addition of carbon to the soil, such as sugar) (Gibson-Roy and Delpratt 2015).

In certain circumstances, careful use of natural or artificial structures (rocks or roof tiles) can assist in providing extra habitat for fauna where the natural equivalents have been lost, or to improve habitat connectivity (such as for the Pink-tailed Worm-lizard) although it is important to monitor their use to ensure that they are not being used by introduced species (Antos and Williams 2015). For example, Brown Snakes are known to prey on Grassland Earless Dragons and so refuges (such as wood piles or rabbit warrens) for this predator should not be created.

Scattered trees and shrubs, where naturally present as part of the grassland community, can provide important habitat for animals such as birds and mammals, and should be retained and managed. However, exotic and non-local trees should not be planted, and any exotic trees present should be removed or replaced by a locally occurring tree (Eddy 2002), unless the tree is of heritage value.

Table 2 summarises the typical attributes for grasslands in various states of condition, and options for enhancement/restoration to promote shifts from one condition state to another.

5.5.1 Guidelines to enhance ecosystem function

- Give priority for restoration to sites that are already in moderately good condition, as these sites will require fewer resources to improve them to a higher quality state (Table 2), and to sites in locations where enhancing ecosystem function would add the most ecological value to the surrounding landscape. For example, priorities might include sites that are critical habitat for threatened species, areas that connect high quality remnants (to improve habitat and facilitate movement of fauna), areas that would increase the size of habitat for threatened species, degraded patches within high quality grassland, buffer areas or sites adjacent to high quality grassland that increase the size of the patch.
- Use the goal and scale of grassland enhancement/restoration to determine the approaches and techniques used. Smaller-scale enhancement/restoration techniques that move a grassland from one state to another (e.g. Table 2) could involve steps such as weed control, improving fauna habitat elements and managing herbage biomass and grazing levels. Larger scale native grassland restoration is more resource-intensive, particularly for highly degraded sites, and requires adequate long-term project resourcing. Consider undertaking actions to promote natural

regeneration before planting to restore native grasslands.

- Maintain the physical structure of grasslands, and enhance where needed, to provide a diversity of habitat for the fauna community. These include soil cracks and holes, rocks where they naturally occur, wet areas and watercourses (e.g. for grassland frogs), specific micro-habitats for particular species (e.g. basking sites for reptiles) and plant litter.

5.6 ENHANCE HABITAT CONNECTIVITY

Maintaining and enhancing habitat connectivity is central to maintaining landscapes that are ecologically functional and for conserving populations of many species, and is integral to planning for a changing climate.

Loss of connectivity (fragmentation) results in a range of negative impacts, including increased edge effects, degradation and the disruption of ecological processes. For example, there are many small urban remnants of Natural Temperate Grassland in Canberra that now lack native grazers such as kangaroos, including Yarramundi Reach and York Park, and regular burning is absent from almost all urban remnants.

Edge effects occur at ecosystem boundaries, particularly where there are strong structural contrasts, and involve changes in abiotic and biotic conditions such as wind speed, soil characteristics, nutrient cycling, species dispersal and composition and increases in weed and pest animal invasions (Fischer and Lindenmayer 2007). These effects are exacerbated in small fragments due to their higher perimeter to area ratio, increasing their risk of becoming degraded (Williams, McDonnell and Seager 2005).

Fragmentation of Natural Temperate Grassland can also increase the risk of extinction of populations of grassland flora and fauna, particularly in urban areas (Williams *et al.* 2005, 2006; Hoehn *et al.* 2013). Fragmentation results in the restriction of the movement of animals and plant propagules due to the reduced connectivity between habitats. For fauna, movement between fragments depends on mobility and movement patterns. For example, the female Golden Sun Moth (*Synemon plana*) has poor flying ability and populations that are separated by more than 200 m are considered to be isolated (Mulvaney 2012). Movement of fauna between patches can be further impeded by unsuitable habitat between patches, such as urban development, or by barriers such as major roads (Antos and Williams 2015). In the absence of dispersal, small populations of plants and animals in grassland remnants are more vulnerable to extinction after unpredictable events, such as fire and drought, as there are few opportunities for re-colonisation from other populations (Dimond *et al.* 2012; Keller 2002). Small and isolated remnant populations can also

Perunga Grasshopper Gungaderra Nature Reserve

be at greater risk of inbreeding, reducing genetic diversity and population fitness and viability, and ultimately increasing extinction risk (Keller 2002; Dudash and Fenster 2000).

5.6.1 Guidelines to maintain and enhance habitat connectivity

- Explore options to enhance ecological connectivity between native grassland patches. Examples include improving links between the Gungahlin Grassland Reserves; between Jerrabomberra east grasslands (including 'Bonshaw') and NSW grasslands.
- Explore options to enhance ecological connectivity between grasslands and other vegetation communities (woodlands, forests, riparian corridors), such as Black Mountain–Aranda Bushland–Glenloch.
- Avoid further fragmentation of grasslands from infrastructure such as roads and cycle paths. Grassland fauna, particularly lizards, tend to avoid crossing non-grassed areas (especially hard-surfaced areas), which can act as dispersal barriers and contribute to fragmentation/degradation of habitat.
- Maintain existing grassland/woodland interfaces. Important grassland/woodland interfaces occur at Caswell Drive and Glenloch interchange, Majura west grassland (with woodland on Mt Majura), Majura Training Area, Jerrabomberra West.
- Improve habitat connectivity at small scales, such as using rocks to connect habitat patches for Pink-tailed Worm-lizards.

Table 2. Grassland states, typical attributes, and options for enhancement/restoration – modified from McIntyre and Lavorel 2007.

	Grassland states, typical characteristics and transition steps from highest quality to lowest quality					
	Highest quality					**Lowest quality**
Attributes	**Reference (historical) grassland**	**High quality native grassland**	**Low quality native grassland**	**Degraded grassland**	**Fertilised pasture**	**Sown pasture**
Native marsupial grazing	Present at moderate levels	Present at moderate levels	Present but potentially at levels that are too high or too low	Absent or at levels that are too high or too low	Absent or at levels that are too high or too low	Absent
Native grassy sward	Present and maintained at moderate levels	Present and maintained at moderate levels	Present but either too high (not managed) or too low (overgrazed)	Absent	Absent	Absent
Weed invasion	Low	Moderate	Moderate - High	High	High	High
Weed seed bank	Low	Low	Medium – high	High	High	High
Fauna habitat elements (e.g. rocks)	Present	Present	Present	Low to absent	Low to absent	Absent

Attributes	Grassland states, typical characteristics and transition steps from highest quality to lowest quality					
	Highest quality					Lowest quality
	Reference (historical) grassland	High quality native grassland	Low quality native grassland	Degraded grassland	Fertilised pasture	Sown pasture
Threatened fauna	Present	Potentially present	Potentially present	Potentially present	Absent	Absent
Threatened flora	Present	Potentially present	Potentially present	Absent	Absent	Absent
Native flora diversity	High	High	Moderate	Low	Very low / absent	Very low / absent
Native fauna diversity	High	Moderate – high	Moderate	Low	Low	Low
Soil disturbance	Low	Low	Low	Low	Low - moderate	Moderate - high
Soil nutrients	Low	Low	Low	Low - moderate	High	High
Introduced grazers	Low	Low - Moderate	Moderate	Moderate	High	High
Restoration / management steps (cumulative) – with reference to relevant section in *Strategy*.	Maintenance of site in current state.	Threatened species translocation (Chapters 4 and 5) Weed control (Chapter 4)	Native grass biomass management (Chapter 4) Native flora re-establishment (seeding, planting, Chapter 5)	Native grassy sward re-establishment (Chapter 5) Addition of fauna habitat elements (Chapter 5)	Soil nutrient and weed seed bank removal (Chapters 4 and 5) Cessation of fertilisation	Soil nutrient and weed seed bank removal (Chapters 4 and 5)

Lemon Beauty Heads (photo J. Lidner)

6. STRATEGY: MONITORING AND RESEARCH

6.1 OVERVIEW

Since the previous strategy, monitoring and research undertaken by the ACT Government, often in partnership with research organisations such as local universities and CSIRO, has significantly contributed to the body of knowledge about the ecology and management of native grasslands and grassland species, particularly threatened lizards, Golden Sun Moth and Eastern Grey Kangaroos.

Monitoring changes in the condition of ecological communities and their biodiversity is a key part of effective protection and long-term management of species and ecological communities. Monitoring is the repeated measure of an entity to detect change over time. Observation of ecosystem changes can result in a better understanding of underlying processes, and change can be quantified into limits at which action is required for the management of the species/community. The ACT Government undertakes regular monitoring of many of its listed flora and fauna species, and these programs are outlined in the respective action plans. More recently the government has embarked on a systematic and comprehensive approach to monitoring through the Conservation Effectiveness Monitoring Program (CEMP).

Knowledge gaps still remain related to management of grasslands (such as long-term effects of grazing, burning and slashing/mowing regimes) and the ecology of grassland species and methods to promote threatened species recovery. Research for threatened species is outlined in the respective action plans. Building on the strong research and monitoring foundation related to the conservation of native grasslands and component species, and facilitating partnerships between the ACT Government and research institutions, remains a priority in this strategy.

6.2 MONITOR GRASSLAND COMMUNITY CONDITION

Regular monitoring of native grassland communities over time provides important information on trends in grassland community condition, potentially triggering management actions when grassland condition declines. The ACT Government will continue to develop the Conservation Effectiveness Monitoring Program (CEMP) which uses current best-practice monitoring actions outlined in the Lowland Native Grassland Ecosystem Monitoring Plan (ACT Government 2015b). These monitoring actions were developed for key ACT ecological communities, including native grasslands.

The CEMP gathers information from monitoring projects and qualitative sources across government and non-government groups to make structured assessments of reserve condition and effectiveness of management programs. The program uses indicators of reserve condition and ecological stress levels imposed by threatening processes in ACT reserves. The indicators used for grassland monitoring by the CEMP are listed in Table 3.

Since the previous strategy, the ACT Government has adopted the Floristic Value Score (FVS) to quantify native grassland condition (Rehwinkel 2007, 2014). This relatively recently developed measure is widely-used for assessing grassland condition, with sites measuring 5 or more being considered to have a floristic value sufficient to be considered part of the Natural Temperate Grassland Endangered Ecological Community under the Commonwealth EPBC Act (Commonwealth of Australia 2016, Rehwinkel 2007, 2014).

6.2.1 Priorities for current and future monitoring

- Use the Conservation Effectiveness Monitoring Program as a framework for monitoring the condition and long-term changes in grassland ecosystems, and other targeted, adaptive management (see Chapter 4) monitoring programs to investigate the effectiveness of different grassland management strategies.
- Increase replication of monitoring sites to adequately represent all grassland associations in the ACT, including higher elevation grasslands, which may be particularly important for detecting woody species encroachment under climate change (i.e. community associations r1, r2, a14 and a30, see section 8.1.4).
- Finalise mapping of native grassland community boundaries and canopy cover of trees and shrubs, to provide a baseline to detect woody species encroachment under climate change.
- Use action plans to guide monitoring for individual threatened species.

Table 3. Monitoring indicators for ACT Grasslands from the Lowland Native Grassland Monitoring Plan (ACT Government 2015b) (indicators highlighted with *are additional to the indicators identified in the Lowland Native Grassland Ecosystems Monitoring Plan)

Element	Indicators	Metrics
Native flora diversity	C1: Threatened flora abundance and distribution	C1.1: Button Wrinklewort abundance C1.2: Ginninderra Peppercress abundance C1.3: Baeuerlen's Gentian abundance
	C2: Grassland flora diversity	C2.1: Grassland floristic value scores C2.2: Rare plant species richness
	C3: Native species cover	C3.1: Cover of functional groups
Native fauna diversity	C4: Threatened fauna populations	C4.1: Golden Sun Moth abundance C4.2: Striped Legless Lizard abundance C4.3: Grassland Earless Dragon abundance C4.4: Perunga Grasshopper abundance
	C5: Fauna diversity	C5.1: Reptile species richness and abundance C5.2: Invertebrate species richness and abundance C5.3: Small mammal records
	C6: Fauna habitat	C6.1: Grassland Earless Dragon habitat structure C6.2: Golden Sun Moth habitat structure C6.3: Striped Legless Lizard habitat structure
Natural Temperate Grassland ecological community	C7: Extent of Natural Temperate Grassland community	C7.1: Total area of NTG rated grassland contained in reserves.
	C8: Connectivity of Natural Temperate Grassland community	C8.1: NTG connectivity spatial analysis
Soils	C9: Soil condition	C9.1: Soil fertility
Inappropriate grazing regime	S1: Herbivore pressure	S1.1: Kangaroo density S1.2: Rabbit density

Element	Indicators	Metrics
		S1.3: Stock levels S1.4: Pig density*
	S2: Pasture growth	S2.1: Grassland productivity S2.2: Herbivore off take
Inappropriate fire regime	S3: Fire regime	S3.1: Fire intervals within ecological thresholds S3.2: Fire within season recommended in ecological guidelines S3.3: Fire extent
Invasive weeds	S4: Invasive weed distribution	S4.1: Change in priority weed distribution and abundance S4.2: New invasive weed incursions
Feral predators	S5: Predation	S5.1: Fox density S5.2: Cat density
Adjacent landuse	S6: Urban development	S6.1: Area of urban development around grassland reserves
	S7: Development in reserves	S7.1: Infrastructure development through reserves
Climate	S8: Rainfall	S8.1: Annual rainfall total S8.2: Season rainfall totals S8.3: Extreme rainfall events
	S9: Temperature	S9.1: Mean annual temperature S9.2: Mean monthly temperature S9.3: Extreme temperature occurrences
	S10: ENSO indicators	S10.1: Southern Oscillation Index S10.2: Indian Ocean Dipole

6.3 COLLECT BASELINE INFORMATION

The effective management of grassland connectivity and ecosystem function requires baseline information on the distribution and characteristics of the ecosystem. The distribution of Lowland Natural Temperate Grassland in Canberra's urban areas has been relatively well-mapped at a broad scale, although there remain important baseline knowledge gaps. The ACT Government is committed to the on-going collection of data and information to inform management and planning. There are a number of projects currently underway that will contribute high quality data for conservation management. These include:

- Mapping of the ACT's vegetation communities at the 1:25,000 scale.
- Classification of mapped grassland units to the association level defined by Armstrong *et al.* (2013).
- Soil mapping for the ACT.
- Hydro-geological profiles for the ACT.
- Mapping of the ACT's most serious weeds.
- Connectivity mapping of grassland patches at scales appropriate to plant and animal dispersal.

- Grassland Enhancement Program (section 8.5.4).
- Participation in cross border planning and sharing of data for the ACT and region's grasslands.

6.3.1 Map the extent and condition of grasslands

Significant advances are being made towards a high resolution vegetation map for the ACT that is suitable for use at scales ranging from broad regional planning to local planning and property planning.

The method used to produce existing maps (based on a combination of aerial photography interpretation and fieldwork) is unable to separate lowland native grassland units into the various temperate grasslands of Armstrong *et al.* (2013), and existing maps instead show grassland as either native grassland, exotic grassland, or Natural Temperate Grassland (if the site meets the definition of Natural Temperate Grasslands of the South Eastern Highlands Endangered Ecological Community) (Baines *et al.* 2014). Work has begun to map the higher elevation grasslands according to the classification of Armstrong *et al.* (2013) and allocated to the r1, r2, a14 or a30 association types (see section 8.1.4).

Mapping methods used to date have not been able to determine if a grassland site is naturally treeless or if the site had been cleared by humans (Baines *et al.* 2014). Existing maps are therefore unable to distinguish between natural grasslands and derived secondary grasslands.

Two long-term priorities for future mapping in lowland grassland communities are:

- Fine-scale field-based mapping of individual grassland associations in lowland grasslands based on Armstrong *et al.* (2013).
- Development of methods to distinguish and map secondary grasslands as distinct from natural grasslands.

6.4 ADDRESS KNOWLEDGE GAPS IN GRASSLAND CONSERVATION AND RESEARCH

Knowledge through research and monitoring (and consequently management techniques) are improving steadily although substantial knowledge gaps remain. These include:

- Future tools for grass structure and biomass manipulation.
- Techniques and approaches to improving grassland condition.
- Effects of a changing climate.
- Aspects of the ecology of grassland species important to their conservation.
- Effects and control of biological invasions.

A recent international literature review by Richter and Osborne (2014) identified these and other knowledge gaps. The limited taxonomic and ecological understanding of grassland invertebrates is reflected in the ACT, although there have been several recent projects investigating beetle dynamics in the ACT's lowland woodlands (Barton *et al.* 2011, 2013a, 2013b, 2014) as well as species-specific research on the Golden Sun Moth (Richter *et al.* 2013; Richter *et al.* 2009). The decline of populations of Grassland Earless Dragons during the 2002–10 drought has highlighted the need for a better understanding of the effects of drought and/or overgrazing on this species. Taxonomic research is still lacking for many grassland species, including plants. In particular, taxonomic refinement is still needed for some of the ACT's rare plants that can occur in grasslands including the orchids and several species of forbs. Comprehensive ecological and genetic studies are also lacking for most plant species, with most of the focus so far being on the threatened plant species.

A major knowledge gap is ecology and management techniques for grassland associations that are not dominated by *Themeda triandra*, such as those dominated by *Rytidosperma*, *Poa* and *Austrostipa* (Morgan 2015; Williams and Morgan 2015; Lunt, Prober and Morgan 2012). These knowledge gaps include management of grass biomass and appropriate fire and grazing regimes. Morgan (2015) also highlights a lack of knowledge of the impact of slashing as a grass biomass management technique in native grasslands. The ACT Government is currently investigating biomass management techniques as part of the Grasslands Enhancement Program, to determine the impacts of managed disturbances on biodiversity across ACT lowland grasslands and address these knowledge gaps. See section 8.5.4 for further detail.

6.4.1 Research priorities

Research priorities for threatened species are outlined in threatened species action plans. Other research is required for a better understanding of:

- Short and long-term effects of grazing levels, fire and mowing/slashing as tools to manage grasslands and appropriate regimes for these tools.
- Ecology and management of non-*Themeda triandra* dominated grassland associations, and native grasslands that occur at higher elevations, particularly for biomass management and disturbance regimes and the development of management guidelines in these ecosystems.
- Techniques to improve the condition of native grasslands, including degraded grasslands.
- Interaction between kangaroo density, climatic factors and grassland biomass management, and techniques to improve management of kangaroo densities (including the use of fertility control).
- Taxonomy and ecology of grassland invertebrates (including burrow-making species) and grassland plant species.

Eastern Grey Kangaroos

7. STRATEGY: ENGAGE THE COMMUNITY

7.1 OVERVIEW

Community engagement in nature conservation has a long and active history in the ACT (ACT Government 2013a). However, compared to other vegetation types (forests, woodlands, riparian zones); community appreciation of grasslands can be difficult to achieve, particularly because grassland values are not necessarily obvious (Lunt 1994). The lack of awareness and appreciation of grasslands by the general public is still considered to be a major issue in grassland conservation (Williams 2015). Activities that engage the public in grassland conservation can promote an appreciation of grassland values by fostering an emotional connection between people and grasslands (Reid 2015).

A range of community engagement activities in nature conservation are underway in the ACT (see Section 8.5.8 for a list of activities undertaken since the previous strategy). These include activities that specifically focus on grasslands, as well as activities that include other ecosystems. Strengthening community engagement in grasslands is likely to be central to promoting community support and awareness of grassland conservation.

7.2 KEY PRINCIPLES

- Community engagement in grassland conservation can foster an appreciation and awareness of the value of grasslands and build support for grassland conservation in the community.
- Understanding the motivations and goals of volunteers is important in recruiting and retaining volunteers. Volunteers are more likely to stay motivated and engaged when they know their work is valued and respected, and is having a broader impact (Reid 2015).
- Citizen science programs can make a valuable contribution to environmental science.
- The benefits of increasing recreation and tourism in grasslands must be balanced against potential impacts on the grassland community.

7.3 ENGENDER COMMUNITY INVOLVEMENT THROUGH AWARENESS RAISING AND VOLUNTEERING

The ACT Government aims to increase the number of volunteer groups and areas actively managed by volunteers by introducing new engagement strategies and targeting new interest groups (ACT Government 2013a). Recent market research found that around one in twenty ACT residents were currently involved as a volunteer in the ACT's reserve system, and 29% of residents expressed interest in becoming a volunteer (Market Attitude Research Services Pty Ltd 2014).

Environmental volunteering has a range of benefits for participants as well as the environment, such as social wellbeing, meeting like-minded people, gaining work experience and learning new skills.

The Friends of Grasslands (FoG), established in 1994, is a community, not for profit association dedicated to conservation of natural temperate grassy ecosystems in south-eastern Australia. FoG advocates, educates and advises on matters to do with the conservation of grassy ecosystems, and undertakes surveys and other on-ground work. FoG is based in Canberra and has over 200 members that include professional scientists, landowners, land managers and interested members of the public.

Community education campaigns can assist in building community awareness about native grasslands and their management, particularly at the urban interface, as well as encouraging community activities to reduce threats to grassland ecosystems.

7.3.1 Guidelines to engender community involvement

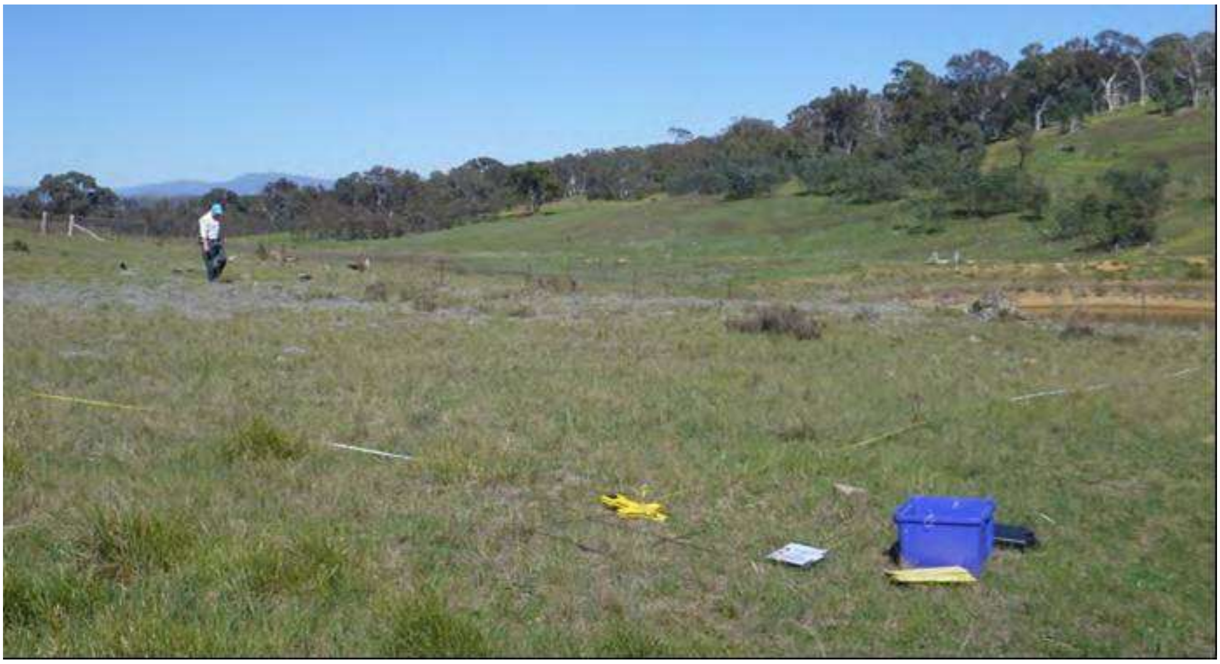
- Continue to support ParkCare groups with training and access to equipment, and provide Parks and Conservation Service resources such as staff support and coordination (ACT Government 2013a).
- Build community awareness and support of native grasslands through activities that create emotional connections between people and grasslands. Effective approaches include: hands-on events such as weeding or planting, raising awareness about activities that impact on grasslands (e.g. off-leash dog walking, weed spread from urban gardens), promoting understanding of grassland ecology and values (e.g. interpretive walks and talks, on-site signage, and art- and photography-based projects), and informing the community about the importance and role of particular management strategies (e.g. controlled burning, weed spraying).

7.4 ENHANCE AND PROMOTE USE OF CITIZEN SCIENCE

Citizen science is an increasingly popular and widely-used method in environmental science and land management, with applications in data collection, data processing, monitoring and research. Enhancing and promoting the use of citizen science is an important strategy in the ACT, particularly because of the wealth of skills and knowledge in the ACT community (ACT Government 2013a). Examples of citizen science projects include Frogwatch, Waterwatch, and the Canberra Ornithologists Group, which have all contributed large amounts of monitoring data.

Some of the most popular and fast-growing citizen science activities involve use of the latest internet-based and smart-phone technology. Well-designed tools such as these have the capacity to collect large amounts of data and increase community interest in conservation and research, including projects that are conducted entirely online, such as data-processing projects (Bonney *et al.* 2014). An example of a recent citizen science project in the ACT that embraces the latest technology and harnesses the community's passion for photography is the Canberra Nature Map (Visit the Canberra Nature Map website). This project

Grassland condition monitoring, Gungaderra Nature Reserve



commenced in 2014 as an internet-based repository for geo-referenced community photographs of rare native plants. Within a year its popularity had increased the scope to all plants (including weeds) and other taxonomic groups (e.g. reptiles, mammals, butterflies and birds) in the ACT and surrounding region.

7.4.1 Guidelines to enhance and promote citizen science

- Embrace the use of recent and emerging technologies to harness the enthusiasm and skills of citizen scientists.
- Ensure the potentially large amount of data collected by citizen scientists is subject to quality control. This can be achieved through effective training, robust data collection protocols and expert screening of data.
- Support community groups involved in grassland citizen science through the provision of necessary equipment and training (when resources are available) and though access to competitive grants schemes.
- Provide biodiversity monitoring data to the Atlas of Living Australia where appropriate.

7.5 BUILD INDIGENOUS ENGAGEMENT IN THE MANAGEMENT OF NATURAL RESOURCES

The ACT has been working with Indigenous communities in natural resource management in partnership with the ACT Government. The ACT Nature Conservation Strategy (2013) lists several key actions to build Indigenous engagement, dependent on resources:

- Employment of Indigenous rangers and development of the Yurung Dhaura Aboriginal team to work on Country.
- Programs to promote traditional ecological knowledge, such as the Ngunnawal Plant Use guide published in 2014 and Indigenous Fire Management Framework.
- Employment of an Indigenous Natural Resource Management Facilitator.

Ecological spring burn

7.6 SUPPORT APPROPRIATE RECREATIONAL AND TOURISM USE OF NATURAL AREAS

Facilitating recreation and tourism in natural areas is an important approach to engaging the community with the natural landscape and broadening understanding and support for these areas. This is particularly relevant to ACT urban grassland reserves given that research suggests the community generally does not appreciate the values of grasslands (Williams 2015). Recent surveys of ACT residents' use of Canberra Nature Parks found the grassland reserves had among the lowest visitation rates of the urban nature reserves (Market Attitude Research Services Pty Ltd 2014).

Although recreation and tourism in natural areas is an important part of developing appreciation of these areas, visitation can also result in negative impacts on flora and fauna. For example, Rankin *et al.* (2015) found that threats related to tourism and recreation are of concern for at least 42% of all vascular plant species (particularly native forbs) listed as endangered or critically endangered across Australia. These threats included trampling by hikers and plant enthusiasts, damage from recreational vehicles, road and tourism infrastructure, horse riding, unofficial track creation, trail and mountain biking and camping. The most common threat is the illegal collection of plant parts by visitors, particularly native orchids, with 61% of listed orchid species potentially affected (Rankin, *et al.* 2015).

Recent research has found conflicting views between reserve managers regarding encouragement of more community use of, and access to, grassland reserves. Whilst some mangers support increased visitation in some grasslands, others are concerned that increased public access risks exacerbating impacts such as rubbish dumping, dog poo, and weed invasion (Williams 2015). In the ACT there are existing plans of management that already define appropriate use for reserves, though additional strategic guidance will help ensure appropriate recreation and tourism is encouraged that will support conservation management across multiple tenures (ACT Government 2013a).

7.6.1 Enhance key partnerships across government, community and the private sector.

Native grasslands in the ACT occur across a range of tenures and are managed by landholders that include government departments and the community. Native grassland conservation is strengthened where partnerships exist between relevant government agencies, community groups (ParkCare and FoG), the private sector (rural landholders and Greening Australia) and research networks (such as local universities). At the regional level, native grassland conservation can be enhanced by working with regional and cross-border partners such as the NSW Office of Environment and Heritage, the Kosciuszko to Coast (K2C) partnership, South East Local Land Services and the Yass and Queanbeyan-Palerang Regional Councils.

The ACT Government will work with other landholders to facilitate conservation management of grasslands across tenure boundaries. These include rural landholders, the Australian Government and Canberra International Airport.

8. BACKGROUND

8.1 WHAT ARE NATIVE GRASSLANDS?

8.1.1 Native grassland composition

Native grasslands are vegetation communities that are dominated by perennial native grass species where the cover of shrubs and trees is less than 10% (Eddy 2002).

Over 110 species of native grasses are currently recognised in the ACT, with the most species-rich genera being *Rytidosperma*, *Poa*, and *Deyeuxia* (Lepschi, Mallinson and Cargill 2012). Common species of grasses in the ACT and region are presented in Table 4.

In south-eastern Australia, native grasslands can be species-rich (high number of species) at small spatial scales, and relatively undisturbed native grasslands often contain a diversity of herbaceous species (forbs), including orchids, lilies, and broad-leaved herbs such as daisies. Species that often co-dominate with grasses include *Chrysocephalum apiculatum* (Common Everlasting Daisy) and a range of *Lomandra* (Mat-Rush), *Juncus* (rushes), and *Carex* (sedges) species (Table 4).

Most plant species in native grasslands of south-eastern Australia can be classified as either 'hemicryptophytes', which produce annual growth of leaves and stems from buds located near or at the soil surface, or 'geophytes', which die back each year to a tuberous root or bulb (Morgan and Williams 2015). These life forms allow grassland species to persist through time in the above-ground vegetation, and enable rapid vegetative recovery from unfavourable conditions such as drought and fire.

Native grassland species tend to have short-lived transient seeds, with few species developing a persistent soil-stored seed bank (Morgan 1989; Lunt 1990; Morgan 2015).

Another important biological component of native grasslands is the non-vascular species, including mosses and liverworts (the bryophytes), lichens, cyanobacteria, fungi and algae. These species are found in the inter-tussock spaces where they form a biological soil crust, and play an important ecological role in native grasslands (Morgan 2004).

Exotic plants are also now common in native grasslands of south-eastern Australia, due to the widespread modification and degradation of native grasslands.

8.1.2 Native grassland structure

The presence of perennial native grasses imparts a characteristic structure to native grasslands. Many of the dominant grass species are tussock grasses, which can be defined as a dense, erect clump of tillers, usually tufty in appearance (Groves and Williams 1981). This upper canopy stratum of the ground layer plants generally varies in height from mid high (0.25–0.5 m) to tall (0.5–1.0 m), and in cover from open to dense (greater than 70% ground cover) (Walker and Hopkins 1994).

A second, lower stratum growing in the inter-tussock space comprises shorter perennial and annual grasses with forbs. At ground level there may also be a third stratum of low-growing forbs and grasses, the biological soil crust, and rocks.

An important characteristic of grasslands is that woody plants (trees and shrubs) are naturally infrequent, and have less than 10% projective foliage cover (Eddy 2002; Benson 1996), although woody plants are still important contributors to local diversity and grassland habitat (Morgan and Williams 2015).

Table 4. Common native grasses and forbs of Natural Temperate Grasslands in the ACT (Eddy *et al.* 1998; Benson 1994; Environment ACT 2005)

Scientific name	Common Name	Notes
Grasses		
Themeda triandra	Kangaroo Grass	Important and widespread dominant or co-dominant structural component of many native grasslands in the ACT, particularly in productive and less disturbed sites.
Poa sieberiana	Poa Tussock	Important and widespread dominant or co-dominant structural component of many native grasslands in the ACT.
Austrostipa bigeniculata	Tall Speargrass	Very common and widespread. Tends to occur on deeper soils and drainage lines.
Austrostipa scabra	Corkscrew Grass	Very common and widespread. Tends to occur in drier grassland sites and on shallow soils such as hill crests, upper slopes and ridges.
Rytidosperma spp.	Wallaby Grass (various species)	Very common and widespread. Can become dominant with increased grazing. Over 20 species occur in the ACT. Formerly known as *Austrodanthonia* spp.
Poa labillardierei	River Tussock	A large tussock grass mainly found in wet grassland sites such as drainage lines, river and creek flats, and seepage areas.
Bothriochloa macra	Redleg Grass	Moderately common and widespread, usually occurs as a minor component of native grasslands.
Aristida ramosa	Purple Wiregrass	Moderately common and widespread. Usually occurs as scattered plants or in small clumps.
Anthosachne scabra	Common Wheat Grass	Common and widespread. Usually occurs as a minor component of native grasslands in the inter-tussock spaces. Formerly known as *Elymus scaber*.
Panicum effusum	Hairy Panic	Common and widespread, particularly in well-drained soils where summer soil moisture is more reliable. Usually occurs as a minor component of native grasslands in the inter-tussock spaces
Forbs		
Chrysocephalum apiculatum	Common Everlasting	Common and widespread. Can co-dominate with grasses at some sites.
Leptorhynchos squamatus	Scaly Buttons	Common and widespread.
Acaena ovina	Sheep's Burr	Common and widespread.
Lomandra spp.	Mat-Rush (various species)	Common and widespread, with the four main species being *L. multiflora* (Many-Flowered Mat-Rush),

Scientific name	Common Name	Notes
		L. longifolia (Spiny-Headed Mat-Rush), Wattle Mat-Rush (*L. filiformis*) and *L. bracteata* (Short-Flowered Mat-Rush).
Carex spp.	Sedges (various species)	Usually found in damp to wet sites, with the main species being *C. inversa* (Knob-Sedge), *C. appressa* (Tall Sedge) and *C. breviculmis* (Short-Stem Sedge).
Juncus filicaulis	Pinrush	Found in seasonally moist grasslands, where it often co-dominates with *T. triandra*.

The establishment and growth of trees and shrubs in native grasslands is hindered due to environmental conditions such as poor drainage, seasonal water logging, cold air drainage, severe frost, and competition from grass (Moore and Williams 1976; Fensham and Kirkpatrick 1992; Morgan and Williams 2015). Communities in which tree cover exceeds 10% are referred to as grassy woodlands, and native grasslands often intergrade (or form a continuum) on slopes at higher elevations with grassy woodlands.

8.1.3 Native grassland fauna

Fauna are an intrinsic part of grassland ecosystems, and are essential for a range of functions such as pollination, seed dispersal, nutrient recycling and maintenance of soil condition. Grasslands provide habitat for animals and are a source of food for both herbivores and predators. Common grassland fauna include mammals, birds, reptiles, frogs and invertebrates such as spiders, ants, flies, moths, beetles, and grasshoppers (Eddy 2002; Antos and Williams 2015). A range of fauna can be found below ground, including organisms such as worms and micro-organisms. Grazing herbivores, such as kangaroos, wallabies, wombats and termites, are particularly important in native grasslands due to both their role in transferring energy and nutrients from the producers to other parts of the ecosystem and also their effect on habitat structure for a wide range of organisms.

Termites are a major consumer of grass biomass in tropical ecosystems, but in natural grassy ecosystems of the Canberra region (within the temperate climatic zone) Eastern Grey Kangaroos consume a high proportion of the plant production.

Significant faunal elements are missing from ACT region grasslands, including bettongs, bandicoots and native rodents. Where bandicoot and bettong species have been reintroduced to temperate grasslands, e.g. at the Mt Rothwell Biodiversity Centre located on the basalt plains grasslands near Melbourne, these fauna species have had a major effect through both their fine scale digging activity, the recovery of abundant raptor populations and by attracting terrestrial native predators (predators missing from ACT grasslands include Rosenberg's Monitor, the Eastern Quoll and the Spot-tailed Quoll). It is unknown what effects the relatively recent losses from ACT grasslands (<100 years) of bettongs, bandicoots, rodents and associated species may be having. It is possible that the grasslands are still responding to the change.

8.1.4 Native grasslands in the ACT and region: descriptions and definitions

This strategy follows the vegetation classifications and descriptions of Armstrong *et al.* (2013) and the vegetation classification hierarchy of Keith (2004), who described and mapped the native vegetation communities of New South Wales and the ACT at the 1:1 million map scale with a resolution of 10-kilometre grid cells. The classification hierarchy consists of three levels:

- Vegetation formations: broad groups defined by structural and physiognomic characteristics. Two vegetation formations contain grasslands, the Grasslands Formation and the Alpine Complex Formation.

- Vegetation classes: groups of vegetation defined primarily by overall floristic similarities, of which 99 were described for NSW and the ACT. Two classes contain grassland communities found in the ACT, the Alpine Herbfield Class and the Temperate Montane Grassland Class.
- Plant Communities: detailed and relatively homogeneous assemblages of plant species that live together in space and time.

Using this hierarchy, Armstrong *et al.* (2013) classified and described the native plant communities of the upper Murrumbidgee catchment in NSW and the ACT (1.741 million ha) based on numerical analysis of full-floristic plot data, using 4106 survey plots compiled from a range of different datasets. Nine grassland communities are found in the ACT (Figure 5). Although these communities are well-described, their distributions have not yet been fully mapped across the ACT.

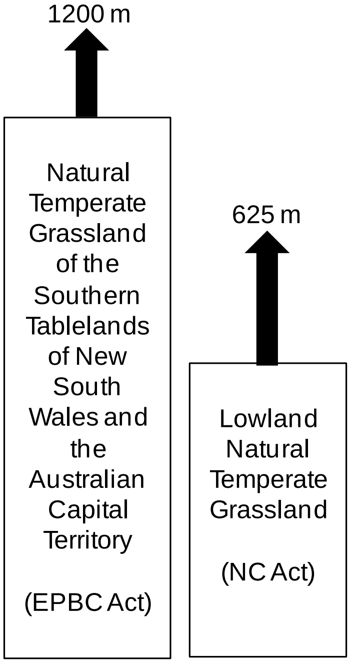
These nine grassland community classifications are detailed in section 8.9, and supersede the floristic associations described in the previous strategy (ACT Government 2005).

8.1.5 Environmental determinants of ACT grassland associations

A range of environmental factors influence the occurrence and distribution of the nine grassland associations found in the ACT. These include climate (particularly moisture availability), landscape position, elevation, geology, drainage patterns and soil nutrients. Changes in these environmental factors are associated with differences in the dominant

Figure 5. Native grassland communities in the ACT and surrounding region. Elevations defining the alpine/subalpine, montane and temperate tracts are taken from Costin (1954).

	Formation: Alpine Complex **Class:** Alpine Herbfields
Alpine / Sub-alpine (> 1500 m)	*Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion (a14)
	Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion (a30)
	Formation: Grasslands **Class**: Temperate Montane Grasslands
Montane approx. 900 m – 1500 m	Sub-montane moist tussock grassland of the South Eastern Highlands bioregion (r1)
	Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion (r2)
Temperate to approx. 900 m	*Rytidosperma sp. - Themeda australis – 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)



grass species and the associated grassland forbs. For example, in creek and river flats, the dominant grass is more likely to be *Poa labillardierei*, whereas *Themeda triandra* dominates on drier well-drained slopes (Williams and Morgan 2015; Armstrong *et al.* 2013).

8.1.6 Natural Temperate Grassland: an endangered ecological community

Some of the native grassland communities in the ACT are part of the endangered ecological community Natural Temperate Grasslands. The definition of Natural Temperate Grasslands is:

- Natural Temperate Grassland is a native ecological community that is dominated by native species of perennial tussock grasses. The dominant grasses are *Themeda triandra*, *Rytidosperma* species, *Austrostipa* species, *Bothriochloa macra* and *Poa* species. The community is dominated by moderately tall (25-50 cm) to tall (50 cm-1.0 m) dense to open tussock grasses. There is also a diversity of native herbaceous plants (forbs), which may comprise up to 70% of species present. The community is naturally treeless or contains up to 10% cover of trees or shrubs in its tallest stratum. In the ACT it occurs up to 1200 m above sea level (asl) in locations where tree growth is limited by cold air drainage. While the definition of Natural Temperate Grassland is expressed in terms of the vegetation, the ecological community comprises both the flora and the fauna, the interactions of which are intrinsic to the functioning of grassy ecosystems.

Sites that meet the defining characteristics of Natural Temperate Grassland encompass those that clearly demonstrate the natural ecological function of grasslands and those that may be deficient in some respects, but are considered recoverable. However, the distinction between what constitutes the ecological community and what are degraded remnants that are beyond recovery may not always be readily apparent.

In 2015 the Australian Government, ACT Government and other states/territories ministers developed a Memorandum of Understanding (MOU) for an agreement on a Common Assessment Method for Listing Threatened Species and Ecological Communities.The aim of the reform is to apply a common methodology to the assessment of threatened species nationally. Signatories to the MOU have also committed to a single list of nationally threatened species in each jurisdiction: some jurisdictions will also list species that are regionally threatened. Jurisdictions are also committed to 'transitioning' all currently listed species and ecological communities into an agreed national or regional threat category.

The Australian and ACT governments are working together under their respective legislation to align the definition of the ecological community Natural Temperate Grasslands of the Southern Tablelands of NSW and the ACT so that it reflects its full distribution and elevation gradient—below 560 and above 625 metres.

Under current definitions, Lowland Natural Temperate Grassland listed under the NC Act does not include grasslands higher than 625 metres above sea level (asl) whereas the EPBC Act listing of the Natural Temperate Grasslands of the Southern Tablelands of NSW and the ACT includes grasslands that occur at altitudes between 560 and 1200 metres on the Southern Tablelands. The Australian Government is in the process of reviewing this definition and the lower limit is likely to be reduced and the range increased. Currently, any grassland over 1200 metres, including those in the Alpine Complex, are not part of any threatened or endangered community listing (see Figure 5).

The listing definition of Natural Temperate Grassland under the NC Act will be updated to reflect the floristic definitions in EPBC Act listing of Natural Temperate Grasslands of the Southern Tablelands of NSW and the ACT. The community occurs within the geographical region of the Southern Tablelands of NSW and ACT, which extends southwards from the Abercrombie River to the Victorian Border, from Boorowa and Jindabyne to the west and Goulburn to Braidwood and Bombala to the east. The altitudinal components of the listing have been deleted from the description as they are not necessary given the floristic and structural characteristics used to define the ecological community.

Gibraltar burn

8.1.7 Native grasslands and degraded grasslands

The condition of Natural Temperate Grassland ranges in a continuum from high quality grassland that retains its ecological integrity, to degraded native grasslands. Areas that do not meet the criteria for the Natural Temperate Grassland endangered ecological community may be either native grassland, or degraded grassland.

Around 5% of the pre-European extent of Natural Temperate Grassland in the Southern Tablelands now exists as native grassland. Native grasslands can still retain a high cover of native grasses and a low cover of exotic species, but have very low to no forb diversity.

Degraded grasslands are at the other end of the continuum from high quality Natural Temperate Grassland. These grasslands contain one or more native grass species, which may not have been the original dominants, and have very few or no native forbs. There is a high cover of introduced perennial species such as Phalaris (*Phalaris aquatica*), African Lovegrass (*Eragrostis curvula*), Cocks-foot (*Dactylis glomerata*) and Chilean Needle Grass (*Nasella neesiana*).

Both native grasslands and degraded grasslands can still have a range of economic, social, functional and biodiversity values. For example, they may provide important habitat for threatened animal species, provide connectivity in the landscape, or play a role in landscape function such as erosion and groundwater management. Native and degraded grasslands have the potential to be restored to Natural Temperate Grassland under favourable management.

Natural Temperate Grassland may occur in a mosaic of native grassland and degraded grassland. In such circumstances the exotic grassland may be part of a continuum of habitat used by native grassland fauna, and may offer refuge during certain times, for example creek-flat exotic grassland may offer refuge during drought. Thus conservation of Natural Temperate Grassland and the native fauna it contains need to be cognisant of the wider grassland patch in which it sits.

8.1.8 Derived grasslands

Derived (or 'secondary') grasslands are the grasslands that remain after the previous woody vegetation has been cleared (Benson 1996). Derived grasslands are often located on hillslopes beyond the extent of the natural grassland. Species composition in derived grassland can be similar to natural grasslands, but derived grasslands may also contain shrubs and herbaceous species more characteristic of the former woodland or forest community. Derived grasslands often have important ecological values, such as habitat for threatened species, and may warrant consideration for protection, management and rehabilitation. Due to their derivation from woodlands or forests, derived grasslands are not covered in this strategy.

8.2 A BRIEF HISTORY OF NATIVE GRASSLANDS IN THE ACT AND SURROUNDING REGION

8.2.1 Historical distribution

Prior to European settlement, native grasslands in south-eastern Australia were irregularly distributed from north of Adelaide through south-eastern Australia to northern New South Wales, and included the Tasmanian midlands (Groves and Williams 1981). The historical boundaries of native grasslands were principally controlled by environmental factors such as soils, topography, rainfall, and temperatures, particularly summer drought and frosts (Williams and Morgan 2015).

Temperatures were particularly important in controlling the boundaries of grasslands at higher elevations, with alpine grasslands occurring above the climatic limit for tree growth, and subalpine grasslands occurring below this limit, where tree growth is instead limited by cold air drainage and frosts (Lunt, Prober and Morgan 2012).

In the ACT and region, historically native grasslands were particularly common in areas of lower elevation to around 1000 m, extending across large parts of the plains and river valleys. Surveys, maps, and observations from the first European explorers in the area indicated that clear open grassy plains were common west and south-east from Lake George, and in the location of the present-day Canberra region, including the Molonglo valley and the Limestone Plains (Gammage 2011).

Surveys by Robert Hoddle of the Canberra and Queanbeyan districts in 1832–5 showed that 'open plains' and 'fine open grassy forest' without undergrowth were the most common vegetation type, dominated by Kangaroo Grass, as depicted in a 1832 painting of the 'Ginninderry Plains' at the present-day Ginninderra Creek in Belconnen (Gammage 2011).

The pre-European extent of temperate and montane grasslands up to 1500 m in the Canberra and Monaro region is estimated to be around 250,000 ha based on mapping by Costin (1954) and notes by early European explorers, with additional smaller areas of subalpine and montane grasslands within Namadgi National Park (Benson 1994).

8.2.2 Aboriginal use and influence

The lowland temperate grasslands of south-eastern Australia were the home of Aboriginal people, and their activities over millennia helped shape the plant and animal communities found by the first Europeans. Land in the ACT region was occupied by the Ngunnawal people, and the ACT Government recognises the Ngunnawal people as the Traditional Custodians of land in the ACT.

Because of the colder temperatures it is likely that Aboriginal people did not make year-round use of the higher elevation montane, subalpine and alpine grasslands, but visited in the summer to collect and cook Bogong Moths (Gott, Williams and Antos 2015; Flood 1980). In the Southern Tablelands region, the earliest known site of Aboriginal occupation is from Birrigai in the ACT, dated at 21 000 years BP, and archaeological evidence points to the more sheltered river valleys as being the main occupation sites (Flood 1980).

The lowland grasslands provided a range of food sources, including kangaroos and other animals, and a range of native grassland forbs. Native seeds and fruit were not a major part of the Aboriginal diet in these areas. Instead, below-ground plant organs of species such as the Yam Daisy (*Microseris lanceolata*) and many orchids and lilies, were available and harvested all year around, and were an important food source that could comprise half the diet of Aboriginal people (Gott, Williams and Antos 2015).

The Aboriginal people used fire to manage the lowland native grasslands to encourage a supply of food, particularly plants. Many of the first European explorers noted the deliberate use of fire (Gott, Williams and Antos 2015). For example, in the Canberra region, the first European explorers in the 1820s observed fires and burnt grasslands, with fires having been lit in the summer and early autumn months (Gammage 2011).

8.2.3 Early exploration and settlement

The Canberra district was first visited by European explorers in the late 1810s and the early 1820s. Charles Throsby, Joseph Wild and James Vaughan were the first to visit the Limestone Plains (the location of present-day Canberra) in December of 1820, and during a later expedition in March 1821 Throsby discovered the Murrumbidgee River in the vicinity what is now the suburb of Kambah (Moore 1999).

Other explorers during this period included Hamilton Hume and James Meehan (who explored the Goulburn Plains in 1817), Major John Ovens and Captain Mark Currie (who found the Tuggeranong Plains and sighted the Monaro Plains in 1823), and the botanist Allan Cunningham (who explored as far as the Gudgenby River in 1824) (Moore 1999; Costin 1954).

These early explorers reported fine grazing country and vast expanses of grassy open plains and woodlands, and the area was soon settled from the mid-1820s onwards, with settlers eager to secure land for stock grazing. Mapping of land grants in the Colony of New South Wales up to June 1836 shows that in the region of what is now present-day Canberra, landholdings were clustered along the rivers and creeks (Dixon 1837), closely matching the distribution of the original lowland Natural Temperate Grassland thought to be present at the time of European settlement.

Drought in the summer of 1827–28 encouraged the search for more grasslands for stock feed, leading to the expansion of settlement and grazing to the lower reaches of the Cotter River (Moore 1999). By 1829, the grasslands in the mountains of the Monaro region had been discovered by Currie and Ovens, and summer grazing started soon after (Costin 1954).

The impacts of this early settlement did not take long to become evident. By 1840 P.E. de Strzelecki, in a report to Governor Gipps, expressed concern about the effects that drought, cropping and over-grazing were having on soil erosion. In the higher mountain grasslands, fifty years of summer stock grazing and the practice of burning off had already resulted in the reduction in plant cover, soil erosion and loss of some plant species by the late 1800s (Costin 1954).

Acquisition of ACT rural freehold land by the Federal authorities commenced in 1911, with a surge of acquisitions in the 1950s. Further acquisitions occurred in the 1960 and 70s. Owners were paid out and the land was often leased back to the existing landholders for continuing rural production until required for the expansion of Canberra or for other public purposes. All leases contained a withdrawal clause allowing the land to be withdrawn from lease with three months' notice in writing. This lack of tenure due to the withdrawal clause prevented many lessees from investing in pasture improvement.

8.3 CURRENT NATIVE GRASSLAND DISTRIBUTION IN THE ACT

The distribution of native grasslands in the ACT is shown in Figures 1 and 2. These maps will be refined and updated over time as further grassland surveys are undertaken and more data on the locations of grasslands and grassland types become avaiable.

Table 5 shows the known distribution of grassland types in the ACT, and this information will continue to be refined as vegetation mapping progresses. The most up to date distribution data for this community is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

Native grassland occurs on a mix of land tenure types, including on:

- ACT Government managed land such as urban nature reserves, urban open space, roadsides, and Namadgi National Park.
- Commonwealth land, including areas managed by the Department of Defence (e.g. Majura Training Area and Campbell Park), CSIRO (e.g. Ginninderra Experimental Station) and the National Capital Authority (e.g. Yarramundi Reach).
- Canberra International Airport.
- Rural leases and agistments.

The largest areas of lowland native grassland are found in the eastern and southern areas of Canberra's urban area, particularly the Jerrabomberra and Majura Valleys, including native grasslands in the Majura Training Area and the Canberra International Airport. Relatively large areas of native grasslands can also be found in Gungahlin and Belconnen, including Crace Nature Reserve, Mulanggari Nature Reserve, Gungaderra Nature Reserve and the former Belconnen Naval Transmission Station. Smaller grassland fragments in Canberra's west include Dunlop Nature Reserve, Umbagong Park and Kama Nature Reserve.

The total area of Lowland Natural Temperate Grassland below 625 metres (as listed under the NC Act) is 880 ha. Individual sites containing this community, including descriptions, sizes, and management priorities, are provided in the ACT Natural Temperate Grassland action plan. About two thirds of these Natural Temperate Grasslands are on ACT land, with a high level of reservation and protection, while about one third occur on Commonwealth lands that are not specifically or exclusively managed for conservation. The most extensive areas of higher elevation grasslands are at Long Flat, Grassy Creek, Orroral Valley, Sam's Creek, Nursery Creek, Rendezvous Creek, Emu Flats and Bogong Creek. All these areas are within Namadgi National Park.

Detailed mapping has been completed for Long Flat, Grassy Creek, Orroral Valley and Emu Flats. At the time of writing mapping was being completed for Sam's Creek, Grassy Creek, Nursery Creek, Rendezvous Creek and Bogong Creek.

No higher elevation grassland is known to occur outside of Namadgi National Park though there is potential for sites to exist on leasehold land in the central Naas Valley, upper Gudgenby River area and lower Blue Gum Creek area.

Table 5. Grassland community types based on most recent mapping of 73,740 hectares of the eastern ACT. These totals will change as mapping of the remainder of the ACT progresses.

Grassland Community	Area mapped	Notes
Natural Temperate Grassland < 625 m	880 ha	Not mapped at the association level.
Natural Temperate Grassland >625 m	2000 ha	Approximate area, grassland not mapped at the association level, includes r1, r2, a14.
Native grassland (excluding Natural Temperate Grassland)	2400 ha	May include areas of secondary grassland – currently unable to differentiate. Not mapped at the association level.

Table 6. Conservation Status of ACT and Commonwealth threatened flora and fauna species found in ACT native grasslands.

Species	Common Name	Cwlth	ACT	NSW	VIC	QLD
Gentiana baeuerlenii	Baeuerlen's Gentian	E	E	E	-	-
Lepidium ginninderrense	Ginninderra Peppercress	V	E	-	-	-
Rutidosis leptorrhynchoides	Button Wrinklewort	E	E	E	T	-
Thesium australe	Austral Toadflax	V	-	V	-	-
Leucochrysum albicans var.	Hoary Sunray	E	-	-	E	-
Delma impar	Striped Legless Lizard	E	V	V	T	-
Tympanocryptis pinguicolla	Grassland Earless Dragon	E	E	E	T	E
Synemon plana	Golden Sun Moth	CE	E	E	T	-
Aprasia parapulchella	Pink-tailed Worm-lizard	V	V	V	T	
Perunga ochracea	Perunga Grasshopper	-	V	-	-	-

E: endangered; V: vulnerable; T: threatened (as defined under Victorian legislation); (Nom.): nominated; Legislation: Commonwealth: *Environment Protection and Biodiversity Conservation Act 1999*; ACT: *Nature Conservation Act 2014*; NSW: *Threatened Species Conservation Act 1995*; Vic: *Flora and Fauna Guarantee Act 1988* (Note that under this Act, species are listed as 'threatened' rather than being assigned to categories).

8.4 THREATENED AND UNCOMMON GRASSLAND SPECIES IN THE ACT

8.4.1 Threatened species

Native grasslands in the ACT are an important ecosystem for a range of threatened flora and fauna species. These species include three plant species and four animal species declared as threatened in the ACT under the NC Act (2014) (Table 6), and an additional two plant species listed as threatened under the EPBC Act.

Currently, the plant *Gentiana baeuerlenii* is only known from one location in higher elevation montane grasslands of the Orroral Valley, ACT, and despite annual surveys has not been recorded since 1998.

The Hoary Sunray (*Leucochrysum albicans* var. *tricolor*) and the Austral Toadflax (*Thesium australe*) are found in native grasslands and grassy woodlands, and are included in the ACT Lowland Woodland Conservation Strategy (ACT Government 2004).

8.4.2 Uncommon and rare species

There are many species occurring in native grasslands of the ACT that may be of conservation concern (Table 7 and 8) even though they are not listed under ACT or Commonwealth legislation as threatened. These include species that are uncommon or rare because they are either at the margin of their distribution or they occur naturally at low density. Some of these species are of conservation concern because they are declining (in the ACT or elsewhere) and because small populations tend to be more vulnerable to disturbance. Minimising threats and monitoring their abundance and/or habitat is required to help prevent these species becoming threatened.

An example of one of these uncommon species is the Canberra Raspy Cricket (*Cooraboorama canberrae*). The historic and present distribution of this species appears to be extremely restricted. The species is predominantly known from grasslands in the north of the ACT, with some records also from the Queanbeyan area and near Bungendore in NSW. The species has mostly been recorded in high quality native grassland during surveys for threatened reptiles. Given the paucity of Natural Temperate Grassland, it is not surprising that a recent targeted survey for the species in the Canberra area found only 18 individuals at four locations (Vertucci and Speirs 2014), and 23 of 32 records for this species (ACT Government Wildlife Atlas) have come from Canberra Airport or the adjoining Majura Training Area (Department of Defence land), which are grassland sites that have an uncertain future.

8.5 GRASSLAND CONSERVATION ACTIVITIES IN THE ACT SINCE 2005

The previous ACT Lowland Grassland Conservation Strategy (ACT Government 2005) described a range of conservation activities carried out in lowland temperate grasslands of the ACT. These activities included protection of grassland sites within reserves, development of recovery plans, surveys and monitoring of threatened species, and research into the ecology of threatened species including the Grassland Earless Dragon, Striped Legless Lizard, Perunga Grasshopper, Golden Sun Moth, Button Wrinklewort and Ginninderra Peppercress.

Since the previous strategy, these activities have continued to be undertaken in addition to a range of new conservation activities in both lowland and higher elevation grasslands of the ACT. The conservation activities at the grassland community-level undertaken since the previous report are summarised below. Conservation activities pertaining to individual grassland species are detailed in the respective action plans.

Table 7. Uncommon and rare grassland Fauna species in the ACT.

Common Name	Fauna Species
Canberra Raspy Cricket	*Cooraboorama canberrae*
Lewis's Laxabilla	*Laxabilla smaragdina*
Key's Matchstick Grasshopper	*Keyacris scurra*
Shingleback Lizard	*Trachydosaurus rugosus*
Stubble Quail	*Coturnix pectoralis*
Brown Quail	*Coturnix pypsilophora*
Horsfield's Bushlark*	*Mirafra javanica*
Brown Songlark	*Cincloramphus cruralis*

* previously Singing Bushlark

Table 8. Uncommon and rare grassland Flora species in the ACT.

Common Name	Flora Species
Dawson's Wattle	*Acacia dawsonii*
Muellers Bent	*Agrostis muelleriana*
Water Plantain	*Alisma plantago-aquatica*
Plump Swamp Wallaby-grass	*Amphibromus pithogastrus*
Bunch Wiregrass	*Aristida behriana*
Comb Wheat Grass	*Australopyrum pectinatum*
Mountain Wheat Grass	*Australopyrum velutinum*
Slender Bamboo Grass	*Austrostipa verticillata*
Prostrate Bossiaea	*Bossiaea prostrata*
Blue Grass Lily	*Caesia calliantha*
Cut-leaved Burr-daisy	*Calotis anthemoides*
Yellow burr-daisy	*Calotis lappulacea*
Annual Bittercress	*Cardamine paucijuga*
Green-top Sedge	*Carex chlorantha*
Dry Land Sedge	*Carex hebes*
Bristly Cloak Fern	*Cheilanthes distans*
	Gentianella muelleriana subsp. *jingerensis*
Snow Coprosma	*Coprosma nivalis*
Emu-foot	*Cullen tenax*

Common Name	Flora Species
Thick Bent-grass	*Deyeuxia crassiuscula*
Alpine Bent-grass	*Deyeuxia frigida*
Blue Flax-Lily	*Dianella longifolia var. longifolia*
Fisch's Greenhood	*Diplodium fischii*
Little Dumpies	*Diplodium truncatum*
Australian Anchor Plant	*Discaria pubescens*
Late Mauve Doubletail	*Diuris dendrobioides*
Purple Donkey Orchid	*Diuris punctata var. punctata*
Small Snake Orchid	*Diuris subalpina*
Prostrate Blue Devil	*Eryngium vesiculosum*
A Cranesbill Geranium	*Geranium obtusisepalum*
Alpine Crane's Bill	*Geranium sessiliflorum subsp. brevicaule*
Fan Grevillea	*Grevillea ramosissima subsp. ramosissima*
Pennywort	*Hydrocotyle sibthorpioides*
Mountain black-tip greenhood	*Hymenochilus clivicola*
Alpine Swan Greenhood	*Hymenochilus crassicaulis*
Shade Peppercress	*Lepidium pseudotasmanicum*
Alpine Blown Grass	*Lachnagrostis meionectes*
Australian Mudwort	*Limosella australis*
Australian Trefoil	*Lotus australis var. australis*
Murnong, Yam Daisy	*Microseris lanceolata*
Sweet Onion Orchid	*Microtis oblonga*
Southern Rustyhood	*Oligochaetochilus squamatus*
Bog Carraway	*Oreomyrrhis ciliata*
Rosemary Everlasting	*Ozothamnus rosmarinifolius*
Parantennaria	*Parantennaria uniceps*
Austral Pillwort	*Pilularia novae-hollandie*
Narrow Plantain	*Plantago gaudichaudii*
Hooker's Tussock Grass	*Poa hookeri*
Rock Poa	*Poa saxicola*
Long Podolepis	*Podolepis hieracioides*
Channelled Leek Orchid	*Prasophyllum canaliculatum*

Common Name	Flora Species
Subalpine Leek Orchid	*Prasophyllum sphacelatum*
Tadgell's Leek Orchid	*Prasophyllum tadgellianum*
Charming Leek Orchid	*Prasophyllum venustum*
Stocky Leek Orchid	*Prasophyllum viriosum*
Mountain Greenhood	*Pterostylis alpina*
Small Mountain Greenhood	*Pterostylis aneba*
A Wallaby Grass	*Rytidosperma nudiflorum*
A Wallaby Grass	*Rytidosperma oreophilum*
Medusa bog sedge	*Schoenus latelaminatus*
Pink Five-Corners	*Styphelia triflora*
Hooked Cudweed	*Stuartina hamata*
Behr's Swainson-pea	*Swainsona behriana*
Silky Swainson-pea	*Swainsona sericea*
Collared Sun Orchid	*Thelymitra simulata*
Twining Fringe Lily	*Thysanotus patersonii*
Swamp Violet	*Viola caleyana*
A Violet	*Viola fuscoviolacea*
Flat Bluebell	*Wahlenbergia planiflora subsp. planiflora*
Zornia	*Zornia dyctiocarpa var. dyctiocarpa*

Table 9. Grassland areas added (or in the process of being added) to the ACT's conservation estate since 2005.

New or extended reserve	Area NTG (ha)	Area Native	Area exotic
Callum Brae (largely a woodland reserve)	-	8	-
East Jerrabomberra (Committed to	19	12	60
Gungaderra Extension Area	-	14	4
Harman-Bonshaw (in process of being	12	160	22
Jarramlee (Committed to conservation but	5	60	35
Kama (largely a woodland reserve)	22	-	-
Kenny (Committed to conservation but not	-	16	48
Mullangarri Extension	-	15	8
Percival Hill (largely open forest)	1	-	3
West Jerrabomberra	110	62	8
Total	169	347	188

8.5.1 Protection in conservation reserves

A key objective for grassland conservation arising from the previous Strategy was: "a comprehensive, adequate and representative system of Natural Temperate Grassland areas in the ACT is protected by reservation, or other measures where reservation is not practical or desirable". This has been largely achieved for land owned and managed by the ACT Government by the addition of over 700 ha of grasslands, including 169 ha of lowland Natural Temperate Grassland, as either new reserves or as additions to existing reserves (Table 9).

There are still substantial tracts of native grassland on Commonwealth-owned land, which are not specifically protected for long-term conservation (such as Department of Defence lands and the Canberra International Airport).

8.5.2 Management of kangaroo grazing pressure

A 'conservation culling' program for kangaroos commenced in five reserves in 2009 and expanded gradually to 11 reserves containing areas of the endangered grassland or woodland communities. The program is managed in accordance with the ACT Kangaroo Management Plan (ACT Government 2010). Where possible it is also managed on a co-operative basis with adjoining rural landholders as outlined in 'Calculation of the Number to Cull' (ACT Government 2016a). For more information, [view the Calculation document (1467Kb)]

Conservation culling is also conducted by the Australian Government on its Majura Training Area (> 4,000 ha) and the former Belconnen Naval Transmitter Station (116 ha) to standards consistent with those adopted by the ACT Government. These sites include the two largest areas of Lowland Natural Temperate Grassland in the ACT.

Elements of the ACT rural kangaroo culling program would also have benefits for conservation of native grasslands in some cases, although this program is primarily carried out by private landholders to reduce economic impacts of kangaroos on rural production.

8.5.3 Mapping and surveys

A range of projects involving mapping and surveying of vegetation that includes grasslands of the ACT have been undertaken since the previous strategy.

- **The Native Vegetation of New South Wales and the ACT**. State-wide mapping, classification and descriptions of vegetation (Keith 2004).
- Plant communities of the upper Murrumbidgee catchment in New South Wales and the Australian Capital Territory. Classification and descriptions of vegetation communities (Armstrong *et al.* 2013).
- **The peat-forming mires of the Australian Capital Territory**. Mapping and descriptions of peat-forming mires of the ACT by the Australian National University. Includes mapping and description of Poa sod tussock grassland (fen), equivalent to community a14 *Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion of Armstrong *et al.* (2013) (Hope, Nanson and Flett 2009).
- **The vegetation of the Kowen, Majura and Jerrabomberra districts of the ACT**. Vegetation mapping of approximately 21,000 ha in the Kowen, Majura and Jerrabomberra districts. This ACT Government project mapped 4,906 ha of native grassland and

Rocky knoll, Jerrabomberra East Grassland

424 ha of Natural Temperate Grassland (Baines *et al.* 2014).

- **ACT Vegetation Community Mapping**. Territory-wide mapping of vegetation communities commenced by the ACT Government in 2013 is expected to be completed by 2017. Where possible the mapping classifies grasslands dominated by native species into the appropriate association (see section 8.1.4). Where it is not possible to classify grassland to the association level it is mapped as Native Grassland (areas dominated by native species but with unknown diversity), Natural Temperate Grassland (areas that have a diversity of native forbs and are known to meet the criteria that define this endangered ecological community) or Exotic Grassland (areas dominated by exotic species).
- **Surveys for the Pink-tailed Worm-lizard** have been undertaken in the Molonglo River valley and adjacent areas to inform planning for urban development. Mapping was also undertaken for this species in the Urambi, Cooleman and Pinnacle areas.

8.5.4 Research projects

Mulligans Flat-Goorooyarroo Woodland Experiment. Although this project focuses on restoration of a grassy woodland habitat, many of the results and conclusions could potentially be extended to grassland habitats of the ACT. The project uses an experimental approach to understanding grassy woodland dynamics and comparing possible management strategies, and includes a predator-proof Sanctuary in Mulligan's Flat (Manning *et al.* 2011). Research topics include species reintroductions; vegetation patterns and processes; impacts of grazing and fire management; ecological effects of woody debris; invertebrate and reptile ecology; ecological impacts of carrion; and litter and soil dynamics. A full list of publications can be viewed at [Mulligans Flat – Goorooyarroo Woodland Experiment website].

Eastern Grey Kangaroo Research. A variety of research on kangaroos and their impacts has been conducted or is currently underway, much of which has included grassland ecosystems:

- Doctoral Thesis by B. Howland (Australian National University) on the interactions between kangaroos and grassland fauna.
- Doctoral Thesis by D. Fletcher (University of Canberra) 2006 on population dynamics of Eastern Grey Kangaroos in temperate grasslands.
- Methods for estimating kangaroo densities (Howland 2008).
- Impacts of kangaroo grazing on lowland woodland and grassland communities, including vegetation structure, herbage mass, floristics, insects reptiles and birds (Armstrong 2013; McIntyre *et al.* 2010; Barton *et al.* 2011; Manning *et al.* 2013; McIntyre *et al.* 2015; Vivian and Godfree 2013; Howland *et al.* 2014, 2015).
- Movement behaviour of kangaroos in urban Canberra (ACT Government unpublished data).
- Fertility control (ACT Government 2013b). The ACT Government has supported research into fertility control for Eastern Grey Kangaroos since 1998, undertaken in collaboration with the Invasive Animals CRC and CSIRO using the immunocontraceptive vaccine GonaCon™.

Development of the Floristic Value Score. A method to assess the relative conservation value of grasslands in the ACT and surrounding NSW region has been researched and developed by Rehwinkel (2007, 2014). The method incorporates species richness and the abundance of significant 'indicator' species to calculate a Floristic Value Score (FVS). The FVS is now commonly used by the ACT Government and ecological consultants to assess the quality of native grassland sites in the ACT and has been adopted by the NSW Office of Environment and Heritage.

Ecology of threatened species. Since the previous Strategy several significant research projects have been undertaken in partnership with the ACT Government on the ecology of threatened grassland species, including:

- Doctoral thesis by W. Dimond (University of Canberra) "Population decline in the endangered Grassland Earless Dragon in Australia : identification, causes and management".
- Post-doctoral research by L. Doucette on the field ecology of the species and reproduction in captivity.

- Genetics studies by S. Sarre and others (University of Canberra) to examine the effects of habitat fragmentation on Grassland Earless Dragons.
- Honours thesis by T. Stevens on home ranges of Grassland Earless Dragons.
- Golden Sun Moth: survey methods (A. Richter, University of Canberra), habitat management (P. Downey and W. Sea University of Canberra) and translocation methods (P. Downey, W. Sea, SMEC Australia Pty Ltd).
- Research by the ACT Government on rock placement to improve habitat connectivity for Pink-tailed Worm-lizards in the Molonglo River corridor (ACT Government).
- Experimental grassland management using small scale burns (ACT Government).

Grassland enhancement project. The ACT Government is undertaking a three year project to trial positive disturbance regimes for grassland management using fire, grazing, planting tube stock, slashing, rock placement and complementary weed and pest animal control. These trials aim to inform adaptive management of Natural Temperate Grassland to support the recovery of a suite of threatened grassland species, including the Grassland Earless Dragon, Striped Legless Lizard, Golden Sun Moth, and the Pink-tailed Worm-lizard.

8.5.5 Monitoring

Conservation Effectiveness Monitoring Program (CEMP). This program provides the framework for systematically assessing and evaluating effectiveness of reserve management actions aimed at maintaining and improving reserve condition. The program gathers information from various monitoring programs and qualitative sources across government and non-government groups to make structured assessments of reserve condition and effectiveness of management programs. This ensures information is available to support adaptive, evidence-based decision making into the future. One of the eight ecosystem units for which a condition monitoring plan is being developed is lowland grasslands (the Lowland Native Grassland Ecosystems Condition Monitoring Plan) (ACT Government 2015b).

Vegetation condition monitoring. Monitoring of ACT lowland grassland and woodland has been carried out since 2009 in a range of reserves. The project commenced during the end of the drought in response to concerns about kangaroo grazing (Armstrong 2013). Sites were resurveyed in 2012 (Baines and Jenkins 2012) and 2013 (Vivian and Godfree 2013). In 2014, a subset of 24 sites, including eleven in grasslands, were retained to focus solely on monitoring vegetation condition (Vivian and Baines 2014), with research on the effect of kangaroo grazing allocated to a separate project. Vegetation condition is assessed by measuring changes in the floristic value score and vegetation structure.

Long-term threatened species monitoring is undertaken by the ACT Government for the ACT's threatened grassland species (Table 6) and is outlined in the respective action plans for each species (Part B). These survey and monitoring programs have been undertaken for over two decades and form the basis for determining long-term trends in the distribution and abundance for threatened species. A long-term monitoring program for Grassland Earless Dragons that was established in 2003 detected the severe population decline of this species during the 2002–2010 drought, and subsequent signs of population recovery. The detection of this decline prompted a number of studies into Grassland Earless Dragon ecology, including two PhD studies.

Grassland enhancement project. This ACT Government project will be monitoring reptiles, birds, and floristics, with targeted surveys for threatened fauna (Grassland Earless Dragon, Striped Legless Lizard, Perunga Grasshopper, Golden Sun Moth) to better understand how grazing, slashing and fire can be used to manage grasslands. This program involves over 250 permanent monitoring plots across seven grassland reserves. These plots are subject to detailed floristic (5 x 1 m quadrat), structure (grass structure, cover) and fauna surveys annually or biannually from 2015 to 2018.

8.5.6 Herbage mass management.

In 2009 large fenced kangaroo exclosures were constructed at Jerrabomberra West Nature Reserve, at Jerrabomberra East Grassland conservation area and at the Majura Training Area to protect core habitat for the Grassland Earless Dragon from overgrazing during the drought of 2002–2010. High rainfall in subsequent years led to high grass biomass within the exclosures, which is now experimentally managed by a combination of patch burning and grazing (Cook, Evans and Osbourne 2015).

8.5.7 Fire Ecology

Restoring grasslands through fire in the Ginninderra Catchment. This experimental project aims to restore native grassland in the urban open space of the Ginninderra Catchment using autumn burns, and to explore the social concerns and economic impacts associated with mid-scale burning in the urban environment. This project is a collaboration between the ACT Government, ACT Rural Fire Service, City Services, CSIRO, Umbagong Landcare Group, Giralang Ponds Landcare Group, Mt Friends of Mt Painter and Friends of Grasslands.

Grassland enhancement project. This project (see section 8.5.4) will investigate the use of fire, slashing and grazing as a tool for conservation management of native grasslands and threatened species habitat.

8.5.8 Community engagement

A broad range of community organisations and dedicated individuals volunteer their time and expertise to activities that support nature conservation in the ACT (ACT Government 2013a). Community organisations supporting grassland conservation activities include Friends of Grasslands, Molonglo Catchment Group, Ginninderra Catchment Group, Southern ACT Catchment Group, Friends of the Pinnacle, Friends of Mt Painter, and Umbagong Landcare Group. Members of these groups are involved in projects that include monitoring, weeding, revegetation, research, advocacy, workshops and conferences, and education/outreach.

Since the previous strategy, community engagement activities involving, or focusing on, grasslands include the following:

- Golden Sun Moth: community monitoring (Richter *et al.* 2009).
- Vegwatch: a robust monitoring tool developed by the Molonglo Catchment Group to enable its volunteer member groups to monitor the effectiveness of their on-ground work (Sharp, Garrard and Wong 2015).
- The Grass Experiment at the Pinnacle Nature Reserve: a collaborative project between the Friends of the Pinnacle, the Australian National University and ACT Parks and Conservation to experimentally investigate methods to reduce the dominance of exotic species in a grassy ecosystem (Friends of the Pinnacle 2011).
- A 2014 forum run by Friends of Grasslands: 'Grass half full or grass half empty? Valuing native grassy landscapes' to present and demonstrate achievements in grassland conservation and management throughout south-eastern Australia.
- Seeing Grasslands: a project funded in 2010 that aimed to raise the profile of grasslands through community photographic workshops, resulting in exhibitions and a book (Reid 2015).
- Canberra Nature Map: a website and app founded by an ACT resident in 2014 allowing citizens to report sightings of plant species through photography. The tool is being expanded to include reptiles and birds.
- Weed Spotter: a website and app allowing citizens to report sightings of weeds or to map weed extent.
- Snakes Alive!: an annual exhibition by the ACT Herpetological Association and Australian National Botanic Gardens raising awareness of reptiles and amphibians, including the threatened grassland species Grassland Earless Dragon and Striped Legless Lizard (Reid 2015).
- ACT Region Catchment Groups Art Prizes 2015 'Native Grasslands' Exhibition.

8.6 EVIDENCE BASE FOR THE ACT NATIVE GRASSLAND STRATEGY

Over the past few decades there has been significant interest in grassland research, conservation and management, both in Australia and globally, particularly for lowland Natural Temperate Grassland. This interest has resulted in improved knowledge of grassland management for long-term conservation and the publication of a range of management guidelines. This strategy draws upon this literature to provide guidance on best-practice, evidence-based strategies and principles for grassland conservation and management. Gaps in knowledge and evidence are highlighted where relevant. Examples of recent publications, reports and initiatives that have contributed to advancing the field of conservation and management relevant to the grasslands of the ACT include:

- The book *Land of Sweeping Plains: managing and restoring the native grasslands of south-eastern Australia* (Williams, Marshall and Morgan (eds.) 2015: a synthesis of the scientific literature on temperate grassland ecology, management, and restoration.
- The formation of the Temperate Grasslands Conservation Initiative (TGCI) through the International Union for Conservation of Nature, directed at fostering a new regime of communications and cooperation at the global level to enable the increased conservation and protection of indigenous temperate grasslands (Henwood 2010; Peart 2008).
- Research from the Grassy Groundcover Restoration Project, a restoration and research initiative by Greening Australia and the University of Melbourne (Gibson-Roy and Delpratt 2015; Gibson-Roy *et al.* 2010).
- Research from the TasFACE (free-air CO_2 enrichment) experiment, which examines climate change impacts on *Themeda-Rytidosperma* grasslands of south-eastern Australia (Hovenden *et al.* 2006).
- Research on Grassland Earless Dragons: Honours thesis (Stevens *et al.* 2010), PhD thesis (Dimond *et al.* 2012), Post-doctoral genetics studies (Hoehn *et al.* 2013), Post-doctoral study of field ecology and captive breeding (Doucette unpublished data).
- Research into the management of kangaroo grazing pressure for the conservation of grassland reptiles (Howland *et al.* 2014, 2015), and birds (Howland *et al.* 2016) in ACT grassland ecosystems.
- Effects of stock grazing in grassy ecosystems of south-eastern Australia (Lunt 2005);

Pink-tailed Worm-lizard (photo R. Milner)

- Management regimes in Victorian lowland grassy ecosystems (Wong and Morgan 2007);
- Action plans for the ACT's threatened grassland flora and fauna.

8.7 CLIMATE CHANGE: POTENTIAL IMPACTS ON NATIVE GRASSLANDS

The increase in greenhouse gas emissions caused by human activities is predicted to have a range of impacts on the climate of the Canberra region. Recent climate change projections by the CSIRO and the Bureau of Meteorology (Timbal *et al.* 2015) predict that the Canberra region will experience:

- Higher mean, maximum and minimum temperatures. For example, for 2030 the mean warming is projected to be around 0.6 to 1.3°C above the climate of 1986–2005, and for 2090, it is projected to be between 1.3 and 4.5°C, depending on the emissions scenario.
- An increase in the temperature reached on the hottest days, the frequency of hot days and the duration of warm spells.
- A decline in the number of frost days.
- A decline in cool season rainfall and increased intensity of heavy rainfall events.
- A decline in annual snowfall and maximum snow depth.
- Increased duration of meteorological drought and frequency of extreme drought.
- An increase in the number of severe fire danger days (i.e. with a Forest Fire Danger Index of greater than 50).

These climate changes projections are predicted to affect grasslands in south-eastern Australia in a range of ways, although there remains substantial uncertainty in exact nature of the effects on grasslands mainly due to the complex interactions between changes in CO_2, temperature, seasonal rainfall, water availability and soil nutrients (Hovenden, Newton and Wills 2014; Prober *et al.* 2015).

Many of the native grassland associations in the ACT and region are dominated by a mix of C_3 species such as *Austrostipa* spp., *Poa* spp. and *Rytidosperma* spp., and the C_4 species *Themeda triandra* and *Bothriochloa macra*. Climate change can potentially alter the composition of these species in grasslands due to the different impacts of increased CO_2 and temperatures on C_3 and C_4 species, leading to changes in grassland structure, function and resources for grassland fauna. It has been suggested *Themeda triandra* will increase in abundance (increased CO_2 levels) (Hovenden and Williams 2010) and forbs will decrease (due to lower availability of water). However, experimental research on the effects of climate change on temperate grassland species has yielded mixed results.

Climate change will also affect grassland fauna, both directly (e.g. effect of temperature on physiology, behaviour or food availability), as well as indirectly through changes in the composition, structure and extent of grassland plant communities. Species most at risk include those with long generations, poor mobility, narrow ranges, specific host relationships, isolated and specialised species and those with large home ranges (Hughes and Westoby 1994). In contrast, some pest animal species (which are often habitat and dietary generalists) may be advantaged by climate change, adding further pressure on native fauna. Drought and altered seasonal rainfall patterns are likely to have already contributed to the recent decline of the Grassland Earless Dragon in the ACT because of the impacts on the species' survival and reproductive rates (Dimond *et al.* 2012). Other grassland reptiles (such as the Striped Legless Lizard (*Delma impar*)) may also be at risk from an increased incidence/severity of drought (NSW Government 2011).

Changes to the dominant grasses can impact fauna by altering habitat structure and the availability of resources. For example, a shift to an increased dominance of *Themeda triandra* at the expense of C_3 grasses could result in a decline in food availability for the Golden Sun Moth, which prefers C_3 grasses for food. The Golden Sun Moth might also be susceptible to changes in grassland productivity and/or invasion of critical inter-tussock spaces by weeds (NSW Government, 2011). However, Golden Sun Moth larvae are able to use Chilean Needle Grass as food and so an increase in this weed might not be detrimental to the moths.

Another potential impact is the effect of altered leaf chemistry due to climate change on herbivores, including insects, with the effect on grazing mammals an important area of future research (Hovenden and Williams 2010).

De-coupling of essential obligate symbiotic relationships under climate change is another concern. An example is the loss of a specialist pollinator (either because the pollinator and flowering are out of synchrony or the pollinator has become locally extinct), resulting in local extinction of the plants dependent on the pollinator.

A loss in the quality or extent of native grassland (through invasion by weeds, trees or shrubs) will affect plant and animal species dependent on native grassland for habitat. To ensure the survival of viable wild populations of species dependent on native grassland (such as Grassland Earless Dragons), management of habitat will need to consider the requirement for control of weeds and invading woody species. Maintaining grassland habitat by controlling woody species will be ongoing if there is climatic pressure to change native grassland to grassy woodland, and in such situations long-term conservation goals (and long-term resource requirements) should be carefully considered and clearly defined.

Grasslands are expected to experience more frequent and greater extremes in temperature and rainfall. Grasslands with a higher grass biomass may help buffer small fauna species (e.g. reptiles and arthropods) from temperature extremes by providing shade and minimising soil temperature extremes (through shade and acting as a thermal buffer). Higher grass biomass may also help maintain soil moisture by reducing evaporation. Management of grassland habitat will need to take into account the potential benefits of maintaining adequate sward biomass and structure to help buffer grassland fauna from predicted climatic extremes.

8.8 KANGAROO GRAZING OF NATIVE GRASSLANDS

The ACT region is within an area that is bioclimatically favourable to Eastern Grey Kangaroos and some of the highest densities measured for any kangaroo species have been recorded on a number of ACT sites (ACT Government 2010 p 154–5), for example 4–7 kangaroos per ha (equivalent to 400–700 kangaroos per square km).

In natural grasslands (not managed for livestock) where kangaroo abundance is limited by food availability rather than culling or predation, Eastern Grey Kangaroos are responsible for almost all of the grazing. Kangaroos can eat 4.5 tonnes of living plant parts per ha each year when the density of kangaroos is relatively high at 2.4 kangaroos/ha (ACT Government 2010, p104). The level and nature of this herbivory largely determines the vegetation structure (such as height and density of vegetation) of the grassland, which can affect the suitability of habitat for many other organisms. The heterogeneous grass structure considered desirable for conserving a diversity of fauna is not generally observed in either overgrazed or undergrazed conditions. Management of grazing pressure from kangaroo can have profound effects on a natural grassland ecosystem and be used to maintain herbage biomass and grassland structure within desirable limits for conservation. Such manipulation may also be a necessary step to achieving some other goals.

For example, moderation of grazing pressure is likely to be an essential precursor to the successful control of many weed species because overgrazed conditions favour many weed species. However all herbivores graze selectively and the plant species they do not eat will tend to increase in abundance, which can include weeds. For example Burgan (*Kunzea phylicoides*) and St John's Wort (*Hypericum perforatum*) are not eaten by kangaroos, though these species may be eaten by sheep.

Grazing pressure from kangaroos is generally more difficult to manipulate than grazing pressure from domestic livestock because numbers of livestock on a paddock can be more easily changed (livestock can be more easily fenced in or out of areas and can be easily added or removed from a paddock though yarding and transport).

Despite the practical advantages of livestock, kangaroos are preferable for long term conservation because they are distinctly different grazers to livestock, being highly selective for grasses (Jarman and Phillips 1989). Native grasslands have also evolved under kangaroo grazing, and kangaroos cause less damage to soils of grasslands than hard-hoofed livestock.

However, under certain circumstances it may be necessary to use livestock for conservation grazing purposes, for example where grazing by kangaroos is unable to maintain grass structure and biomass within desired limits for conservation (which may be for a short period of time during wetter years). Also, kangaroos are not able to create an eaten down 'asset protection zone' (a 100m wide strip alongside housing to reduce the bush fire risk), nor do kangaroos graze-down Phalaris (*Phalaris aquatica*) pasture (which cattle readily consume).

8.9 DESCRIPTIONS OF GRASSLAND ASSOCIATIONS

The following descriptions of the nine grassland associations found in the ACT that are likely to contain Natural Temperate Grassland are from Armstrong *et al.* (2013).

r1: Sub-montane moist tussock grassland of the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): No equivalent

Community r1 is a dense moist tussock grassland dominated by *Poa sieberiana* and/or *Themeda triandra* in the upper stratum with a variety of forbs in the inter-tussock spaces, including *Brachyscome scapigera*, *Asperula* spp. (*Asperula conferta* or *Asperula scoparia*), *Coronidium* sp. 'Alps', *Plantago antarctica*, *Hydrocotyle algida*, *Ranunculus lappaceus*, *Geranium antrorsum* and *Leptorhynchos squamatus*. Other grasses are present including *Rytidosperma* spp., *Anthosachne scabra* and *Hemarthria uncinata*. A variety of rushes *Juncus* spp. and sedges *Carex* spp. may also be present. Isolated or scattered trees may occur including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus dalrympleana*, *Eucalyptus ovata* or *Acacia melanoxylon*. There may be isolated shrubs or patches of shrubs including *Hakea microcarpa*, *Discaria pubescens*, *Banksia marginata*, *Bossiaea riparia*, *Bursaria spinosa* and *Mirbelia oxylobioides*. Trees and shrubs increase in density at ecotones with adjacent woodland and forest communities. Relatively undisturbed sites may have a variety of uncommon grassland forbs, including *Prasophyllum wilkinsoniorum*, *Diplarrena moraea* and *Thysanotus tuberosus*.

Golden Sun Moth (photo by D. Rees)

This community is found on a variety of substrates but most commonly on colluvium or alluvium on footslopes and flats. It also occurs on basalt and granite lithologies and on midslopes and plateaux.

Poor soil drainage, seasonal waterlogging and severe frosts drive the distribution of this community, as they restrict the establishment of woody species. Community r1 occurs in the southern ACT (Namadgi NP) and the adjacent Yaouk area in NSW.

Elsewhere in NSW, it occurs near Delegate, Nunnock Swamp (South East Forests NP), Kydra River and the upper headwaters of the Shoalhaven River (Deua NP).

Degraded sites (i.e. lacking some of the main species that define this community) may be difficult to distinguish from degraded sites of Community r2 [*Poa labillardierei – Themeda triandra – Juncus* sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion] or Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion].

r2: *Poa labillardierei – Themeda triandra –* Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): Wet Themeda grassland

Community r2 is a tall, dense or mid-dense wet tussock grassland dominated by *Poa labillardierei* usually with *Themeda triandra*, the sedge *Carex appressa* and rush *Juncus* spp. in the upper stratum and a variety of grasses and forbs in the inter-tussock spaces, including *Microlaena stipoides*, *Rytidosperma* spp., *Anthosachne scabra*, *Acaena ovina*, *Asperula* spp. (*Asperula conferta* or *Asperula scoparia*), *Euphrasia* spp., *Coronidium* sp. 'Alps' and *Hemarthria uncinata*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus viminalis*, *Eucalyptus rubida*, *Eucalyptus stellulata*, *Eucalyptus aggregata*, *Eucalyptus bridgesiana*, *Acacia dealbata*, *Acacia mearnsii* or *Acacia melanoxylon*. Isolated shrubs or patches of shrubs may also occur including *Kunzea parvifolia*, *Melaleuca parvistaminea*, *Astroloma humifusum*, *Einadia nutans* and *Hakea microcarpa*. Trees and shrubs increase in density where this community merges into the adjacent woodland communities. Relatively undisturbed sites may have a variety of uncommon grassland forbs including *Craspedia* spp., *Geranium antrorsum*, *Calocephalus citreus*, *Ranunculus lappaceus* and *Brachyscome decipiens*.

Community r2 is found on colluvium or alluvium and on drainage lines in footslopes and particularly on the broad flats associated with creeks and rivers. Poor soil drainage associated with frequent seasonal waterlogging and, to a lesser degree winter frosts, drive the distribution of this community as they restrict the establishment of woody taxa. It is distributed widely across the region wherever suitable habitat exists.

Degraded sites (i.e. lacking some of the main diagnostic taxa) may be confused with degraded examples of Community r3 [*Rytidosperma* sp. – *Themeda triandra – Juncus* sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion] or Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion].

r3: *Rytidosperma* sp. – *Themeda triandra – Juncus* sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion (r3)

Equivalent community in previous Action Plan (ACT Government 2005): No equivalent

Community r3 is a dense to mid-dense, low to mid-high tussock grassland dominated by Wallaby Grasses (*Rytidosperma* spp.) and/or *Themeda triandra*, with rushes (*Juncus* spp.) in the upper stratum and a variety of smaller grasses, sedges and forbs in the lower stratum. Lower stratum species include *Lachnagrostis* spp., *Schoenus apogon*, *Haloragis heterophylla*, *Hydrocotyle algida*, *Carex appressa*, *Amphibromus* spp. and *Anthosachne scabra*. Isolated or scattered trees may be present, including *Eucalyptus ovata*, *Eucalyptus rubida* and *Eucalyptus pauciflora* subsp. *pauciflora*. Trees increase in density at ecotones with adjacent woodland or (rarely) forest communities. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Craspedia* spp., *Dichopogon fimbriatus*, *Montia australasica* and *Calotis anthemoides*.

This community is found most commonly on flats on or adjacent drainage lines or wetlands, and occasionally on footslope and midslope situations. Substrates are colluvium or alluvium derived from sedimentary or granite parent material. Poor soil drainage associated with frequent seasonal waterlogging and severe winter frosts drive the distribution of this community, as they restrict the establishment of woody taxa.

This community occurs in the Bondo and Murrumbateman subregions of the South Eastern Highlands bioregion and the upper Shoalhaven valley. Degraded sites (i.e. lacking some of the main diagnostic taxa) may be confused with degraded examples of Community r2 [*Poa labillardierei – Themeda triandra – Juncus* sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion], although Community r3 generally occurs on drier sites than those occupied by Community r2. Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion] is another grassland community with which Community r3 frequently co-occurs.

r5: *Rytidosperma* sp. – *Austrostipa bigeniculata* – *Chrysocephalum apiculatum* tussock grassland of the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): Austrodanthonia Grassland and Austrostipa Grassland

Community r5 is a mid-dense to dense, low to tall tussock grassland dominated by *Rytidosperma* spp. (mainly *Rytidosperma carphoides* and *Rytidosperma auriculatum*), *Bothriochloa macra*, *Austrostipa bigeniculata* and *Themeda triandra*. *Chrysocephalum apiculatum* and *Lomandra bracteata* are common components of the lower stratum. Other grasses and forbs are present, including *Panicum effusum*, *Plantago varia*, *Austrostipa scabra*, *Anthosachne scabra*, *Goodenia pinnatifida*, *Triptilodiscus pygmaeus*, *Calocephalus citreus*, *Schoenus apogon* and *Tricoryne elatior*. One of the very few NSW populations of *Lepidium hyssopifolium* is found in this community. Isolated or scattered trees and tall shrubs may be present including *Eucalyptus melliodora*, *Eucalyptus blakelyi*, *Eucalyptus rubida*, *Eucalyptus bridgesiana*, *Eucalyptus pauciflora* subsp. *pauciflora* or *Acacia dealbata*. Smaller shrubs may occur including *Lissanthe strigosa*, *Daviesia genistifolia*, *Melichrus urceolatus* and *Acacia genistifolia*. Trees and shrubs increase in density where this community merges with the adjacent woodland communities.

Relatively undisturbed sites have a variety of uncommon grassland forbs, including *Eryngium ovinum*, *Tricoryne elatior*, *Calocephalus citreus*, *Pimelea curviflora*, *Rutidosis leptorrhynchoides*, *Wurmbea dioica*, *Microtis* spp., *Dichopogon fimbriatus*, *Bulbine bulbosa* and *Calotis anthemoides*.

Community r5 is found on a variety of topographic situations, including footslopes, midslopes and flats and on a variety of substrates, including sedimentary strata, colluvium, alluvium or granite. The combined factors of severe winter and spring frosts, exposure to hot drying westerly winds in summer, and to a lesser degree seasonal waterlogging and cracking clays, limit the establishment of woody taxa in this community.

This grassland is mainly found in the Murrumbateman subregion, but is also found in the Shoalhaven River valley. Degraded sites (i.e. lacking some of the main species that define this community) may be difficult to distinguish from degraded examples of Community r3 [*Rytidosperma* sp. – *Themeda triandra – Juncus* sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion] or Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion].

r6: Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): Dry Themeda Grassland

Community r6 is an open to dense, mid-high to tall tussock grassland dominated by one or more of the following in the upper stratum: *Poa sieberiana*, *Rytidosperma* spp., *Themeda triandra*, *Austrostipa scabra* and *Austrostipa bigeniculata*. There is a diversity of forbs and other grasses in the inter-tussock spaces, including *Chrysocephalum apiculatum*, *Acaena ovina*, *Asperula conferta*, *Wahlenbergia* spp., *Scleranthus diander*, *Anthosachne scabra*, *Plantago varia*, *Poa meionectes*, *Bothriochloa macra*, *Brachyscome heterodonta*, *Enneapogon nigricans* and *Leptorhynchos squamatus*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp.

pauciflora, *Eucalyptus lacrimans*, *Acacia dealbata* or *Acacia rubida*. Isolated patches of shrubs may also occur, generally containing *Einadia nutans*, *Melicytus* sp. 'Snowfields', *Cryptandra amara*, *Pimelea glauca*, *Discaria pubescens*, *Mirbelia oxylobioides* and *Dodonaea procumbens*. Trees and shrubs increase in density in ecotones with adjacent woodland communities or on rocky sites. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Geranium antrorsum*, *Rutidosis leiolepis*, *Swainsona sericea*, *Cullen tenax*, *Pimelea curviflora* and *Stackhousia monogyna*.

This community is found on a variety of substrates; most commonly on basalt and sedimentary strata, occasionally occurring on granite, and rarely on colluvium or alluvium. It commonly occurs on midslope, upperslope and plateau situations, and rarely on footslopes and flats. It occurs within the drier portions of the Monaro region, commonly referred to as the Monaro rainshadow.

Severe winter and spring frosts, exposure to hot drying westerly winds in summer, periodic snow and the occurrence of cracking clays (particularly on colluvial soils derived from basalt) all serve to limit the establishment of woody taxa in this community. Community r2 [*Poa labillardierei – Themeda triandra – Juncus* sp. Wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion] may be found in moist depressions and drainage lines adjacent to this community. Sites along the wetter fringe of the region, especially degraded sites (i.e. lacking some of the main species that define this community) may be confused with degraded examples of Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion].

r7: *Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): Wet Themeda Grassland

Community r7 is an open to dense, mid-high to tall tussock grassland with the upper stratum dominated by *Themeda triandra* and with a sub-dominance of *Rytidosperma* spp. and *Poa sieberiana*.

Inter-tussock spaces are generally occupied by herbaceous taxa including *Chrysocephalum apiculatum*, *Leptorhynchos squamatus*, *Microlaena stipoides*, *Wahlenbergia* spp., *Asperula conferta*, *Juncus* spp., *Acaena ovina*, *Anthosachne scabra*, *Schoenus apogon* and *Plantago varia*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus rubida*, *Eucalyptus aggregata*, *Eucalyptus melliodora*, *Acacia dealbata* or *Acacia mearnsii*. Isolated shrubs or patches of shrubs may also occur including *Melicytus* sp. 'Snowfields', *Hovea linearis*, *Pimelea glauca*, *Lissanthe strigosa*, *Daviesia latifolia*, *Daviesia mimosoides*, *Leucopogon fraseri*, *Melichrus urceolatus*, *Bossiaea buxifolia*, *Cryptandra amara* and *Kunzea parvifolia*. Trees and shrubs increase in density at ecotones with adjacent woodland communities. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Hypericum japonicum*, *Tricoryne elatior*, *Pimelea curviflora*, *Microtis* spp., *Prasophyllum petilum*, *Calocephalus citreus*, *Eryngium ovinum*, *Craspedia* spp., *Ranunculus lappaceus*, *Rutidosis leptorrhynchoides*, *Bulbine bulbosa*, *Stackhousia monogyna* and *Wurmbea dioica*.

This community is found on midslopes and footslopes and to a lesser degree on flats. It is most commonly found on sedimentary, colluviums and granite lithologies, and infrequently on alluvium and basalt. It is distributed widely, being found in the Murrumbatemen and Crookwell subregions of the South Eastern Highlands, the Shoalhaven Valley, and in moister outer fringes of the Monaro region beyond rainshadow areas. Outliers occur near Tumbarumba, Tumut, Bathurst and Orange. Severe winter and spring frosts, exposure to hot, drying westerly winds in summer, occasional waterlogging and the occurrence of cracking clays limit the establishment of woody taxa. Community r7 grades into Community r2 [*Poa labillardierei – Themeda triandra – Juncus* sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion] and Community r3 [*Rytidosperma* sp. – *Themeda triandra – Juncus* sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion] in moist depressions and drainage lines.

Where distribution overlaps, it may be confused with Community r6 [Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion]. Confusion between this community and those above may occur where the communities intergrade, especially in degraded sites (i.e. those lacking some of the main diagnostic taxa that define Community r7).

r8: *Themeda triandra – Lomandra filiformis – Aristida ramosa* dry tussock grassland in the South Eastern Highlands bioregion

Equivalent community in previous Action Plan (ACT Government 2005): No equivalent

Community r8 is an open to dense, mid to tall tussock grassland with the upper stratum dominated by *Themeda triandra*, *Aristida ramosa*, *Lomandra filiformis* and *Austrostipa densiflora*. Other gramonoids may include *Rytidosperma* spp., *Microlaena stipoides*, *Lomandra multiflora*, *Austrostipa scabra* and *Poa sieberiana*. Inter-tussock spaces are generally occupied by a diverse range of forbs including *Chrysocephalum apiculatum*, *Wahlenbergia* spp., *Pimelea curviflora*, *Goodenia hederacea* subsp. *hederacea* and *Gonocarpus tetragynus*. Isolated or scattered trees may be present including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus melliodora*, *Jacksonia scoparia*, *Acacia mearnsii* or *Acacia dealbata*.

Isolated patches of shrubs may also occur including *Lissanthe strigosa*, *Hibbertia obtusifolia*, *Melichrus urceolatus*, *Astroloma humifusum*, *Bursaria spinosa*, *Dillwynia sericea* and *Dodonaea boroniifolia*. Trees and shrubs increase in density at ecotones with adjacent woodland communities, and shrubs may be especially dense in rocky areas. Relatively undisturbed sites have a variety of herbaceous taxa uncommon in grassland communities including *Pimelea curviflora*, *Tricoryne elatior*, *Dianella revoluta*, *Boerhavia dominii*, *Stylidium graminifolium* sens. lat., *Bulbine glauca*, *Cymbopogon refractus* and *Dianella longifolia*.

This community is most commonly found on midslopes and upperslopes, although it can infrequently occur on rocky flats adjacent to creeks. It is found most commonly on soils derived from sedimentary strata and infrequently from granite, usually on steep exposed northwest- facing slopes, including in river gorges.

Sites generally overlook extensive valleys or plains; thus they are subjected to hot, drying north-westerly winds in summer, which is a main determinant of species composition in this community.

It is sparsely distributed, with isolated occurrences in the Yass, Goulburn, Tarago and Braidwood regions. Often, Community r8 occurs adjacent to Community r7 [*Themeda triandra – Rytidosperma* sp. – *Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion], which occurs on moister sites downslope. Confusion between these two communities is expected to occur where the communities intergrade, and especially in degraded examples (i.e. lacking some of the main diagnostic taxa that define these communities). Community r8 does not occur in the Monaro, where it is generally replaced by a subtype of Community r6 [Dry Tussock Grassland of the Monaro in the South Eastern Highlands bioregion].

a14: *Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion

Equivalent community in previous Action Plan (ACT Government 2005): No equivalent

Community a14 is a grassland or occasionally open heathland confined to broad valley floors and seepage areas on gentle slopes. Dominant species vary between localities, but common components include herbaceous species such as *Poa costiniana*, which is usually dominant, *Hookerochloa hookeriana*, *Baloskion australe*, *Carex gaudichaudiana*, *Empodisma minus* and *Stylidium montanum* as well as shrubs including *Epacris breviflora*, *Epacris gunnii* and *Hakea microcarpa*. In the northern part of its range, including the ACT, *Poa labillardierei* is often dominant. Soils are typically sodden humified peats.

Community a14 is common from Bimberi, Brindabella and Scabby Ranges (ACT), through lower altitude plains within Kosciuszko NP (Kiandra and Tantangara areas, Mt. Selwyn, Tooma/Tumut Divide, Cooleman Plain, Happy Jacks Plain and Currango Plain). It also occurs in the more easterly ranges of Victoria (e.g. Mt. Wombargo-Cobberas area, Nunniong Plateau, Davies Plain and Dinner Plain).

It commonly grades into Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum* wet heathland of the Australian Alps bioregion (Bog)] in areas with impeded drainage and Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola* grassland of the Australian Alps bioregion] on drier sites.

a30: *Poa hookeri – Poa clivicola – Oreomyrrhis argentea* – Ranunculus graniticola grassland of the Australian Alps bioregion

Equivalent community in previous Action Plan (ACT Government 2005): No equivalent

Community a30 is a grassland characterised by a dense cover of one or often several species of *Poa* (mainly *Poa clivicola*, *Poa costiniana*, *Poa hiemata* or *Poa hookeri* but occasionally *Poa petrophila* or *Poa phillipsiana*) with numerous intertussock spaces containing a large range of herbaceous species. Tall shrubs such as *Hakea microcarpa* and *Cassinia monticola* may be present in this community and at times are abundant enough for the vegetation to be structurally an open heathland.

Despite the greater shrub cover, such examples are floristically inseparable from surrounding grasslands. There is photographic evidence that these shrubs are recent invaders of the grassland community. Their invasion has probably been facilitated by past grazing disturbance, although climate change will also favour expansion of shrubs into frost hollows. The component of this community dominated *by Poa hookeri* was regarded as a distinct community by McDougall & Walsh (2007) and may well be so.

In the places where it occurs (Kosciuszko NP north from the Happy Jacks area), it forms a mosaic with grassland dominated by other species, making it hard to collect homogeneous samples and increasing the likelihood of combination in the classification. In any case, the grasslands would be inseparable as a mapping unit. The *Poa hookeri*-dominated variant is characterised by dwarf tussocks of *Poa hookeri* and the closed cover of mat-forming herbs, shrubs and low shrubs (e.g. *Calotis pubescens*, *Coprosma nivalis*, *Dillwynia prostrata*, *Pimelea biflora*, *Pultenaea fasciculata*, *Pultenaea polifolia*, *Rutidosis leiolepis*). Community a30 is the most common grassland of the treeless plains in Kosciuszko NP, occurring from the upper Thredbo Valley in the south to Emu Plain in the west, Cooleman Plain in the north and Snowy Plain in the east. It is the dominant community of large plains such as Kiandra, Happy Jacks and Long Plains and also occurs in the ACT at Cheyenne Flat and Bimberi (and probably elsewhere at high altitude).

Its distribution is controlled by temperature and soil depth: low temperatures associated with cold air drainage in the growing season do not favour tall shrub and tree establishment. It is best expressed where soils are deep and on shallow soils it is replaced by heathlands and woodlands.

The lower edge of this community commonly adjoins Community a14 [*Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion] and its upper edge is usually Community u158 [Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps Bioregion]. Patches of Community a33 [*Bossiaea foliosa – Cassinia monticola – Kunzea muelleri – Hovea montana* heathland of the Australian Alps bioregion] and Community a34 [Weeping Snow Gum – Small-fruited Hakea – Blue Snow-grass grassy open woodland of the Australian Alps bioregion] may be found in a mosaic within the grassland.

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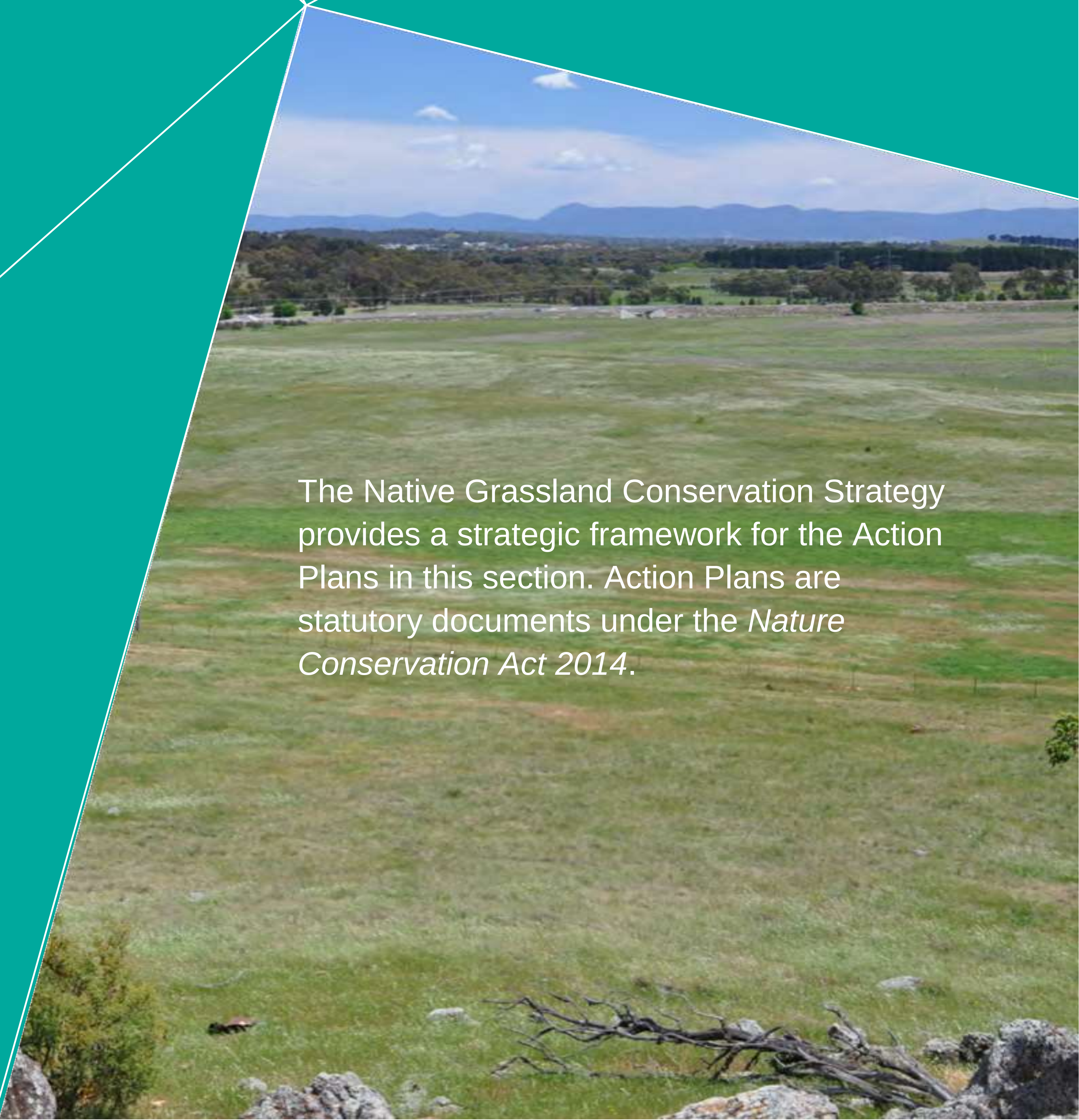
PART B
DRAFT ACTION PLANS



The Native Grassland Conservation Strategy provides a strategic framework for the Action Plans in this section. Action Plans are statutory documents under the *Nature Conservation Act 2014*.

NATURAL TEMPERATE GRASSLAND ENDANGERED ECOLOGICAL COMMUNITY

DRAFT ACTION PLAN

PREAMBLE

Natural Temperate Grassland was declared an endangered ecological community on 15 April 1996 (Instrument No. DI1996-29 *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed ecological communities. The first action plan for this species was prepared in 1997 (ACT Government 1997). This revised edition supersedes all previous editions.

Measures proposed in this action plan complement those proposed in the action plans for Yellow Box / Red Gum Grassy Woodland, and component threatened species that occur in Natural Temperate Grassland: Striped Legless Lizard (*Delma impar*), Grassland Earless Dragon (*Tympanocryptis pinguicolla*), Golden Sun Moth (*Synemon plana*), Perunga Grasshopper (*Perunga ochracea*), Ginninderra Peppercress (*Lepidium ginninderrense*), Button Wrinklewort (*Rutidosis leptorrhynchoides*) and Baeuerlen's Gentian (*Gentiana baeuerlenii*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Natural Temperate Grassland is recognised as a threatened community in the following sources:

National

Critically Endangered – Natural Temperate Grassland of the South Eastern Highlands – *Environment Protection and Biodiversity Conservation Act 1999* (Department of Environment 2016b)

Australian Capital Territory

Endangered – Natural Temperate Grassland – *Nature Conservation Act 2014*

New South Wales

Natural Temperate Grassland currently has no formal conservation status as an ecological community under NSW legislation.

COMMUNITY DESCRIPTION AND ECOLOGY

DEFINITION

Natural Temperate Grassland is defined as follows:

Natural Temperate Grassland is a native ecological community that is dominated by native species of perennial tussock grasses. The dominant grasses are *Themeda triandra*, *Rytidosperma* species, *Austrostipa* species, *Bothriochloa macra* and *Poa* species.

The community is dominated by moderately tall (25–50 cm) to tall (50 cm–1.0 m) dense to open tussock grasses. There is also a diversity of native herbaceous plants (forbs), which may comprise up to 70% of species present. The community is naturally treeless or contains up to 10% cover of trees or shrubs in its tallest stratum. In the ACT it occurs up to 1200 m above sea level (asl) in locations where tree growth is limited by cold air drainage. While the definition of Natural Temperate Grassland is expressed in terms of the vegetation, the ecological community comprises both the flora and the fauna, the interactions of which are intrinsic to the functioning of grassy ecosystems.

The key defining characteristics to identify Natural Temperate Grassland in the field are:

- Occurrence within the ACT's temperate zone where tree growth is climatically limited (elevation up to approximately 1200 m).
- Treeless or contains up to 10% projective cover of trees, shrubs or sedges.
- Dominated by native grasses and/or native forbs (more than 50% total vegetative cover, excluding introduced annuals)

- A diversity of native forbs present, or if disturbed, having components of the indigenous native species (including both existing plants and reproductive propagules in the soil e.g. soil seed banks) sufficient to re-establish the characteristic native groundcover (Environment ACT 2005).

A more detailed description of the ecological community is below.

DESCRIPTION

Structure

Natural Temperate Grassland is dominated by perennial native grasses, which impart a characteristic structure to the community. Many of the dominant grass species are tussock grasses, which can be defined as dense, erect clumps of tillers that are usually tufty in appearance (Groves and Williams 1981). These tussock grasses form the upper stratum of the community, and usually range in height from moderately tall (25–50 cm) to tall (50 cm–1.0 m) (Walker and Hopkins 1994). The gaps between the dominant tussock grasses are referred to as inter-tussock spaces, which provide important habitat for other grassland plants and ground-dwelling animals (Morgan 2015, 1998a). A second vegetation stratum persists in the inter-tussock spaces, consisting of shorter perennial and annual grasses, and forbs. At ground level there is a third stratum, consisting of low-growing grasses and forbs, the biological soil crust and rocks.

An important structural characteristic of Natural Temperate Grassland is that woody plants (i.e. trees and shrubs) are naturally absent, or occur infrequently with up to 10% cover (Eddy 2002; Benson 1996). Communities in which tree cover exceeds 10% are referred to as grassy woodlands.

Secondary, or derived, grassland is an ecological community that develops when the woody canopy vegetation of grassy woodland or forests is permanently removed (Benson 1996). Secondary grassland is not classified as Natural Temperate Grassland, even where both ecological communities have apparently similar structure and component species, and is not covered by this action plan.

Floristic Composition

Native plant species richness in Natural Temperate Grassland can be very high, particularly at small scales (i.e. alpha diversity) (Morgan and Williams 2015; Tremont and McIntyre 1994). This diversity is due to the wide variety of native forb species present, which can comprise up to 70% of the species at a site. Native forbs include sedges, rushes, orchids, lilies, and broad-leaved herbs such as daisies. Over 700 forb species have been identified in grasslands across south-eastern Australia (Eddy 2002), including *Chrysocephalum apiculatum* (Common Everlasting Daisy) and a range of *Lomandra* spp. (Mat-Rush), *Juncus* spp. (rushes), and *Carex* species (sedges). A diversity of native grasses also occur in Natural Temperate Grassland, with dominant and widespread species including *Themeda triandra* (Kangaroo Grass), *Poa sieberiana* (Poa Tussock), *Austrostipa bigeniculata* (Tall Speargrass), *Austrostipa scabra* (Corkscrew) and *Rytidosperma* spp. (Wallaby Grasses). Less dominant grasses that commonly occur in the inter-tussock spaces include *Bothrichloa macra* (Redleg Grass), *Anthosachne scabra* (Common Wheat Grass) and *Panicum effusum* (Hairy Panic). In addition to vascular plants, Natural Temperate Grassland also contains non-vascular plants and other organisms that constitute the biological soil crust, such as mosses, liverworts, lichens, cyanobacteria, algae and fungi (Morgan 2004).

Three plant species found in Natural Temperate Grassland in the ACT are listed as threatened (Table 1). Button Wrinklewort (*Rutidosis leptorrhynchoides*) is the most widespread of these species, occurring in eight Natural Temperate Grassland sites in the ACT (ACT Government 2016a). Ginninderra Peppercress (*Lepidium ginninderrense*) is endemic to the ACT and known from just two sites: Lawson and North Mitchell (Franklin) (ACT Government 2016b). The third threatened species, Baeuerlen's Gentian (*Gentiana baeuerlenii*), is only known from one location in moist, higher elevation grassland in the Orroral Valley, Namadgi National Park, although the species has not been recorded there since 1998 (Department of the Environment 2015). A further 70 plant species found in Natural Temperate Grassland are considered to be uncommon or rare (ACT Government 2016c).

Table 1. Threatened species in ACT Natural Temperate Grasslands

Species	Status	Natural Temperate Grassland Sites*
Button Wrinklewort (*Rutidosis leptorrhynchoides*)	Endangered - EPBC Act 1999 and NC Act 2014	Campbell Park Offices, Crace NR, HMAS Harman, Woods Lane, Kintore St (Yarralumla), Majura Training Area, St Mark's Cathedral (Barton), Tennant St (Fyshwick)
Ginninderra Peppercress (*Lepidium ginninderrense*)	Vulnerable - EPBC Act 1999, Endangered - NC Act 2014	Lawson Grasslands (Belconnen Naval Transmission Station), North Mitchell (Frankiln)
Baeuerlen's Gentian (*Gentiana baeuerlenii*)	Endangered - EPBC Act 1999 and NC Act 2014	Orroral Valley (Namadgi National Park)
Grassland Earless Dragon (*Tympanocryptis pinguicolla*)	Endangered - EPBC Act 1999 and NC Act 2014	Majura Training Area, Canberra Airport, Majura Valley West, Jerrabomberra West NR, Jerrabomberra East, Cookanalla, Bonshaw
Striped Legless Lizard (*Delma impar*)	Endangered - EPBC Act 1999, Vulnerable -NC Act 2014	Mulangarri NR, Gungaderra NR, Crace NR, Lawson Grasslands, Yarramundi Reach, Majura Valley West, Majura Training Area, Fyshwick, Jerrabomberra East, Jerrabomberra West NR, Bonshaw, Amtech East
Golden Sun Moth (*Synemon plana*)	Critically Endangered - EPBC Act 1999, Endangered - NC Act 2014	Mulangarri NR, Gungaderra NR, Crace NR, North Mitchell, Lawson Grasslands, Dunlop NR, Jaramlee, Lake Ginninderra, Lawson Grasslands, University of Canberra, Yarramundi Reach, Limestone Ave, St John's (Reid), Lady Denman Drive, Dudley Street, Novar Street (Yarralumla), Black Street (Yarralumla), Kintore Street (Yarralumla), St Marks (Barton), York Park, Constitution Ave, Campbell Park, Majura Valley West, Majura Training Area, Canberra International Airport, Amtech East, Jerrabomberra West NR, Jerrabomberra East, HMAS Harman
Perunga Grasshopper (*Perunga ochracea*)	Vulnerable - NC Act 2014	Crace NR, Gungaderra NR, Mulangarri NR, Lawson Grasslands, Yarramundi Reach, Canberra Airport, Majura Training Area, Majura Valley West, Cookanalla, Amtech East, Jerrabomberra West NR, Jerrabomberra East
Pink-tailed Worm-lizard (*Aprasia parapulchella*)	Vulnerable – EPBC Act 1999 and NC Act 2014	Molonglo and Murrumbidge River Corridors, also sites in woodlands

* Species may also occur in sites in the ACT in addition to those containing Natural Temperate Grassland.

Although woody plants are infrequent in Natural Temperate Grassland, the species most likely to be encountered are those occurring in adjacent woodland communities. Common species include *Eucalyptus blakelyi* (Blakely's Red Gum), *E. melliodora* (Yellow Box), *E. bridgesiana* (Apple Box), *Acacia dealbata* (Silver Wattle), *Brachyloma daphnoides* (Daphne Heath), *Lissanthe strigosa* (Peach Heath), *Melichrus urceolatus* (Urn Heath), and *Cryptandra amara* (Bitter Cryptandra) (Eddy *et al.* 1998).

Introduced plants are also now widespread in Natural Temperate Grassland. Common species include perennial grasses such as *Phalaris aquatica* (Phalaris) and *Dactylis glomerata* (Cocksfoot), annual grasses such as *Avena* sp. (Oats), *Bromus* spp. (Brome grasses), *Vulpia* sp. (Fescue) and *Aira* sp. (Hairgrasses), forbs such as *Hypochaeris radicata* (Catsear) and *Acetosella vulgaris* (Sorrel), and woody species such as *Rubus* spp. (Blackberry), *Rosa rubiginosa* (Sweet Briar) and *Lycium ferocissimum* (African Boxthorn).

Descriptions of the most common native and introduced plant species likely to be found in Natural Temperate Grassland in the ACT are provided in Eddy *et al.* (1998).

Fauna

Natural Temperate Grassland is important habitat for a wide range of fauna, and provides a source of food for both herbivores and predators. Invertebrates and micro-organisms are a particularly significant component, occurring both above and below the ground, and can account for over 90% of grassland biodiversity (ACT Government 2005). Common grassland invertebrates include spiders, ants, flies, moths, beetles, worms and grasshoppers (Antos and Williams 2015; Eddy 2002). Natural Temperate Grassland in the ACT is also home to two threatened species of invertebrates (Table 1): the Perunga Grasshopper (*Perunga ochracea*), and Golden Sun Moth (*Synemon plana*), as well as several species that are considered to be rare, such as the Canberra Raspy Cricket (*Cooraboorama canberrae*), Lewis's Laxabilla Grasshopper (*Laxabilla smaragdina*) and Key's Matchstick Grasshopper (*Keyacris scurra*) (ACT Government 2016c).

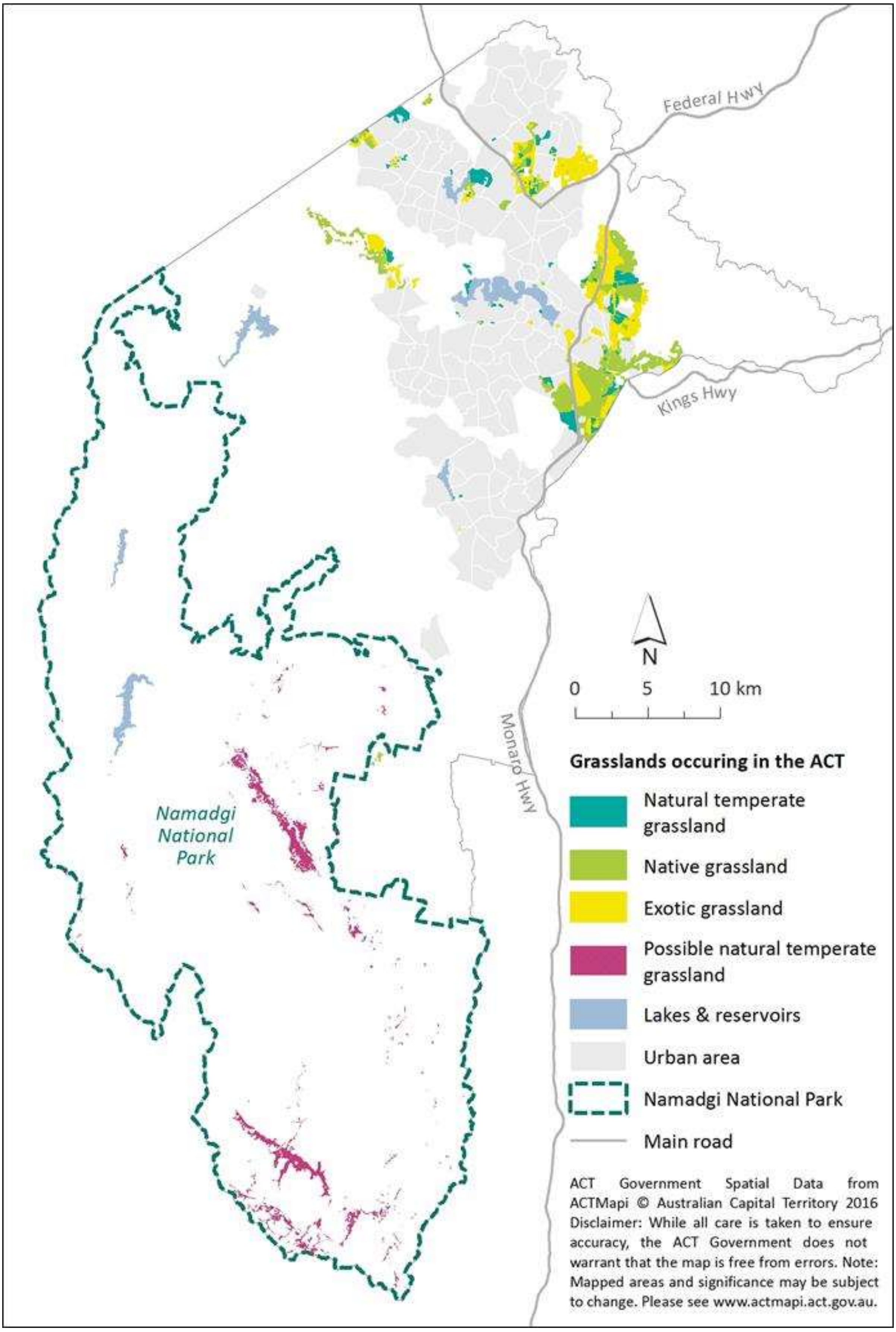
Over 20 species of native reptiles and amphibians inhabit Natural Temperate Grassland in the ACT. The more common grassland species include the Delicate Skink (*Lampropholis delicata*), Spotted Marsh Frog (*Limnodynastes tasmaniensis*) and Spotted Burrowing Frog (*Neobatrachus sudelli*). Three threatened grassland reptiles are found in Natural Temperate Grassland (Table 1): Grassland Earless Dragon (*Tympanocryptis pinguicolla*), Striped Legless Lizard (*Delma impar*) and Pink-tailed Worm-Lizard (*Aprasia parapulchella*). The Pink-tailed Worm-lizard is associated with both grasslands and grassy woodlands, where Kangaroo Grass is a component. The Striped Legless Lizard persists in grasslands in a wide variety of condition states whereas the presence of the Grassland Earless Dragon is often indicative of a site in higher condition.

Many birds inhabit and forage in Natural Temperate Grassland. In the ACT, five birds are considered to be grassland specialists: the Stubble Quail (*Coturnix pectoralis*), Brown Quail (*Coturnix australis*), Singing Bushlark (*Mirafra javanica*), Brown Songlark (*Cinclorhamphus cruralis*) and Australasian Pipit (*Anthus novaeseelandiae*). Latham's Snipe (*Gallinago hardwickii*), a species protected under migratory bird agreements with Japan and China, utilises wetlands in native grassland sites and flooded grasslands.

A large number of other bird species forage in Natural Temperate Grassland, including the Australian Magpie (*Gymnorhina tibicen*). Birds of prey commonly hover or soar over native grasslands in search of food.

A diversity of native and exotic mammals exists within Natural Temperate Grassland, although none are considered grassland specialists. Eastern Grey Kangaroos (*Macropus giganteus*) are the most abundant native mammalian herbivore in grasslands in the ACT.

Figure 1. Distribution of Natural Temperate Grassland and lower condition grasslands in the ACT.



DISTRIBUTION

The distribution of Natural Temperate Grassland in the ACT extends from the low-lying plains of Canberra's urban area to valleys of up to 1200 m asl in the mountains of Namadgi National Park (Figure 1). However, the extensive modification of Natural Temperate Grassland since European settlement in the Canberra district from the early 1800s has resulted in the loss and fragmentation of the community. As a consequence, throughout its distributional range, Natural Temperate Grassland usually occurs as small and often isolated remnants, particularly in the lower elevation plains where the ACT's urban and industrial development is concentrated (ACT Government 2005).

The definitions and descriptions of Natural Temperate Grassland community types have changed over time as research into the composition, distribution and ecology of native grasslands has developed. In the previous action plans, Natural Temperate Grassland was considered to consist of five floristic associations: Wet *Themeda* Grassland, *Poa labillardieri* Grassland, *Danthonia* (now *Rytidosperma*) Grassland, Dry *Themeda* Grassland and *Stipa* (now *Austrostipa*) Grassland (ACT Government 2005, 1997). These community types and descriptions have been recently refined at a regional level (Armstrong *et al.* 2013), and an ACT-wide map based on these newer classifications is in development. Natural Temperate Grassland is now considered to exist in nine native grassland communities in the ACT (Armstrong *et al.* 2013; Table 2). Each grassland community type is differentiated by structure, dominant and co-dominant native grass species, native forb composition, and distribution across the landscape (Table 2).

These characteristics are dependent on a range of site factors and land use practices since European settlement including drainage, slope, elevation, landscape position, geology, soil type, and agricultural history. Site productivity is a particularly important factor influencing the distribution of different grassland communities (Schultz *et al.* 2011; Lunt *et al.* 2012; Williams and Morgan 2015; Armstrong *et al.* 2013). For example, Natural Temperate Grassland in wet sites such as creek and river flats is likely to be dominated by the large tussock grass *Poa labillardierei*, with co-dominant sedges and rushes such as *Carex appressa* and *Juncus* spp. present. Natural Temperate Grassland in productive and undisturbed sites is often dominated by the C4 grass *Themeda triandra* with *Poa sieberiana* as a co-dominant or sub-dominant species. On drier sites with poorer soils, or on sites with a long history of grazing, Natural Temperate Grassland is instead often dominated by C_3 grasses such as *Rytidosperma* and *Austrostipa* species.

The identification of Natural Temperate Grassland within these grassland communities generally requires field surveys to determine whether the four key defining characteristics (see Definition section) relating to location, tree cover, native vegetation and diversity are met (e.g. Baines *et al.* 2014). Grasslands in the ACT exist across a continuum of quality, and those that do not fit the definition and criteria provided in this action plan may be considered instead as native grassland or exotic grassland.

In the ACT, Natural Temperate Grassland occurs on a mix of land tenure types, including:

- ACT Government managed land such as urban nature reserves, urban open space, roadsides, and Namadgi National Park.
- Commonwealth land, including areas managed by the Department of Defence (e.g. Majura Training Area and Campbell Park), CSIRO (e.g. Ginninderra Experimental Station) and the National Capital Authority (e.g. Yarramundi Reach).
- Canberra International Airport.
- Rural leases and agistments.

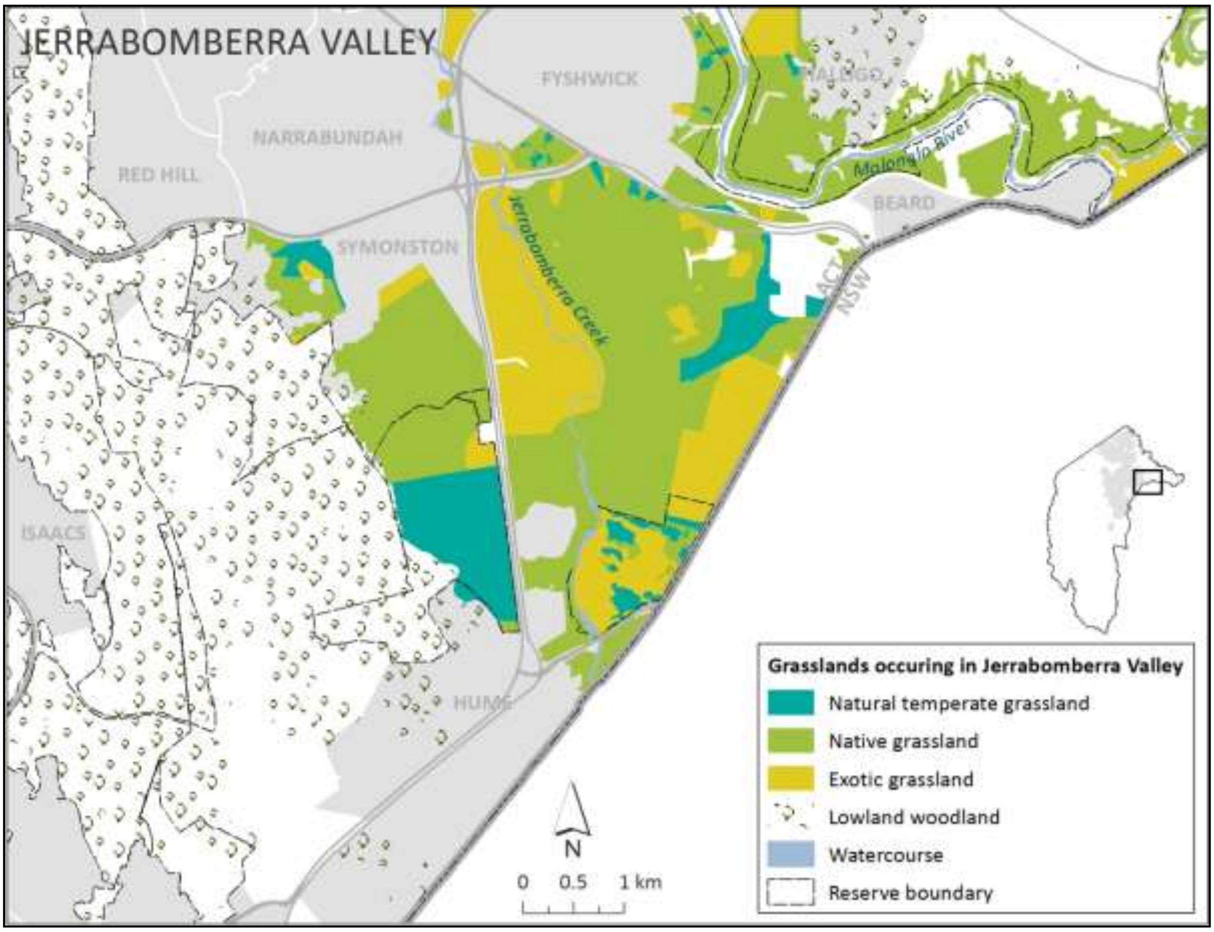
In Canberra's lowland urban area, Natural Temperate Grassland is particularly fragmented and restricted. The largest extent can be found in the east and south, particularly the Jerrabomberra (Figure 2) and Majura (Figure 3) valleys, including native grasslands in Majura Training Area and Canberra International Airport. Relatively large areas of native grasslands can also be found in Gungahlin (Figure 4) and Belconnen (Figure 5), including Crace Nature Reserve, Mulangarri Nature Reserve, Gungaderra Nature Reserve and Lawson Grasslands (previously known as Belconnen Naval Transmission Station). Smaller grassland fragments in Canberra's west include Dunlop Nature Reserve, Umbagong Park and Kama Nature Reserve (Figure 6). The smallest remnants are scattered throughout central Canberra, including patches in Yarralumla, Barton and Reid (Figure 7). The total area of Natural Temperate Grassland in these lowland areas (below 625 m) is approximately 880 ha.

Table 2. Overview of grassland community types in the ACT that may contain Natural Temperate Grasslands threatened ecological communities (Armstrong *et al.* 2013). Refer to the Draft ACT Native Grassland Conservation Strategy (ACT Government 2016c) for full descriptions.

Name of community	Structure	Floristic composition	Distribution
Sub-montane moist tussock grassland of the South Eastern Highlands bioregion (r1)	Dense moist tussock grassland	Dominated by *Poa sieberiana* and/or *Themeda triandra* in the upper stratum with a variety of forbs in the inter-tussock spaces.	Commonly on colluvium or alluvium on footslopes and flats. Can be difficult to distinguish from degraded examples of community r2.
Poa labillardierei – *Themeda triandra* – *Juncus* sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion (r2)	Tall, dense or mid-dense wet tussock grassland	Dominated by *Poa labillardierei*, usually with *Themeda triandra*, *Carex appressa* and *Juncus* spp., in the upper stratum with a variety of other grasses and forbs in the inter-tussock spaces.	Drainage lines in footslopes and particularly on the broad flats associated with creeks and rivers.
Rytidosperma sp. – *Themeda triandra* – *Juncus* sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion (r3)	Dense to mid-dense, low to mid-high tussock grassland	Dominated by *Rytidosperma* spp. and/or *Themeda triandra* and *Juncus* spp. in the upper stratum with a variety of smaller grasses, sedges and forbs in the inter-tussock spaces.	Commonly on flats on or adjacent drainage lines or wetlands, and occasionally on footslope and midslope situations.
Rytidosperma sp. – *Austrostipa bigeniculata* – *Chrysocephalum apiculatum* tussock grassland of the South Eastern Highlands bioregion (r5)	Mid-dense to dense, low to tall tussock grassland	Dominated by *Rytidosperma* spp., *Bothriochloa macra*, *Austrostipa bigeniculata* and *Themeda triandra* in the upper stratum, with *Chrysocephalum apiculatum* and *Lomandra bracteata* common components of the lower stratum along with a variety of other grasses and forbs.	Located on a variety of topographic situations. Can be difficult to distinguish from degraded examples of community r3.

Name of community	Structure	Floristic composition	Distribution
Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion (r6)	Open to dense, mid-high to tall tussock grassland	Dominated by one or more of the following in the upper stratum: *Poa sieberiana*, *Rytidosperma* spp., *Themeda triandra*, *Austrostipa scabra* and *Austrostipa bigeniculata*, and with a variety of forbs and other grasses in the inter-tussock spaces.	Commonly occurs on midslope, upperslope and plateau situations, and rarely on footslopes and flats.
Themeda triandra – Rytidosperma sp. *– Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion (r7)	Open to dense, mid-high to tall tussock grassland	Dominated by *Themeda triandra* and with a sub-dominance of *Rytidosperma* spp. and *Poa sieberiana* in the upper stratum with a variety of forbs in the inter-tussock spaces.	Commonly found on midslopes and footslopes and to a lesser degree on flats.
Themeda triandra – Lomandra filiformis – Aristida ramosa dry tussock grassland in the South Eastern Highlands bioregion (r8)	Open to dense, mid to tall tussock grassland	Dominated by *Themeda triandra*, *Aristida ramosa, Lomandra filiformis* and *Austrostipa densiflora* in the upper stratum with a variety of forbs and other grasses in the inter-tussock spaces.	Most commonly found on midslopes and upperslopes, although it can infrequently occur on rocky flats adjacent to creeks.
Poa costiniana – Carex gaudichaudiana subalpine valley grassland of the Australian Alps bioregion (a14)	Open to dense, mid to tall tussock grassland to open heathland	Dominated by *Poa costiniana* or *Poa labillardierei* in the ACT along with *Hookerochloa hookeriana, Baloskian australe, Carex gaudichaudiana* and *Empodisma minus*.	Confined to broad valley floors and seepage areas on gentle slopes.
Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion (a30)	Dense tall tussock grassland	Dominated by *Poa clivicola, Poa costiniana, Poa heimata* or *Poa hookeri*. Tall shrubs such as *Hakea microcarpa* and *Cassinia monticola* may be present.	Commonly on cold air drainage flats or on adjacent drainage lines at altitude.

Figure 2. Natural Temperate Grassland distribution in the Jerrabomberra Valley.



Dry Tussock Grassland

Figure 3. Natural Temperate Grassland distribution in the Majura Valley.

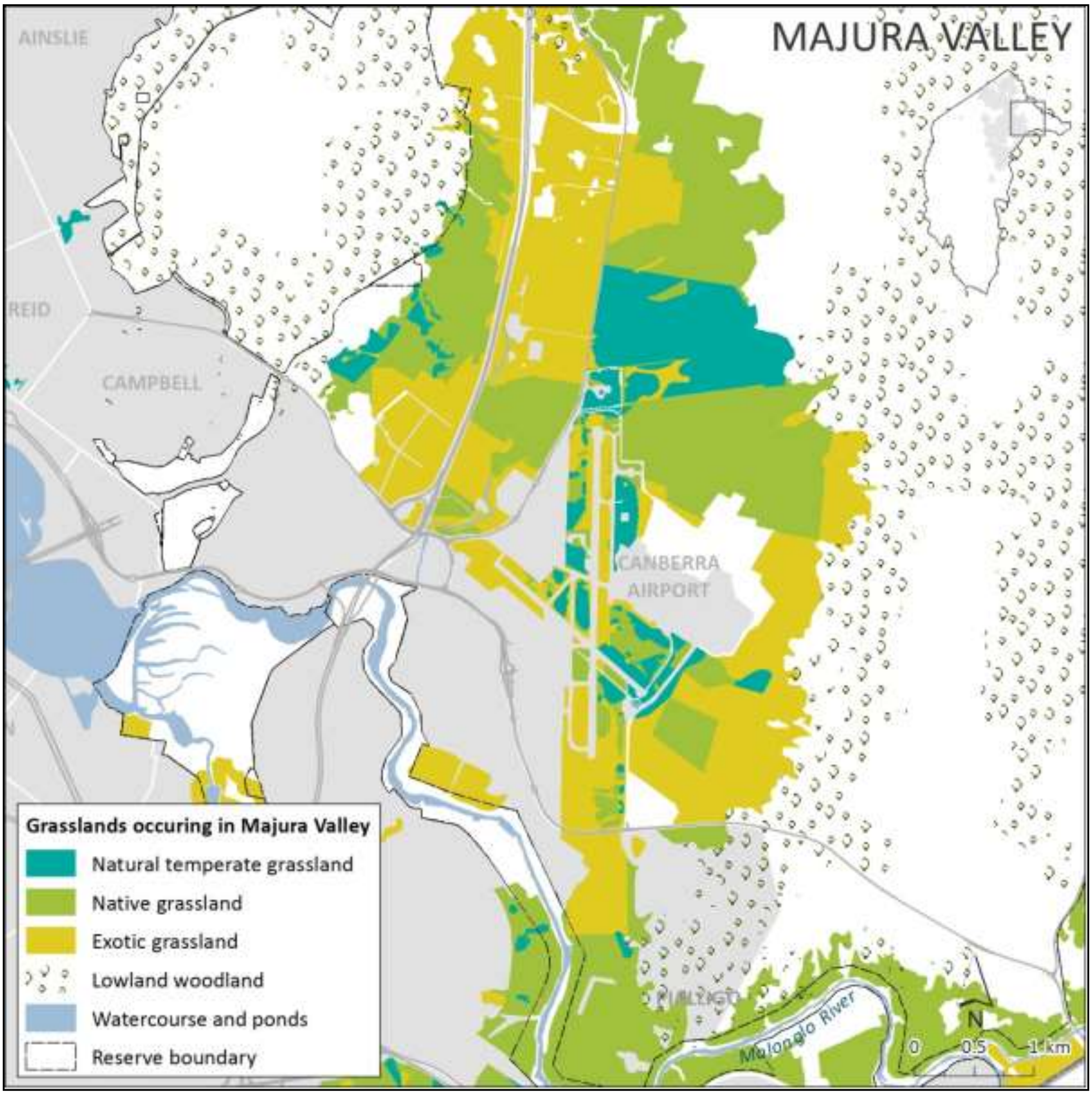


Figure 4. Natural Temperate Grassland distribution in Gungahlin.

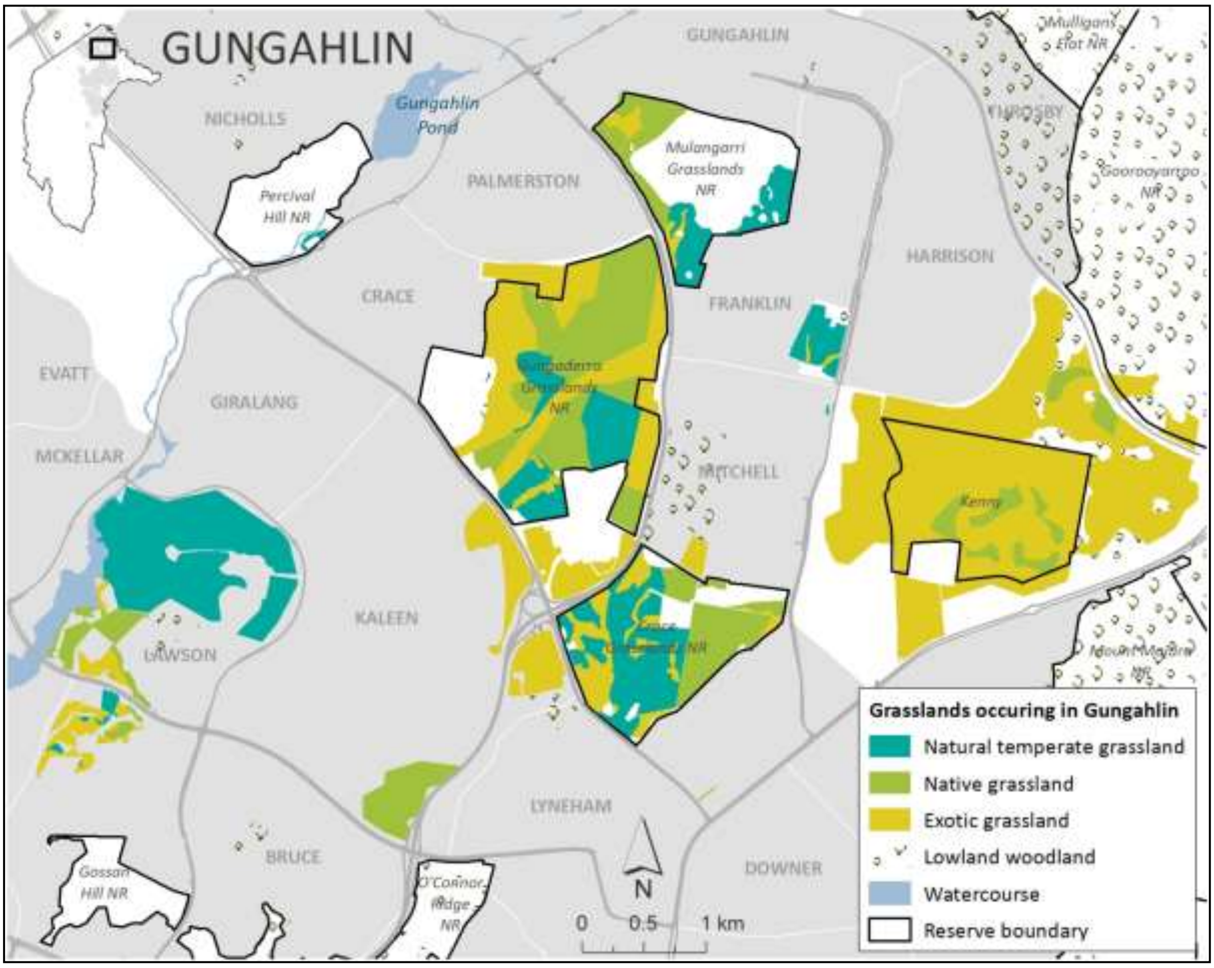


Figure 5. Natural Temperate Grassland distribution in Belconnen.

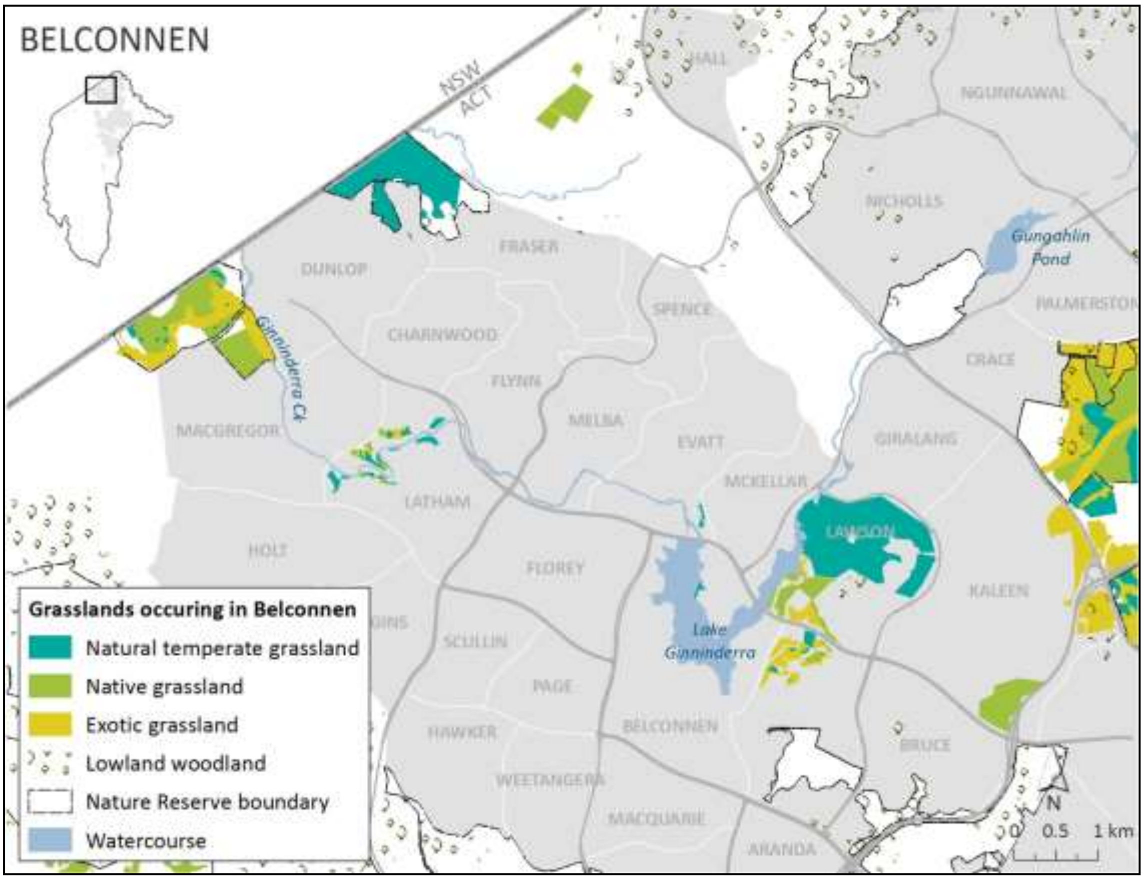


Figure 6. Natural Temperate Grassland distribution in the Molonglo Valley.

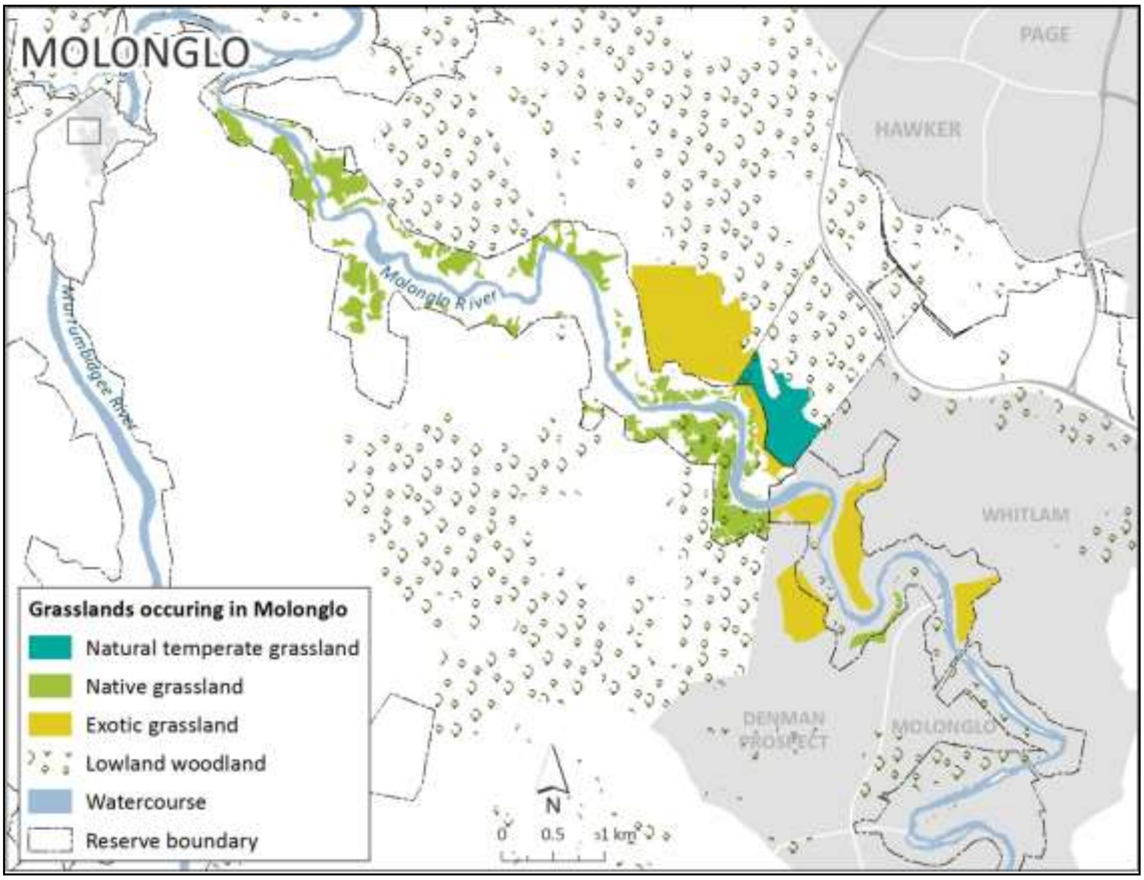
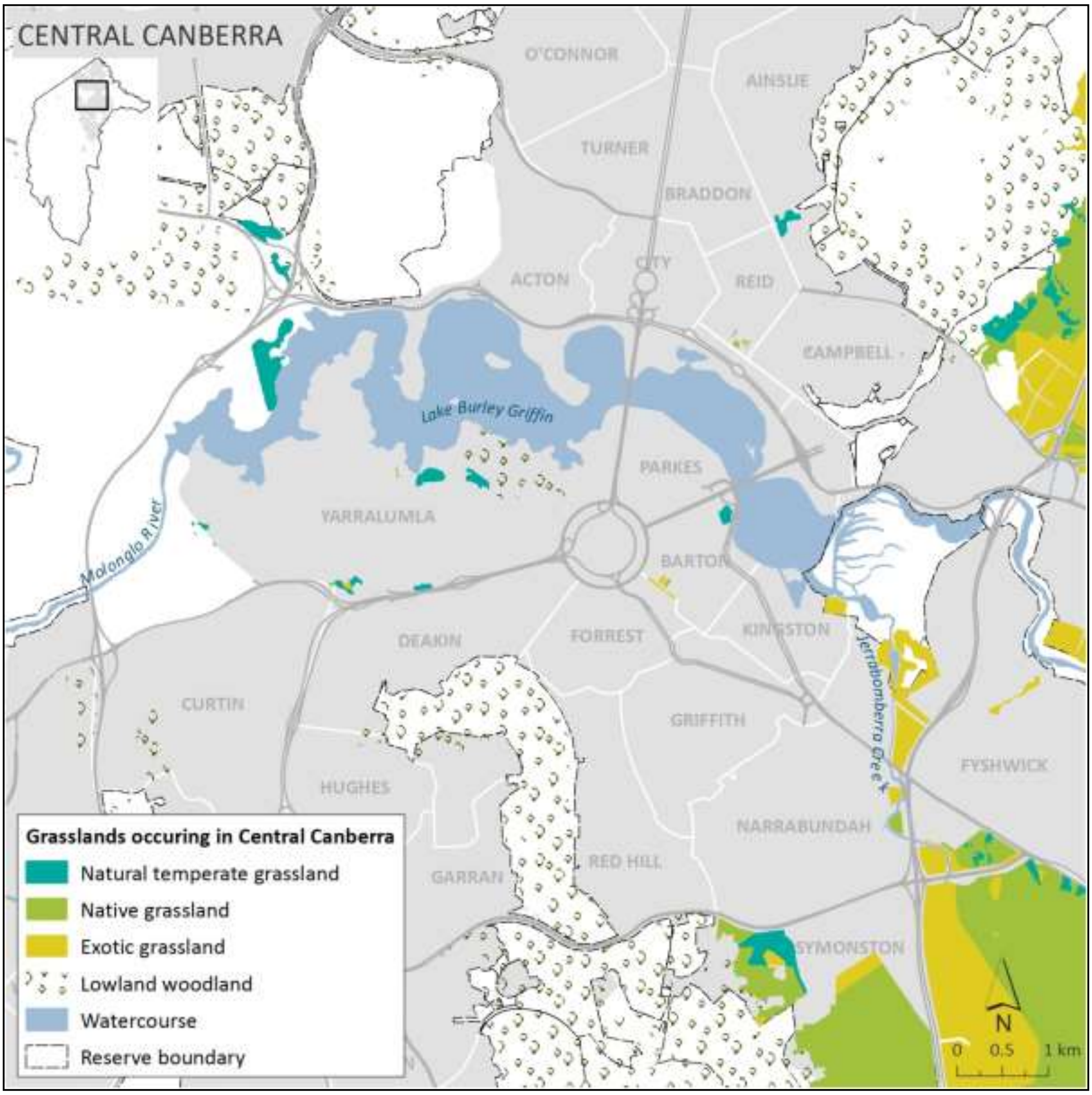


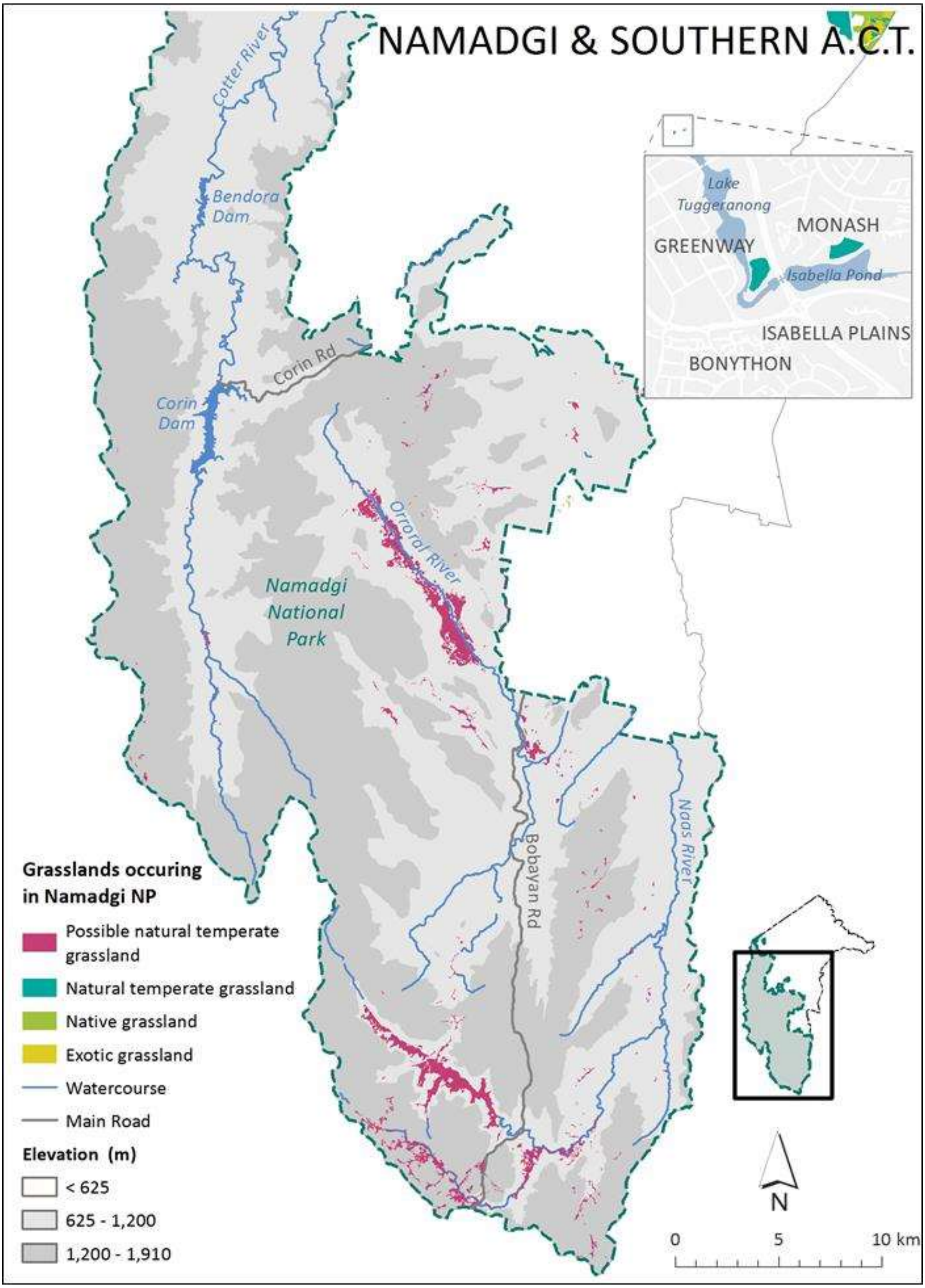
Figure 7. Natural Temperate Grassland distribution in Central Canberra.



Natural Temperate Grassland has been recently mapped in higher elevation areas of the ACT (Figure 8). The most extensive areas are to be found in the high quality native grasslands in the valleys of Namadgi National Park. These include Long Flat, Grassy Creek, Orroral Valley, Sam's Creek, Nursery Creek, Rendezvous Creek, Bogong Creek, and Emu Flats.

In some of these valleys, the grasslands have been extended by the clearing of trees during the pastoral period, and these locations should be considered secondary grasslands (ACT Government 2010). The most up to date distribution data for this community is publicly available on the ACT Government's mapping portal, (Visit the ACTmapi website).

Figure 8. Natural Temperate Grassland distribution within Namadgi National Park.



HABITAT AND ECOLOGY

In the ACT and surrounding region, Natural Temperate Grassland occurs where the establishment and growth of trees and shrubs is restricted by factors such as poor drainage, seasonal water logging (particularly on heavy clays in low-lying areas), summer drought, cool air drainage, cold winter temperatures, severe frost and winter snow (particularly at higher elevations), erosion, herbivory, shading and competition from grass (Lunt *et al.* 2012; Moore and Williams 1976; Fensham and Kirkpatrick 1992; Morgan and Williams 2015; Tremont and McIntyre 1994). However, where they do occur naturally, scattered woody plants in Natural Temperate Grassland can provide important habitat for fauna and contribute to grassland diversity (Morgan and Williams 2015).

One of the most important ecological processes in Natural Temperate Grassland is the disturbance regime, particularly because of its role in limiting the growth of the dominant native tussock grasses (Schultz *et al.* 2011; Morgan and Williams 2015; Morgan 2015). In healthy functioning temperate grasslands, disturbances such as fire, native animal grazing and periodic drought reduce grass biomass, resulting in an open canopy structure and a mosaic of grass tussocks and inter-tussock space (Tremont and McIntyre 1994). This opens up habitat for ground-dwelling animals, provides space for the germination, growth and reproduction of a diversity of native forbs, and maintains the vigour of tussock grasses (Morgan 2015, 1998a; Morgan and Lunt 1999). In the absence of disturbances, the canopy closes over and inter-tussock space declines, shading out habitat for other flora and fauna. Over time, dead litter accumulates and the health and vigour of tussock grasses declines (Morgan and Lunt 1999).

In high quality Natural Temperate Grasslands, the presence of a heterogeneous grassy sward provides habitat for a range of fauna and flora species. This is particularly important at sites where more than one threatened species is present, as the optimal habitat structure for one threatened species may be suboptimal for another. In general, a Natural Temperate Grassland site with a heterogeneous and patchy sward structure (i.e. patches of longer, dense grass mixed with patches of shorter, more open sward), as well as supporting a range of habitat features such as woody debris and rocks, is likely to provide a broader range of habitat niches for a variety of fauna (ACT Government 2016c).

The life history and growth form of plant species in Natural Temperate Grassland enables their persistence in unfavourable conditions, such as drought and fire, and under intense competition for light. Most species are perennial, and persist through time in the above-ground vegetation. Data on the longevity of perennial grassland plants is generally lacking (Lauenroth and Adler 2008); however, the suggestion of a 20 year lifespan for a temperate grassland forb in the Monaro Tablelands (Dorrough and Ash 2003) indicates that some species can persist for many years. Recovery after fire, grazing or drought occurs via vegetative re-sprouting from buds located either at or below the soil surface, where they are protected by litter and soil from damage (Tremont and McIntyre 1994; Morgan and Williams 2015). Many species of orchids and lilies are ‘geophytes’, which die back each year to a tuberous root or bulb, allowing them to remain dormant during the dry summer. Native short-lived annuals, which tend to require disturbed sites for colonisation, are rare in Natural Temperate Grasslands, probably due to the high competition for light (Morgan and Williams 2015). Instead, most native grassland species exhibit a competitive strategy (tall and fast growing; e.g. *Themeda triandra*) and/or a stress-tolerant strategy (relatively long life spans and persistence under moisture and nutrient stress; e.g. *Rytidosperma* and *Austrostipa*) (Morgan and Williams 2015).

Most native grassland plants have short-lived transient seeds, with few species developing a persistent soil-stored seed bank; seed dispersal tends to occur over short distances (Williams and Morgan 2015; Lunt 1990; Morgan 1998b). An important consequence of these life history and reproductive traits is that if native plants are lost from the standing vegetation of Natural Temperate Grassland there is little capacity for them to recover from a dormant soil seed bank, or disperse and recolonise from nearby remnants.

An important, but often overlooked, ecological component of Natural Temperate Grasslands is the biological soil crust. This crust, composed of a diversity of organisms such as lichens, bryophytes, fungi and algae, is an important part of high quality grasslands where it helps to retain soil water, resists weed germination and invasion, and provides resources for invertebrates (Morgan 2006; Sharp *et al.* 2015; Morgan and Williams 2015).

PREVIOUS AND CURRENT MANAGEMENT

The management and conservation of Natural Temperate Grassland in the ACT has evolved over time from a focus on identification and protection to adaptive management and restoration (ACT Government 2016c). The first major steps towards the conservation of the community in the ACT were undertaken in the early 1990s. Prior to this, knowledge of natural grassland remnants in the ACT was limited, with only a small number of incomplete surveys conducted (ACT Government 1997). This lack of knowledge was addressed by a four year recovery plan, which commenced in 1993. The recovery plan achieved a range of measures including mapping grassland distribution and surveying grassland floristics, ecological research into grassland plants and some threatened species, impacts of herbicides on selected native grasses, development of a management plan, establishment of a long-term monitoring program, compilation of a database, and the presentation of seminars and educational materials (ACT Government 1997). During this period, Natural Temperate Grassland was also declared as an endangered ecological community in the ACT (1996). Since then, action plans have been produced and revised for managing the community and its component threatened grassland species (Table 1) (ACT Government 2016c).

A core focus of Natural Temperate Grassland management has been to ensure the community is protected in an adequate and representative system. The majority of the remaining community is now protected in land managed by the ACT Government, including urban nature reserves, urban open space, roadsides and Namadgi National Park, although this remains an ongoing process. Other areas of Natural Temperate Grassland occur on land that is not exclusively managed for conservation, such as Canberra Airport, and land managed by the Commonwealth Government (e.g. Department of Defence land at Majura Training Area and Campbell Park and land managed by the National Capital Authority such as Yarramundi Reach). In many cases management of Natural Temperate Grassland (and the associated threatened species) is undertaken in consultation with the ACT Government and/or guided by management plans (e.g. Canberra Airport 2010).

All management and conservation actions have been undertaken in a regional context, recognising that Natural Temperate Grassland in the ACT is part of a broader ecological community that includes the surrounding South East Highlands of NSW, as well as being part of the once-widespread grassland belt that extended throughout south-eastern Australia. To achieve this regional emphasis, conservation and management activities are undertaken in partnership and collaboration with other relevant regional and cross-border partners such as the NSW Office of Environment and Heritage, the Kosciuszko to Coast (K2C) partnership, the South East Local Land Services and the Yass and Queanbeyan - Palerang Regional Councils.

Management of Natural Temperate Grasslands in the ACT has five key strategies:

1. management of grass biomass, structure and disturbance regimes
2. monitoring
3. invasive species management
4. restoration
5. community engagement

Each strategy is briefly outlined below, for more in-depth information on each please refer to the ACT Native Grassland Conservation Strategy (ACT Government 2016c).

Management of Grass Biomass, Structure and Disturbance Regimes

The main methods for managing grass biomass are prescribed burning, grazing by native and introduced grazers, and mowing/slashing.

Frequent burning on an annual to five-yearly cycle is considered to be an important ecological process in *Themeda triandra*-dominated Natural Temperate Grassland for maintaining floristic diversity and fauna habitat (Morgan 2015). However, there are logistical challenges in regular prescribed burning of small grassland remnants, particularly in Canberra’s urban area (Hodgkinson 2005). The use of fire for ecological purposes in Natural Temperate Grassland has been investigated in an experimental approach in several sites in the urban area of Canberra, including Jerrabomberra West Nature Reserve

(Cook and Baines 2014; E. Cook pers. comm. 2015) and several grassland sites in the Ginninderra Catchment (ACT Government 2005, Ginninderra Catchment Group), and current research is investigating the benefit of ecological burns across lowland grasslands in the ACT on floristic diversity and reptile abundance (M Gilbert pers comm), with a view to utilising this management tool more broadly across the lowland grasslands.

The manipulation of grazing regimes to manage grassland biomass and structure is achieved by modifying grazing pressure. Grazing by native herbivores is an integral ecological process in native grasslands, and kangaroos are the preferred grazers to manage grassland biomass in the ACT. However, domestic livestock are also used at sites that have a history of stock grazing, such as Dunlop Nature Reserve, Mulangarri Nature Reserve, and parts of Crace Nature Reserve. The strategic use of stock for biomass management (including for fire risk management) is being investigated at several lowland ACT grassland sites to determine how timing and application can achieve the best results for biodiversity (M Gilbert pers comm).

Mowing or slashing is also undertaken in select lowland Natural Temperate Grassland sites, although it is primarily used to clear along fence lines, as fuel hazard reduction and to improve access (Hodgkinson 2005). Mowing is considered to be a useful tool for reducing grass biomass in very small grassland fragments where burning or grazing are impractical, or where kangaroos are present in insufficient numbers or not at all, rather than for maintaining native grassland diversity (Eddy 2002; Morgan 2015). However, current research is investigating the impact of mowing in lowland grasslands on floristic diversity (R Milner pers comm, Ginninderra Catchment Group), to determine if the method may be suitable for high diversity sites where other methods of biomass removal is not practical.

Other grassland enhancement techniques currently being investigated in lowland grasslands in the ACT include rock replacement, to enhance reptile and invertebrate habitat, and scraping, to remove the weed seed bank in exotic grassland patches (M Gilbert pers. comm., R Milner pers. comm.).

Monitoring

Monitoring is a valuable tool for detecting trends in Natural Temperate Grassland communities over time. The ACT Government conducts regular monitoring of Natural Temperate Grassland across a broad range of sites, mostly in the lowland urban grassland remnants. Monitoring generally focuses on trends in grassland floristics and structure as an indicator of overall site quality. Regular monitoring is also carried out in Natural Temperate Grasslands for threatened species, with details described in the respective Action Plans for each species.

The method for assessment of the quality of a Natural Temperate Grassland site in the ACT has changed over time. Previously, a Botanical Significance Rating was used to assist with the identification of conservation values. The ratings, ranging between 1 (very high conservation value) and 5 (minimal conservation value), were determined by the diversity of native and exotic plant species present, uncommon native species, and the level of disturbance (ACT Government 1997). The method at the time of publication for assessing the relative condition of grasslands in the ACT and the broader region is the Floristic Value Score (FVS), developed by Rehwinkel (2007, 2014). The FVS calculates a numerical score for a site based on species richness and the presence and cover abundance of significant Indicator Species (ACT Government 2016c).

Invasive Species Management

Invasive plants and animals are widespread in Natural Temperate Grasslands, but have varying degrees of impact on grassland ecology. Invasive plants are a particularly widespread and large component of most Natural Temperate Grassland sites, and it is not possible to control or eradicate them all. In some locations, invasive grasses can provide important habitat for threatened grassland fauna, and in some areas may be managed in-situ to maintain the habitat rather than controlled or eradicated. For example, Striped Legless Lizards can use areas dominated by *Phalaris aquatica* whereas Golden Sun Moths are known to be present in grasslands comprised entirely of Chilean Needle Grass (*Nassella neesiana*) (Braby and Dunford 2006; Richter *et al.* 2013).

Invasive species management in the ACT is guided by the ACT Pest Animal Strategy 2012-2022 (ACT Government 2012) and the *ACT Weeds Strategy 2009-2019* (ACT Government 2009), which supersede previous strategies. An important focus of invasive species management is the establishment of priorities for invasive species control to assist in the allocation of limited resources. This includes identifying and controlling high-impact species, and areas of high conservation value, such as Namadgi National Park and sites where threatened species are present. For Natural Temperate Grasslands, the four most serious weeds requiring priority control are the perennial grass species African Lovegrass (*Eragrostis curvula*), Chilean Needle Grass (*Nassella neesiana*) and Serrated Tussock (*Nassella trichotoma*), and the perennial forb St John's Wort (*Hypericum perforatum*) (ACT Government 2016c). Priority invasive animals for control include the European Rabbit, the European Red Fox and, in higher elevation grasslands, feral pigs and horses (ACT Government 2012).

Restoration of Natural Temperate Grassland

Restoration is the process of returning existing habitats to a known past state or to an approximation of the natural condition by repairing degradation, by removing introduced species, or by reinstating species or elements that previously existed (Australian Heritage Commission 2002). In practice, however, restoration of very degraded or destroyed habitats is very difficult, and the results of restoration projects can be widely variable (Suding 2011).

In the ACT, restoration of Natural Temperate Grassland has focused on small-scale management activities of sites to achieve attainable targets, particularly in sites that are already in moderately good condition (ACT Government 2016c). These include activities such as weed control, improving fauna habitat elements, threatened species translocation, managing grass biomass and grazing levels, and planting native forbs amongst tussock grasses.

Ecological restoration is recognised as an increasingly important approach in native grassland management in the ACT, and sites that are considered as priorities for restoration are those that add the most ecological value to the surrounding landscape (ACT Government 2016c). These are most likely to be sites that improve connectivity between two high quality remnants, sites that increase the size of a Natural Temperate Grassland patch, and sites that increase the connected area of habitat for a threatened species.

Community Engagement

Community engagement and education is increasingly considered to be important for successful long-term grassland conservation, particularly as many Natural Temperate Grassland remnants are in urban areas. Public appreciation of native grasslands is generally low, with the ecosystems often undervalued and viewed as messy, unmanaged, and even threatening (Williams 2015). Improved community engagement and education raises the appreciation and understanding of Natural Temperate Grassland, and encourages people to become volunteers and advocates for grassland conservation (Reid 2015). Recently, a key strategy identified by the ACT Government for nature conservation is to increase rates of environmental volunteering in the Canberra community (ACT Government 2013). Citizen science is another key community engagement activity that involves the community directly in scientific activities such as collecting data (Reid 2015). An example of citizen science involvement in grassland research is the community monitoring of Golden Sun Moth populations at 28 sites around Canberra (Richter *et al.* 2009).

THREATS

Temperate grasslands are considered to be one of the world's most endangered ecosystems (Peart 2008). This situation is reflected in south-eastern Australia where temperate grasslands have undergone enormous and widespread decline and degradation since European settlement, with agriculture considered to be the greatest cause of grassland loss (Gilfedder *et al.* 2008; Williams and Morgan 2015).

Five emerging major threats to Natural Temperate Grasslands in south-eastern Australia have been proposed by Williams and Morgan (2015), each of which is applicable to Natural Temperate Grasslands in the ACT. These threats, which are likely to intensify over the next few decades, are as follows:

1. The effects of historic habitat loss (such as fragmentation effects).
2. Ongoing loss and modification of native grasslands, mainly due to agricultural and urban development.
3. Invasive plants and animals.
4. Ecologically inappropriate disturbance regimes, particularly a decline in disturbance frequency in productive grasslands.
5. Climate change.

Managing to reduce the impact of these threats are important strategies in conserving and restoring grasslands in the ACT (ACT Government 2016c), and each are described in more detail below.

Historic loss of native grassland

Natural Temperate Grassland throughout south-eastern Australia has a long history of clearing, firstly for agriculture, and more recently for urban and industrial development. The legacy of this historic loss is that there is now very little Natural Temperate Grassland left in south-eastern Australia, and the remnants are often small, fragmented and degraded. Most temperate grassland communities have declined by over 90% in their extent and are listed as either endangered or critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, and in some cases considered extinct (Williams and Morgan 2015). Natural Temperate Grassland in the ACT has undergone a similar degree of loss and degradation, with the broader community in the region (Natural Temperate Grassland of the South Eastern Highlands) thought to have declined by 98.8% of the original pre-European extent (Williams and Morgan 2015).

Accompanying this decline has been a widespread loss of grassland biodiversity, with five grassland animal species and three grassland plant species listed as threatened in the ACT (Table 1), and many more—particularly mammals—considered to be locally extinct (ACT Government 2005; Antos and Williams 2015).

Ongoing loss of native grassland

Urban and infrastructure development remains an ongoing threat to lowland Natural Temperate Grassland in the built-up areas of the ACT, despite significant areas now being protected. In particular, the areas on which the grassland community occurs are usually flat or undulating, and lack trees, making them attractive sites for development.

Ongoing destruction of Natural Temperate Grassland can also occur if the ecosystem becomes degraded to such a degree that it no longer fits the description of or definition of the listed community (see Definition). Destruction of Natural Temperate Grassland can involve changes to soil pH and nutrient levels, destruction of the original soil profile, altered drainage patterns, heavy weed invasion, a long-term and abundant weed seed bank in soil, and disruptions to trophic interactions. Once degraded, it can be difficult and resource-intensive to restore the site to high quality grassland, especially if there has been a considerable loss of native plant species. There are many barriers to restoration once Natural Temperate Grassland has been lost or severely modified, but one of the major factors is that most native grassland species lack a long-lived soil seed bank.

Invasive Plants and Animals

Invasive plants and animals are widespread in Natural Temperate Grasslands across the ACT, including in the highest quality grasslands. The most significant invasive plants are those that alter grassland structure and composition, such as woody weeds and large stipoid tussock grasses (Robinson 2015). Once established, invasive plants can become dominant, resulting in large and dense monocultures that outcompete and eventually exclude other native grassland plants (Faithfull *et al.* 2010; Robinson 2015).

Invasive animals in Natural Temperate Grasslands include grazers, such as the European Rabbit, Brown Hare, House Mouse, feral pig, feral horse and feral deer, and predators, including the European Fox, wild dogs and the domestic cat. Invasive animals in Natural Temperate Grasslands disrupt grassland ecology by predating on or displacing native fauna, altering grassland biomass and structure, causing soil disturbance, changing soil fertility and drainage, trampling, wallowing, spreading weeds and direct consumption of native flora.

Ecologically Inappropriate Disturbance Regimes

Disturbance regimes such as fire and grazing are a key ecological process in native grassland ecosystems, particularly because of their role in regulating grass biomass and inter-tussock space (Lunt *et al.* 2012; Tremont and McIntyre 1994). Ecologically inappropriate disturbance regimes can include disturbances that are too frequent, or too rare. This is dependent on the type of grassland community, with frequent disturbances generally being more important as grassland productivity increases. Insufficient disturbance regimes, where grazing and/or burning is removed from the ecosystem, can result in excess biomass, loss of intertussock space, loss of habitat and loss of species diversity. Excessive disturbance regimes, such as frequent burning events or overgrazing by domestic stock, introduced grazers (e.g. rabbits) and kangaroos, can result in the simplification of grassland structure, change in plant species composition, loss of fauna habitat, soil erosion and compaction and increased weed dispersal.

Climate Change

Climate change is predicted to affect the structure and function of Natural Temperate Grassland ecosystems through a range of direct and indirect processes (Prober *et al.* 2012). However, there remains substantial uncertainty in determining the exact nature of climate change impacts on grasslands, particularly due to the complex interactions between changes in CO_2, temperature, seasonal rainfall, water availability, soil nutrients and grass growth (Hovenden *et al.* 2014; Prober *et al.* 2012). Further information on the potential effects of climate change on native grasslands can be found in the Native Grassland Conservation Strategy (ACT Government 2016c).

MAJOR CONSERVATION OBJECTIVES

The overall objective of this plan is to conserve Natural Temperate Grassland in perpetuity as a viable and well-represented community across its natural geographic range in the ACT. This includes managing and restoring natural ecological and evolutionary processes within the community.

Specific objectives of the action plan:

- Protect all remaining Natural Temperate Grassland (endangered ecological community) sites in the ACT.
- Manage Natural Temperate Grasslands to:
    - maintain and improve grassland structure and function
    - reduce the impacts of threats
    - improve threatened species habitat
    - conserve grassland biodiversity
- Increase the extent, condition and connectivity of Natural Temperate Grassland in the ACT by restoring priority grassland sites.
- Promote a greater awareness amongst all relevant agencies, landholders and stakeholders of the objectives of this Action Plan, and strengthen community engagement in grassland conservation.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

All Natural Temperate Grassland sites in the ACT require protection as they represent the remaining remnants of a community that was once widespread throughout south-eastern Australia. The long term conservation of the remaining remnants is also crucial for the persistence of threatened grassland species. The majority of Natural Temperate Grassland occurs on ACT Government managed land, including urban nature reserves, urban open space and roadsides.

Natural Temperate Grassland at higher elevations is contained within Namadgi National Park, although there is some potential for sites to exist on leasehold land in the central Naas valley, upper Gudgenby River and lower Blue Gum Creek.

Around two-thirds of lowland remnants of Natural Temperate Grassland (i.e. below 625 m) occur on ACT land, with the remaining third occurring on other land, such as Canberra Airport and land under Commonwealth control (ACT Government 2016c). In these other cases, the ACT Government will liaise with the relevant authority to encourage continued protection and management of Natural Temperate Grassland on their land.

Protection of Natural Temperate Grassland not only includes the protection of grassland biodiversity, but also protection of the ecological processes within the community, including interactions between flora and fauna, disturbance regimes, nutrient cycling, pollination, seed dispersal, and evolutionary processes. Increasing the size of remnants and improving connectivity between remnants through restoration will assist in maintaining and improving these ecological processes and functions.

The Native Grassland Conservation Strategy (ACT Government 2016c) provides a Conservation Significance Category classification for guiding the protection and management of the remaining native grassland sites (including sites containing the Natural Temperate Grassland community). The Conservation Significance Category for individual sites is based on grassland condition, area and value of the site as threatened species habitat.

SURVEY, MONITORING AND RESEARCH

The identification of Natural Temperate Grasslands requires on-ground surveys to assess whether the grassland patch meets the definition and the four key defining characteristics (see Definition) of the community (e.g. Baines *et al.* 2014). Currently, native grasslands are well mapped within the ACT up to 1200 m (asl). Natural Temperate Grassland is likely to occur in many of these native grassland communities, particularly those at higher elevation that have been less modified and degraded by past and present land management practices.

As well as assessing the four defining characteristics of Natural Temperate Grassland, field surveys also assess grassland condition by using the Floristic Value Score (FVS), a method to assess the relative conservation value of grasslands in the ACT and surrounding NSW region.

FVS has been researched and developed by Rehwinkel (2007, 2014), with details provided in the ACT Native Grassland Conservation Strategy (ACT Government 2016c). In the ACT, grassland mapping units are generally considered to be Natural Temperate Grassland under both the EPBC and NC Act if they have a FVS of 5 or higher (Commonwealth of Australia 2016). By this criteria, a Natural Temperate Grassland site needs to contain multiple indicator species, which are species that are rare due to being disturbance-intolerant (mostly to grazing) or are declining. Therefore, it is important to ensure surveys to identify Natural Temperate Grassland sites are carried out in spring, when indicator species are most likely to be visible and identifiable.

Monitoring of a subset of Natural Temperate Grassland sites is required to determine whether management actions are resulting in the maintenance or improvement of grassland condition. This is particularly important at sites where the monitoring of grassland threatened species is being undertaken. Current best-practice monitoring actions have been prepared in the Lowland native grassland ecosystems condition monitoring plan: PCS Conservation Effectiveness Monitoring Program (ACT Government 2015), and include a set of monitoring indicators relating to ecosystem condition and stressors. Under this program a monitoring plan is also being prepared for the upland native grassland ecosystems.

Priority sites for monitoring include:

- sites with threatened species present
- sites where kangaroo populations are being managed
- sites where specific management actions are being trialled and carried out, such as experimental or ecological burning (e.g. St Mark's Cathedral), and grazing manipulation, including grazing exclusion (e.g. Jerrabomberra East and West Nature Reserves) and the use of domestic livestock.

An increased monitoring effort (i.e. in frequency and across more sites) is also likely to be required during future droughts. This is particularly important to monitor whether sites are approaching critical thresholds beyond which unacceptable and irreversible degradation will occur (Hodgkinson 2009).

Past research into the ecology and conservation of Natural Temperate Grassland in south-eastern Australia has focused primarily on lowland high productivity *Themeda triandra*-dominated communities. A major research priority is into management approaches and guidelines for other grassland community types, and Natural Temperate Grassland that occurs at higher elevations, particularly in relation to grass biomass management and the use of prescribed fire for ecological purposes. This is being partly addressed by current research investigating grassland biomass management across ACT lowland grasslands, to provide guidelines on the use of fire, grazing and slashing for ecological purposes (Grasslands Enhancement Program, M Gilbert pers. comm.). Other priority research areas include:

- development of methods to distinguish and map secondary grasslands as distinct from Natural Temperate Grassland
- map the Natural Temperate Grassland communities as described in Table 2
- research of the taxonomy and ecology of grassland invertebrates, improved taxonomic understanding of the ACT's rare grassland plant species, and research on grassland plant species ecology (in addition to the threatened species)
- increased replication of monitoring sites to adequately represent all grassland associations in the ACT, including higher elevation grasslands, which may be particularly important for detecting woody species encroachment and plant compositional changes under climate change
- an increase in targeted adaptive management monitoring programs to investigate effectiveness of different grassland management strategies.

MANAGEMENT

Due to the decline in the extent and condition of Natural Temperate Grassland, management actions should be focused on maintaining and improving the existing condition of Natural Temperate Grassland sites and minimising the impacts of any adverse activities on grassland condition, particularly in urban areas where threats are more numerous and in closer proximity.

It is important to recognise that the objectives and targets for each priority management action are specific to the grassland community present at a site. This is due to the variation between native grassland communities and the types of nearby threats (including pest plants and animals), natural disturbance regimes, rates of grass biomass accumulation, degree of site modification and degradation, and history of land use in the ACT Native Grassland Strategy (ACT Government 2016c).

All site-level management actions must also take into account the presence of threatened flora and fauna (Table 1).

Priority management actions in Natural Temperate Grassland are:

- **Management of grass biomass and structure to maximise site quality and biodiversity.** As a general rule, management actions should aim to maintain a grassland structure that has intermediate levels of herbage biomass, which will promote a grass structure suitable for many grassland species, including threatened species. Such grassland will usually have well-defined tussocks mostly ranging in height between 5 cm and 20 cm, and inter-tussock spaces composed of shorter grasses and forbs with perhaps some bare ground. Removing most of the herbage biomass should be avoided as this creates a very short grassland. Short grassland has grass mostly <5 cm high and usually a high proportion of bare ground but may also have dead thatch or short forbs. Maintaining grasslands that have high grass biomass should also be avoided. High biomass grasslands tend to have mostly tall (>20 cm) dense grass with very little or no inter-tussock spaces and potentially a large build-up of thatch. Active management is more frequently required in productive grasslands, particularly lowland grassland dominated by Themeda triandra, and less frequently required (if at all) in higher elevation grasslands. If threatened species are present at the site, grass biomass should be managed to provide the necessary habitat requirements as described in the relevant species' action plan and as summarised in the Native Grassland Conservation Strategy. At sites where more than one threatened species is present, or where there are multiple ecological values, there may be incompatible habitat requirements. In these sites, the priority for management is given in the Native Grassland Conservation Strategy (ACT Government 2016c).
- **Establishment and implementation of ecologically appropriate disturbance regimes.** Implementing disturbance regimes (grazing, fire, mowing/slashing) is particularly important in higher productivity sites where grass growth is fastest. Where grazing is used to manage grass biomass and structure, the preferred method is to use

native herbivores (kangaroos), with grazing by stock used in circumstances where kangaroo grazing is unable to maintain the desired grass biomass/structure at a site. Each Natural Temperate Grassland site should have its own fire management plan and resources allocated to conduct ecological burns (Hodgkinson 2009). Livestock grazing is an alternative disturbance that may be implemented in lower quality sites with a history of grazing and where kangaroos are absent or low in number, and where the focus is on reducing grass biomass rather than maintaining grassland floristic diversity. In sites where fire and grazing is impractical, mowing/slashing can be used as a tool to reduce grass biomass under certain conditions (ACT Government 2016c). Where possible, frequent fire (every 1–5 years) should be implemented in high quality Themeda triandra lowland Natural Temperate Grassland sites for maximising grassland biodiversity.

- **Management of priority weeds, particularly at sites with threatened species present.** These include woody weeds, Weeds of National Significance, and the four most serious grassland weeds—African Lovegrass (Eragrostis curvula), Chilean Needle Grass (Nassella neesiana), Serrated Tussock (Nassella trichotoma) and St John's Wort (Hypericum perforatum). Weed management should be guided by the ACT Weed Strategy (ACT Government 2009).
- **Control of priority pest animals.** These include the European Rabbit and the European Red Fox and, in higher elevation grasslands, the feral pigs and horses. Pest animal management should be guided by the ACT Pest Animal Strategy (ACT Government 2012).
- **Restoration of priority grassland sites.** These are sites that are already in moderately good condition and occur in locations where restoration would add the most ecological value to the surrounding landscape, such as by increasing patch size or improving connectivity between sites, particularly for enabling dispersal of threatened species. Priority sites for increasing connectivity have been identified and include: Gungahlin grassland reserves; West Majura/Campbell Park; Eastern Majura Valley (Majura Training Area/Canberra Airport); Eastern Jerrabomberra Valley (Cookanalla/Bonshaw/Jerrabomberra East Nature Reserve); Western Jerrabomberra Valley (Jerrabomberra West Nature Reserve/Callum Brae) and West Belconnen (Dunlop Nature Reserve/Jaramlee).
- **Avoiding incompatible activities** that will cause further degradation to grassland sites and biodiversity. These include activities that exacerbate threats, such as those that may facilitate weed invasion (e.g. construction of trails and tracks) and activities that impact directly on grassland function, structure and composition, such as planting of non-local trees, rock removal, soil compaction and dumping of materials.
- Incorporating appropriate statements of management actions into relevant plans and strategies.

Strategies for undertaking these priority management actions can be found in the ACT Native Grassland Conservation Strategy (ACT Government 2016c).

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database.

An Environmental Offsets Assessment may result in a development being 'flagged'. A flag identifies an area of land with significant protected matter values. If a proposed impact is flagged, it will require additional consideration by the Conservator of Flora and Fauna as to whether offsets are appropriate in the particular instance. A proposed development on Natural Temperate Grassland will be flagged if it is on a Conservation Significance Category 1 or 2 grassland site as described in the Native Grassland Conservation Strategy (2016c), unless it can be demonstrated that:

- the area of clearance is a peripheral component of a grassland remnant AND
- it is not habitat of significant grassland fauna (or habitat of the Golden Sun Moth) AND

- it has only five or less native herbs in the most diverse 20x20 m of the area of investigation AND
- it is devoid of any significant or regionally rare plants.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- land planning and land management areas of the ACT Government to take into account the conservation of threatened species
- allocation of adequate resources to undertake the actions specified in the Native Grassland Conservation Strategy and action plans
- liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community
- collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research
- collaboration with non-government organisations such as Greening Australia to undertake on-ground actions
- engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 3. Key objectives, actions and indicators

Objective	Action	Indicator
1. Conserve all remaining Conservation Significance Category 1 NTG sites in the ACT. Protect Conservation Significance Category 2 NTG sites in the ACT from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).	Apply formal measures to protect all Conservation Significance Category 1 sites on Territory-owned land. Encourage formal protection of all Conservation Significance Category 1 sites on land owned by other jurisdictions.	All Conservation Significance Category 1 sites protected by appropriate formal measures.
	Protect Conservation Significance Category 2 NTG sites on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect Category 2 NTG sites from unintended impacts.	All Conservation Significance Category 2 sites protected from unintended impacts.
	Ensure protection measures require site management to conserve NTG on Territory-owned land. Encourage other jurisdictions to require site management to conserve NTG on their land.	Protection measures include requirement for conservation management.
2. Manage Natural Temperate Grasslands to: • maintain and improve grassland structure, function and diversity • reduce the impacts of threats • conserve grassland biodiversity.	Manage Natural Temperate Grassland to maintain ecological condition, including implementing an appropriate grazing/slashing/burning regime.	Natural Temperate Grassland ecological condition maintained and management actions are recorded.
	Monitor the condition of Natural Temperate Grassland and the effects of management actions.	Threats are identified and management actions taken to reduce impact.
	Implement site-specific management actions to maintain required habitat structure for threatened species.	Grass biomass levels and inter-tussock spaces are maintained at ecologically appropriate levels.
3. Enhance the long-term viability of Natural Temperate Grassland by increasing the extent, condition and connectivity in the ACT by restoring priority grassland sites.	Identify priority grassland sites for restoration based on quality and potential for adding ecological value to the surrounding landscape. Undertake management or facilitate research and trials into increasing condition, connectivity or extent.	Extent, condition and connectivity of Natural Temperate Grassland has increased.
4. Improved understanding of the ecology, restoration methods and threats to this community.	Undertake or facilitate research on appropriate methods for managing and restoring the community and its habitat (slashing/grazing/ burning etc.), vegetation biomass, lifecycle, germination, recruitment and genetics.	Research undertaken and reported and where appropriate applied to the conservation management of the community.

Objective	Action	Indicator
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in, grassland conservation.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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PERSONAL COMMUNICATIONS

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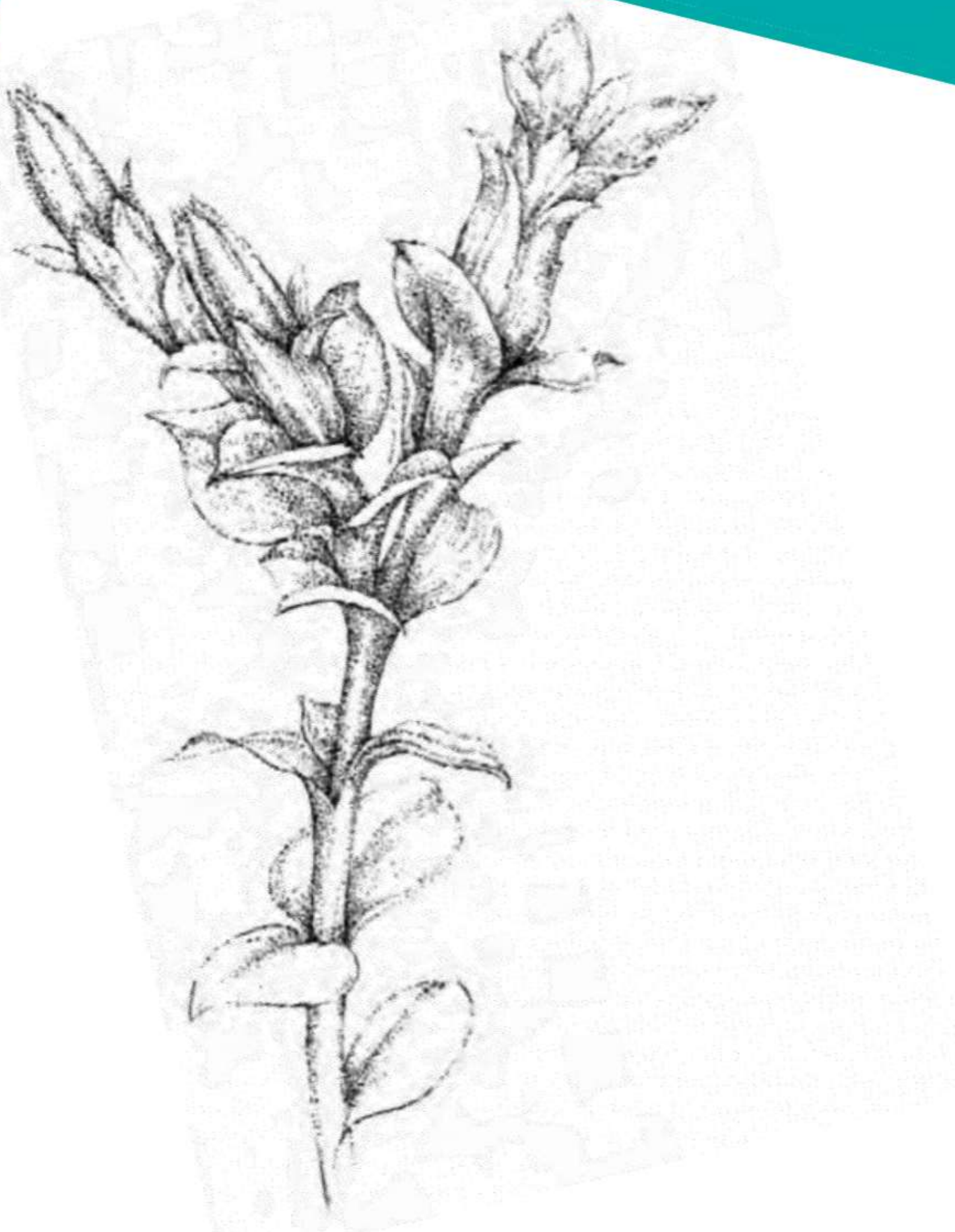
BAEUERLEN'S GENTIAN
GENTIANA BAEUERLENII

DRAFT ACTION PLAN



PREAMBLE

In accordance with section 21 of the *Nature Conservation Act 1980*, the subalpine herb Baeuerlen's Gentian (*Gentiana baeuerlenii* L.G.Adams) was declared an endangered species on 15 April 1996 (formerly Instrument No. 89 of 1997). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1997 (ACT Government 1997). This revised edition supersedes all earlier editions.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland. This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Gentiana baeuerlenii is recognised as a threatened species in the following sources:

National

Endangered – *Environment Protection and Biodiversity Conservation Act 1999*.

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*.

Special Protection Status Species – *Nature Conservation Act 2014*.

New South Wales

Endangered – *Threatened Species Conservation Act 1995*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

Gentiana baeuerlenii is a small annual herb, standing 2–4 cm high. The flowers are borne singly at the ends of branching stems. Each is bell shaped, greenish outside and blue-white inside with five petals.

DISTRIBUTION

The species is currently known only from one location, which was identified during a remarkable chance rediscovery in the Orroral Valley, Namadgi National Park by Mr Laurie Adams of the Australian National Herbarium. It was believed to be extinct, having previously been described from the Quidong area near Bombala NSW from specimens found there in 1887. No plants have been observed at the Namadgi site between 1998 and 2014.

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

The species occurs in the inter-tussock space of moist tussock grassland and sedgeland (*Poa labillardieri* and *Carex gaudichaudii*) associated with ground water, possibly a spring-fed area. The area is probably secondary grassland or a relict grassland opening, once surrounded by open woodland. The site is on the lower slopes of a broad valley, above a river and lower valley floor.

The Flora of NSW notes that flowers have been observed in October, however the only collection in New South Wales was made in March.

The Namadgi National Park population has been recorded as flowering between autumn and early winter (March–June).

The orchid *Spiranthes sinensis*, the herb *Ranunculus pimpinellifolius* and the grass *Hemarthria uncinata* were found in association with the herb and this group of more widespread species may be indicators for other potential sites.

PREVIOUS AND CURRENT MANAGEMENT

Due to the nature of this species and the small size of the site, management actions have been directed towards maintaining existing conditions and ensuring activities located nearby do not adversely affect the site.

Since 2002 the site has been assessed for the presence of the species on an annual basis during May or June. In 2002 extensive pig rooting damage was observed surrounding the site. To mitigate future risks from pig activity while still allowing for kangaroo grazing, a stock proof fence was erected around the population that same year. There is also an annual pig control program conducted across Namadgi National Park by Parks and Conservation.

The site was burnt in the 2003 bushfires; this may have resulted in the death of some seed due to the severity of the fires. Despite kangaroos grazing within the fenced area, the biomass has built up to an extent that could hinder germination. Options such as grass trimming and burning have been investigated. Some physical removal of weeds and grass thatch is carried out during the annual site assessments.

Visitor access is not encouraged, there is no signage to the location and the entry to the area is obscure to access. There has been no walking or vehicle track development near the site.

THREATS

It is very likely the species was once widespread but has become restricted through activities associated with land clearing and grazing, particularly in times of drought as the wet grassy areas in which it is found would have remained palatable well into the driest seasons.

Although the species is likely to be unpalatable to stock because it contains certain chemicals known to render plants distasteful, it could have been grazed inadvertently, along with other herbage species. Its habitat may have been trampled, especially when adjoining areas dried out.

Baeuerlen's Gentian

When the species was last observed in 1998 there were less than ten plants counted at the site. At the time of discovery in 1991, 20 plants were observed.

The main threat to the survival of this population, and therefore the species, is likely to be deliberate or unintended actions associated with park management activities in the local area. It is not clear whether grazing animals such as kangaroos may also pose a threat to survival of remaining plants, or whether some level of grazing may benefit the species by keeping competing grass tussocks and other plant growth short and open.

MAJOR CONSERVATION OBJECTIVES

The overall objective of this plan is to conserve the species in perpetuity in the wild across its natural geographic range in the ACT. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve all ACT populations because the species is not known to occur outside the ACT.

- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to facilitate expansion of populations into suitable habitat, and by establishing new populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The small number of plants known to exist would not support adequate seed production. When the number of available plants is greater, propagation must be undertaken. This is the only way to ensure biodiversity conservation as the habitat is fragile, is being grazed by macropods and could accidentally be burnt. Nothing is known of the species' fire ecology, but it appears to be an annual and dependent on seed regeneration. Further research on this aspect is required.

There will be no track development near the site; thus, visitor access to the area where the species is located is not encouraged.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database.

In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. *Gentiana baeuerlenii* only occurs in a single site in the Namadgi National Park. The assessment methodology applies to lowland species and vegetation communities of conservation importance (below 750 metres) and therefore does not apply to this species. Given this species' extremely limited distribution, offsets for this species are not appropriate and impacts are to be avoided. If threatened species numbers are observed to change dramatically (either increase or

Sub-montane Poa tussock grassland in the ACT, similar habitat to where Baeuerlen's Gentian occurs.

decrease), a review of this species' requirements would be undertaken.

SURVEY, MONITORING AND RESEARCH

It is very unlikely the species exists anywhere else in the ACT. Given this degree of rarity, surveys aimed at finding specimens beyond the immediate area are not economically justified. Survey opportunities will be found in other work by making field workers aware of the species and alerting interested naturalists and conservation groups. Contact will be maintained with the NSW National Parks & Wildlife Service on this matter. Research opportunities will be pursued should the population be observed to have germinated in sufficient numbers to allow for such actions to be carried out.

ACT Government (currently through the Conservation Research unit) will monitor the existing population on an annual basis in collaboration with Namadgi National Park rangers.

Priority research areas include:

- Improved knowledge of life history and ecology, such as plant longevity, seed longevity, conditions associated with germination and recruitment and effects of surrounding vegetation biomass.
- Methods for establishing additional populations, such as translocation of plants, in association with the Australian National Botanic Gardens, Greening Australia and other parties.
- Investigations of chemistry, composition and structure of soil at the known sites to assist with identification of similar sites for establishment of other populations.

MANAGEMENT

Due to the nature and small size of the site containing the species, management actions will be directed towards maintaining existing conditions and ensuring activities located nearby do not adversely affect the site. To aid management and monitoring of the species the site has been unobtrusively marked.

Priority management actions:

- Carry out vegetation biomass management when necessary by artificially trimming the tussock grass during the non-flowering season. This will be done by careful use of a 'whipper-snipper' and removing cut grass by raking to avoid continuous build up of decaying matter which smothers soil and small plants. Any spread of tea-tree will be monitored and appropriately controlled.
- Carry out physical weed control if weeds pose a threat to the population or the site. Herbicides will not be used anywhere in the vicinity of the site where there is any possibility of it adversely affecting the species.
- Avoid incompatible activities such as development of facilities, recreational use or access tracks in or near the sites, especially where these may alter drainage.
- Introduced weeds will not be allowed near the site.
- Maintain feral pig control in the area.
- Consider burning habitat and adjacent areas of similar habitat, subject to assessment.
- Maintain a low profile for the sites where the species is located.
- Incorporate appropriate statements of management actions in relevant plans and strategies.
- Should germination occur, seek expert advice on the need and potential for ex-situ conservation measures to be taken for this species. Both vegetative and seed collection will be considered; and if the species re-emerges, the recovery actions, outlined by Young (2001), will be evaluated and appropriate actions undertaken.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.

- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1. Key Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve all ACT populations because the species is not known to occur outside the ACT.	Maintain formal measures to protect all populations.	All populations protected by appropriate formal measures.
	Ensure protection measures include requirement to conserve the species in the long-term.	Protection measures include requirement for conservation management.
	Maintain alertness to the possible presence of the species while conducting vegetation surveys in suitable habitat.	Vegetation surveys in suitable habitat also aim to detect the species.
	If germination occurs at suitable numbers, develop a seed bank as an insurance against loss of the extant population.	Seed bank in the National Seed Collection is maintained and seed collected at regular intervals (determined by seed longevity).
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor the population and effects of management actions.	Trends in abundance are known. Management actions are recorded.
	Manage habitat to maintain its suitablilty for the species.	Suitable habitat conditions are maintained by site management. Potential threats (e.g. weeds) are avoided or managed. Populations are stable or increasing.

Objective	Action	Indicator
3. Enhance the long-term viability of populations through management of adjacent grassland to facilitate expansion of populations into suitable habitat. Establish new populations.	Undertake or facilitate research and trials into increasing the size of populations or establishing new populations.	Research and trials have been undertaken to increase size of populations or establish new populations. Population size increased or new population(s) established.
4. Improved understanding of the species' ecology, habitat and threats (Subject to finding plants or new populations).	Undertake or facilitate research on appropriate methods for managing the species and its habitat (slashing/grazing/ burning etc.), vegetation biomass, lifecycle, germination, recruitment and genetics.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

ACKNOWLEDGMENTS

The illustration of the species was prepared for the ACT Government by John Pratt.

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BUTTON WRINKLEWORT
RUTIDOSIS LEPTORRHYNCHOIDES

DRAFT ACTION PLAN

PREAMBLE

The Button Wrinklewort (*Rutidosis leptorrhynchoides* F.Muell) was declared an endangered species on 15 April 1996 (Determination No. DI1996-29 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1998 (ACT Government 1998). This revised edition supersedes all previous editions.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*), Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Golden Sun Moth (*Synemon plana*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Rutidosis leptorrhynchoides is recognised as a threatened species in the following sources:

National / International

Endangered – Australian and New Zealand Environment and Conservation Council (ANZECC) Endangered Flora Network (1998).

Endangered – Rare or Threatened Australian Plant (ROTAP) (1996).

Endangered – Part 1, Schedule 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The species is also the subject of a National Recovery Plan (NSW OEH 2012) and Action Statement No. 28, prepared by the Victorian Department of Conservation and Environment. The National Recovery Plan identifies all populations of more than 10 plants and the habitat they occupy as critical to the survival of the species due to the small area of total occupancy and the small proportion of the total population outside formal conservation reserves, and to the threat of weed invasion at most sites.

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*.

New South Wales

Endangered – *Threatened Species Conservation Act 1995*.

Victoria

Threatened taxon – Schedule 2 of the *Flora and Fauna Guarantee Act 1988*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Button Wrinklewort *Rutidosis leptorrhynchoides* (Figure on the opposite page) is an erect perennial forb in the daisy family (Asteraceae). In spring and summer it produces multiple, mostly-unbranched flowering stems 20–35 cm tall. The stems are hairless above and woolly towards the base, and die back to the woody rootstock in late summer or autumn. A new basal rosette of upright leaves appears in early winter, and new stems arise from buds at the soil surface. The stem leaves are narrow, dark green ageing to yellow-green, usually 1.5–3.5 cm long, 0.5–1.5 mm wide, mostly hairless and with the edges rolled under. The yellow flat-topped hemispherical flower-heads are 8–15 mm in diameter, and develop at or near the top of the stems. Each flower-head is made up of a cluster of many small florets surrounded by rows of greenish bracts. The individual fruits are small and dark brown, each topped with whitish scales.

DISTRIBUTION

Rutidosis leptorrhynchoides appears to have been formerly widespread in south-eastern Australia, with disjunct populations in New South Wales and on grassy plains in Victoria. In south-eastern NSW and the ACT it occurs from the Michelago and Canberra/Queanbeyan districts to the Goulburn area. In Victoria it is found across the western plains. Herbarium records show a reduction in the number and size of *R. leptorrhynchoides* populations as the species' grassland and woodland habitat was converted to grazing (Scarlett and Parsons 1990).Nationally, 29 known extant populations occupy a total of about 13.4 hectares (ha), with a further 11 populations having become extinct in recent times. Many populations have fewer than ten plants, and only eight contain 5000 or more plants (NSW OEH 2012). Some are restricted to small, scattered refugia that have escaped grazing, ploughing and the application of fertilisers, including road margins, railway easements and cemeteries (Young 1997). Larger populations occur in grasslands and woodlands on partially modified and lightly grazed land, including a travelling stock reserve and sites on Department of Defence land.

In the ACT region, *R. leptorrhynchoides* occurs at 11 sites in the suburbs just south of Lake Burley Griffin (Barton, Kingston, Yarralumla, Red Hill), the Majura Valley, the Jerrabomberra Valley (ACT and NSW) and at Crace Nature Reserve in Belconnen. The largest populations are in woodland at Stirling Park, Barton (about 49,000 plants) and in grassland at the Defence-owned Majura Training Area (about 27,000 plants) (NSW OEH 2012). The ACT Jerrabomberra/Fyshwick sites are small and fragmented, but are adjacent to larger NSW populations at Queanbeyan Nature Reserve and nearby 'The Poplars' (rural property).

While there are large populations in Red Hill Nature Reserve (>3000 plants) and Crace Grassland Reserve (about 5000 plants), the other ACT sites contain 80 to 2000 plants. The species appears to have been lost from two small sites in recent years.

The most up-to-date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

In the ACT, *R. leptorrhynchoides* occurs on the margins of stands of Yellow Box/Red Gum Grassy Woodland with a ground layer of various native grasses and other forbs, in secondary grasslands derived from that community, and in Natural Temperate Grassland. Soils are usually shallow stony red-brown clay loams.

Apple Box (*Eucalyptus bridgesiana*) is also occasionally present at sites. *Rutidosis leptorrhynchoides* prefers an open habitat and is a poor competitor amongst tall, dense, sward-forming grasses. It is found where the soil is too shallow to support the growth of plants that may rapidly overtop it and on deeper soils where the vegetation is kept short by regular disturbance (Scarlett and Parsons 1990). It may also be adapted to the sparser growth of *Themeda* grass found under trees in woodlands (Morgan 1995a).

In Victoria, intermittent burning is prescribed to maintain floristic diversity and habitat structure at some *R. leptorrhynchoides* sites (DSE 2003). In NSW and the ACT maintenance of habitat structure appears to be less dependent on burning, possibly because poorer soils and/or competition from trees restrict groundcover density and maintain inter-tussock spaces (Morgan 1997, NSW OEH 2012).

Rutidosis leptorrhynchoides flowers between December and April in the ACT. The florets are insect-pollinated, and most of the wind-dispersed seed falls within one metre of the parent plant (Morgan 1995a, 1995b; Wells and Young 2002). The scales at the top of the fruit could facilitate wider dispersal by vertebrates (Scarlett and Parsons 1990). The seeds are short-lived in the soil, only remaining viable for up to 18 months, so recruitment depends on seeds from the previous year and therefore on the survival and reproductive success of the standing population (Morgan, 1995a, 1995b).

Seeds germinate after autumn rains, and seedling mortality is usually high. In Victoria, recruitment may be limited by high summer mortality of seedlings in open microsites and by deep shading in dense, unburnt grasslands

(Morgan 1995b, 1997). Studies of germination under field conditions showed that emergence was greatest in larger inter-tussock gaps (30–100 cm), and seedling survival was greatest in the largest gaps. *Rutidosis leptorrhynchoides* grows slowly and few or no seedlings flower in their first year (Morgan 1995b, 1997). Time from recruitment to first flowering is usually two or three years (ACT Government 1998; Young *et al.* 2000b). Established plants are believed to live longer than 10 years under field conditions (Scarlett and Parsons 1990).

There are two main chromosomal races of *R. leptorrhynchoides*, diploid and tetraploid. All populations in the ACT and NSW that have been tested are diploid, though both diploid and tetraploid populations occur in Victoria (Murray and Young 2001, NSW OEH 2012). The species has a sporophytic self-incompatibility mechanism that prevents self-pollination or crosses between related plants that share self-incompatibility alleles. Self-crosses of *R. leptorrhynchoides* generally result in no fruit, and crosses between unrelated plants produce up to twice as many fruits as those between plants which share one parent (Young *et al.* 2000a). Self-incompatibility systems function to prevent inbreeding and are an advantage in large, genetically diverse populations, but decreasing population size can reduce the number of self-incompatibility alleles leading to a reduction in mate availability and reduced fertilisation success. This has been demonstrated in laboratory and field studies of plants from *R. leptorrhynchoides* populations of varying sizes (Pickup and Young 2008, Young and Pickup 2010).

Seed set appears to be influenced by population density, with sparsely distributed plants producing less seed than plants in denser groups in both natural and planted populations of various sizes (Morgan 1995a, Morgan and Scacco 2006). This may reflect the presence of fewer pollinators or less pollen being picked up and transferred among sparsely distributed plants. Other research has shown reduced seed set in small populations (<200 plants) compared to large populations (>1000 plants), despite the maintenance of pollinator service as measured by the number of pollen grains deposited on open-pollinated stigmas (Young and Pickup 2010).

Research into the genetics and demographics of *R. leptorrhynchoides* has led to the development of a computer model that can be used to predict population trends and the effects of changes in demographic parameters. The model shows a clear relationship between the amount of genetic diversity in a population and how quickly it is likely to go extinct. The model suggests that diploid populations with fewer than 50 mature individuals will become extinct faster than those with more than 200 plants, and that long-term viability requires more than 400 reproductive plants with at least 20 self-incompatibility alleles (Young *et al.* 2000b; Young, unpublished data, in NSW OEH 2012).

PREVIOUS AND CURRENT MANAGEMENT

EX-SITU CONSERVATION AND TRANSLOCATION

Since the 1980s there have been several attempts to establish new populations of *R. leptorrhynchoides* at a number of Victorian sites, by planting of tubestock and direct seeding into areas where the topsoil had been removed. A number of such populations died out without producing a second generation of plants, despite testing of seed from five re-established populations showing no reduction in reproductive fitness (Morgan 2000). Gibson-Roy (2011) reported 90% survival at 12 months for tubestock planted into newly constructed grasslands in Victoria, with widespread and consistent emergence from direct seeding.

There have been several attempts to establish new populations of *R. leptorrhynchoides* in the ACT. An early translocation of plants onto a site near Stirling Park appears to have failed. This may have involved replanting of mature plants removed from the site of the new Parliament House in the 1980s (NCA, unpublished data in Rowell 2007a). Three groups of plants were translocated into a fenced woodland block in Yarralumla, but the site became densely covered in woody weeds and eucalypt regeneration. Six plants from one group were located in 1995, but after weed control in 2007 only one plant remained. In 2011 this plant was seen again, but no seedlings have been recorded on the block (Rowell 2007a, Rowell unpublished data 2011). Between 1994 and 1998, 1705 seedlings were planted at three locations on Red Hill. By 2007 only 14 plants remained, and no recruitment was recorded from the plantings (M Mulvaney, pers. comm. in NSW OEH 2012).

Recent research has shown that to maximise progeny fitness, seed for *R. leptorrhynchoides* restoration projects should be sourced from large genetically diverse populations (Pickup *et al.* 2013). Because most *R. leptorrhynchoides* seed is deposited close to the parent plant, seed should be collected from multiple non-adjacent plants to maximise diversity (especially of self-incompatibility alleles).

To maximise pollen transfer and therefore seed production in new populations, plants should be placed in groups. Because mixing of ploidy levels may result in the production of infertile offspring, diploid races should not be mixed with tetraploid races. As a precaution, ACT restoration projects should use seed sourced from ACT populations for which the chromosome number is known. In the ACT, chromosome number has not been confirmed for populations at Woods Lane, Tennant Street, Baptist Church, Campbell Park, Crace Nature Reserve and HMAS Harman (NSW OEH 2012).

The ACT Parks and Conservation Service (PCS) began a translocation trial in a fenced (kangaroo) exclosure at Jerrabomberra East Nature Reserve in 2010. Seed was collected from four populations of *R. leptorrhynchoides* in the ACT, with some seed used to grow tubestock (by Greening Australia) and some seed retained for direct seeding at the site. In autumn 2010 planting of tubestock and direct seeding took place in six plots that had been prepared by weeding and grass reduction, with further plantings around the same plots in 2011. Monitoring in 2012 showed survival of 33% and 45% of tubestock planted in 2010 and 2011, but very few plants were produced from direct seeding. Almost all (93%) of plants from tubestock were flowering in 2012, while few of the plants derived from direct seeding were flowering and fewer flowers were produced by these plants. There was no evidence of recruitment from either treatment at this early stage of the trial.

The interim conclusion is that planting of tubestock is the preferred method of re-establishing populations in the ACT, due to the rapid result and the reduced impact of seed collection on ex-situ populations (Conservation Planning and Research, unpublished data 2012). The density of the vegetation surrounding the trial site may need to be reduced regularly to enhance *R. leptorrhynchoides* survival, germination and recruitment, due to its location in an (ungrazed) kangaroo exclusion area.

CONTROLLED AND EXPERIMENTAL BURNING

In some Victorian populations burning at a frequency of 2–5 years is used to control grass biomass. Adult plants are reported to be rarely killed by fire (NSW OEH 2012). In the ACT, an experimental spring burn before a dry summer in 2000 killed 40–50% of adult plants, while many fewer died on unburnt control plots (pers. comm. S Sharp and G Baines in NSW OEH 2012). In 1995 an autumn burn of a small site containing a group of seven *R. leptorrhynchoides* plants resulted in all the plants surviving the burn and most flowering in the next summer; however, the population died out because no seedlings were produced, despite some seed collected from the site being re-introduced after the fire (Rowell 1996a, 2007b).

A fuel reduction burn was carried out at the St Marks site in Barton in 2009, with no reported ill effects on *R. leptorrhynchoides* plants (Conservation Planning and Research unpublished data 2011), though it is not certain the plants were in the area burnt.

The National Capital Authority's fire hazard management plan for Stirling Park requires occasional prescribed burns in some areas for fuel reduction. Past mapping of *R. leptorrhynchoides* at Stirling Park has shown changes in the density of trees, eucalypt regeneration and woody weeds, and suggested that increased shading has had a deleterious effect on *R. leptorrhynchoides* (Wittmark *et al.* 1984, Rowell 1996b, Muyt and Watson 2006). In 2011 a study was undertaken of the effects of a controlled autumn burn at Stirling Park. Measurements were taken before and after the burn of *R. leptorrhynchoides*, weeds, grasses, bare ground, litter and shade in burnt and unburnt plots (Ross 2011, Ross and Macris 2012), with further monitoring of the same plots in spring 2012 (C Ross, unpublished data) and spring 2014 (Matthews 2014). The immediate post-burn data showed no evidence of *R. leptorrhynchoides* mortality as a result of the fire, and there was an increase in bare ground and a decrease in native grass and weed cover, changes which could favour establishment of *R. leptorrhynchoides* seedlings.

Monitoring in spring 2011 recorded more seedlings in burnt plots, but results were patchy. By spring 2012 the number of *R. leptorrhynchoides* had declined, but by the same amount on burnt and control plots. Monitoring in spring 2014 recorded a large number of seedlings on some plots, and few or none at others, though this did not appear to be related to the fire treatment (Matthews 2014). In 2014, numbers of established (non-seedling) plants had declined across all treatments, with the decline being greatest on heavily burnt plots and least on unburnt plots.

However, the 2014 results did not meet criteria for meaningful statistical analysis, so further research is required on the effect of fire on *R. leptorrhynchoides* populations in the ACT. Fuel reduction burning at Stirling Park will provide further opportunities for monitoring.

Population modelling for *R. leptorrhynchoides* has shown that a 20–30 fold increase in seedling recruitment would be required to offset a 3–5% loss of reproductive plants, such as may occur following fire (Young, unpublished data in NSW OEH 2012). Where fire is used to reduce biomass in ACT populations, a precautionary approach of burning no more than once every five years has therefore been recommended until further research determines whether fire is beneficial at some sites, and the preferred season and frequency of burning (NSW OEH 2012).

OTHER SITE-SPECIFIC MANAGEMENT ACTIONS

Sites on Territory Land:

- Conservation Research (ACT Government) inspects most sites on Territory land every 2–3 years. Reports are prepared on plant numbers and condition, area of occupancy, site condition, threats and suggested management actions.
- Conservation Research communicates with site owners/managers regarding issues identified during monitoring.

Sites on National Capital Authority Land:

- A management plan has been prepared and implemented for Stirling Park and associated woodlands (Sharp 2009). Major work has included removal of planted eucalypts, controlled burns and weed control.
- Friends of Grasslands and other volunteers have assisted NCA at Stirling Park with woody weed removal, spraying of herbaceous weeds and monitoring of the effects of controlled burning.

Sites on Defence Land:

- Annual weed control is undertaken following strict environmental prescriptions.
- *Rutidosis leptorrhynchoides* populations at Majura Training Area, Campbell Park and Harman are monitored and mapped every two years on average. Monitoring includes counting or sub-sampling populations, measuring area of occupancy, plant size, reproductive status and size/age structure of subpopulations.
- Grass biomass in some subpopulations is managed by occasional high slashing if recommended by consultants monitoring the populations.

The size structure of the subpopulations on Defence sites is measured by recording the number of plants with stem numbers in the following classes: single stem, 2–5, 6–20, >20. Research on *R. leptorrhynchoides* has shown there is a significant relationship between the number of stems and biomass (M. Pickup pers. comm. 2014), and that plant size is associated with survival in natural populations (A. G. Young unpublished data in Pickup *et al*. 2012). New germinants are also counted, being single-stemmed vegetative plants less than 5 cm in height. This monitoring has shown significant differences between sub-populations separated by only 50 to 200 metres (Harman, four sub-populations; Campbell Park, two sub-populations). At Campbell Park no new germinants were found in the eastern sub-population in 2010 and 2013, while the western population had large numbers of single-stemmed plants in 2013. This difference may have been associated with increased biomass and weed cover in the eastern population between monitoring events. At Harman a reduction of plants in the lower stem classes was noted in two sub-populations where grass or woody weed cover had increased between monitoring events, while subpopulations that had been slashed and had woody weeds removed showed an increase in numbers of small plants over the same period (AECOM 2014).

THREATS

Rutidosis leptorrhynchoides is at risk from habitat loss throughout its range due to agricultural and urban development. Stirling Park is a possible future site for a new Prime Minister's residence and Tennant Street Fyshwick could be affected by future expansion of the industrial area. Small sites are more vulnerable to incidental damage associated with human activity, such as roadside maintenance, dumping of waste, inappropriate mowing and parking of vehicles.

Weed invasion poses a risk at many sites. On formerly grazed sites, agricultural weeds are of most concern, and small sites can be invaded by weeds that thrive in disturbed areas. Woodland sites are also vulnerable to invasion by woody weeds.

Competition with other understorey vegetation presents a disadvantage to the species at some sites. In Victoria, 'intermittent' burning of some grassland communities is recommended to maintain floristic diversity (McDougall 1987, Lunt 1990), but whether burning is advantageous to ACT populations of the species is inconclusive at this stage.

Shading and competition from eucalypt and shrub regeneration is a threat at woodland sites such as Stirling Park and Red Hill.

The species disappears under heavy grazing because it is palatable to stock, though there is some evidence to suggest that intermittent grazing in late summer may not be detrimental. Some of the larger surviving national populations had a prior history of sheep rather than cattle grazing, suggesting that light to moderate sheep grazing may not be detrimental whereas cattle grazing may be (NSW OEH 2012).

Erosion of genetic diversity and increased inbreeding may compromise both short and long-term population viability by reducing individual fitness and limiting the gene pool on which selection can act in the future. This applies to populations of fewer than 200 plants.

More frequent drought in south-eastern Australia is one of the predicted effects of climate change. This may adversely affect some *R. leptorrhynchoides* populations, particularly through reduced germinant survival due to dry conditions and/or increasing intervals between rain events.

MAJOR CONSERVATION OBJECTIVES

The overall objective of this plan is to preserve *R. leptorrhynchoides* in perpetuity in the wild across its natural geographic range in the ACT. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan:

- Conserve all large and medium size populations in the ACT. Protect small populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area, and by establishing new populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The long term conservation of *R. leptorrhynchoides* depends on the retention of its native grassy habitat, which in the ACT region is Natural Temperate Grassland and Yellow Box/Red Gum Grassy Woodland. Both of these ecological communities have been declared endangered in the ACT and management principles for each are set out in the respective action plans and strategies. In the ACT the species occurs on a range of land tenures; Territory land (land owned and managed by the ACT Government and leasehold rural land), National Capital Authority land (Commonwealth land controlled and managed by the National Capital Authority) and Defence land (Commonwealth land controlled and managed by the Department of Defence). The ACT Government will liaise with the National Capital

Authority and the Department of Defence to encourage continued protection and management of populations of *R. leptorrhynchoides* on their land, in particular, Stirling Ridge and the Majura Field Firing Range.

Demographic modelling suggests that populations of *R. leptorrhynchoides* need to have at least 200 plants to avoid the deleterious consequences of incompatible genes that result in low reproductive (seed) viability.

Populations of 200 or more plants are likely to be viable in the longer-term and sites where they occur should be protected by formal legal measures. The National Recovery Plan for *R. leptorrhynchoides* (NSW OEH 2012) states that all populations of ten or more plants are important for the survival of the species and to maintain genetic diversity. Consistent with the National Recovery Plan (NSW OEH 2012), any loss of plants from populations of ten or more individuals should be offset by achieving improved long-term protection and management of a suitable currently unreserved population or other compensatory arrangements.

The ACT contains some of the largest and most viable (in the long term) remaining populations of *R. leptorrhynchoides* and their conservation is likely to be critical to the survival of the species; only a small number of viable populations remain in NSW and Victoria. Each site contributes to the overall genetic diversity of the species, because *R. leptorrhynchoides* plants are likely to be genetically distinct between sites.

Conservation effort should focus on protecting populations that are large (> 1000 plants) and medium-sized (200–1000 plants) as a cluster of sites. Small populations (< 200 plants) should be protected from unintended impacts and efforts directed to increasing their size (and hence viability) to 200 or more plants.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. The Button Wrinklewort does not have any special offset requirements.

An environmental offsets assessment may result in a development being ‘flagged’.

A flag identifies an area of land with significant protected matter values. If a proposed impact is flagged, it will require additional consideration by the Conservator of Flora and Fauna as to whether offsets are appropriate in the particular instance. The Button Wrinklewort has been determined as able to withstand further loss in the ACT so offsets are appropriate. A development proposal is not flagged where the loss of ten individuals or less is involved.

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

While it is possible some small populations of *R. leptorrhynchoides* remain undetected in the ACT, it is likely that all medium and large populations have been discovered. Knowledge of the distribution and abundance of the species in the ACT will be refined from data collected during surveys for other plant species or from opportunistic observations from naturalists and other interested persons.

Populations of *R. leptorrhynchoides* will need to be monitored to determine overall abundance trends. A representative set of sites should be monitored to evaluate the effects of management. Intermittent and ad hoc monitoring has shown a decline in a few populations and increases in others.

A protocol for two-yearly monitoring would involve measuring all plants for smaller populations and an appropriate sampling method for large and medium-sized populations, recording:

- Number of plants (total or samples)
- Area occupied
- Reproductive status (vegetative or flowering, number of flowers)

- Population size structure e.g. height, stems/plant (1, 2–5, 6–10, 11–20, >20 etc.)
- Number of new germinants (<5cm, single stem, vegetative). Recording new germinants separately from established plants is desirable to monitor germination and recruitment, and to explain large variations in population numbers that may be caused by flushes of germination followed by mortality of seedlings
- Surrounding herbage mass
- Weed cover
- Management history

Seedling establishment: Monitoring is required to show whether the relative paucity of seedlings in areas of denser vegetation leads to a long-term decline in the number of adult plants present. This should be undertaken in conjunction with monitoring of small experimental burning/slashing plots in some of the larger populations. The results of any accidental burning should also be monitored.

Site inspection for damage: Sites with medium or large populations should be inspected quarterly, or as appropriate, for deliberate or accidental damage. This includes unauthorised grazing, mowing, burning or planting; access by cars, trail bikes or other motor vehicles; trampling; rock, soil, wood or plant removal; and dumping of rubbish. Fences/barriers and signs should be installed or upgraded where necessary.

A priority for research is the identification of appropriate management actions to conserve existing populations, ensuring they remain viable over the long term, and developing techniques to increase the size of small populations so they contain at least 200 plants.

In particular, research is required to identify appropriate grazing, slashing and fire regimes (including intensity, frequency and season). In addition to providing the basis for a slashing, grazing or fire management regime, this information is relevant to the management of other native grassland and woodland communities.

Ongoing fuel reduction burning at Stirling Park provides a starting point for fire regime research, and any results from experimental burning or fuel reduction burning in adjacent NSW populations could also provide relevant data. A secondary priority for research is the development of techniques to establish new populations that have at least 200 plants.

Button Wrinklewort

The Centre for Plant Biodiversity Research (CSIRO Division of Plant Industry) is conducting ongoing research into aspects of the population biology of *R. leptorrhynchoides*, including the effects of inbreeding and outbreeding depression, hybridisation, loss of self-incompatibility alleles, local adaptation, pollinator limitation, and reproductive success and mortality in small and large populations. The results of the research are being used to develop models to predict the outcome for populations of various sizes under a range of management conditions. This information is relevant to the maintenance of existing populations and to the establishment of new populations.

MANAGEMENT

Management actions for *R. leptorrhynchoides* should focus on conserving it as a component of the grassland or woodland ecological community. Management actions need to take into account the need to maintain species diversity in the community, including the requirements of other sensitive species present. A key management aim should be to increase the number of plants in small (< 200 plants) populations to improve long-term population viability.

Specific management issues relating to conservation of the species:

Woody weed control: This is most important on the woodland sites; older woody weeds should be cut and removed, and the stumps dabbed with herbicide. Seedlings and suckers should be controlled annually by hand-pulling and spot-spraying with herbicide (spot spraying of herbicide should not be conducted within 2 metres of any *R. leptorrhynchoides* plant).

Regeneration of native trees and shrubs: Non-indigenous native trees (e.g. *Acacia baileyana*, *A. cultriformis*) and shrubs should be treated as woody weeds. In the absence of fire, slashing or grazing, regeneration of eucalypts and some native shrubs such as *Cassinia quinquefaria*, Bitter Pea (*Daviesia mimosoides*), Silver Wattle (*Acacia dealbata*) and Green Wattle (*A. mearnsii*) may shade out *R. leptorrhynchoides*. Where necessary, a selection of these should be removed (cut and dabbed) annually to maintain an open mixed-age/species woodland.

Herbaceous weed control: Priority should be given to weeds that can be invasive in native grassland/woodland, such as St John's Wort (*Hypericum perforatum*), African Lovegrass (*Eragrostis curvula*), Serrated Tussock (*Nassella trichotoma*) and Chilean Needle Grass (*Nassella neesiana*). Control methods should take account of the characteristics of each site, and proximity to *R. leptorrhynchoides* plants.

Understorey competition: Intervention may be necessary where monitoring shows a continuing lack of seedling establishment around adult plants in dense understorey vegetation, and/or deterioration in the quality of the community. In some local populations (Campbell Park, Crace Nature Reserve, Red Hill Nature Reserve, Majura Training Area and Jerrabomberra East translocation site) kangaroo grazing will affect grass biomass as kangaroos eat grasses in preference to forbs. Recruitment of *R. leptorrhynchoides* should be taken into account when determining the desirable level of kangaroo grazing at a site. Grazing by cattle is not recommended as a management tool as this can have an adverse effect on *R. leptorrhynchoides* and its habitat, though light grazing by sheep might not be detrimental. Occasional careful slashing in late summer may be used on sites where other factors (e.g. fire risk to property) make burning undesirable. Patch burning may be appropriate on other sites but its effects should be monitored. Burning should not be used as a broad-scale management tool on *R. leptorrhynchoides* sites 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). Population modelling and analysis of data from monitoring of populations in the ACT region indicates that the maintenance of reproductive plants should be given priority over intervention aimed at increasing germination and seedling establishment, as a large increase in germination would be required to offset the small increase in the mortality of adult plants which might follow treatments such as autumn burning (A. Young pers. comm.).

Management prescriptions also need to address a general concern about the survival of small remnant populations, namely the increased random fluctuations in demographic parameters such as seedling mortality, genetic erosion owing to genetic drift and inbreeding depression (Young 1997). Demographic and genetic simulation modelling shows that diploid populations with fewer than 50 mature individuals will become extinct significantly faster than those with more than 200 plants (Young *et al.* 2000b). A potential recovery action for small populations with reduced fertilisation success due to mate limitation is to increase genetic diversity by introducing seed, pollen or nursery-grown plants from larger, more genetically diverse populations. Research has shown that fertilisation success increases in crosses between populations, and that small populations would gain the greatest benefit from this 'genetic rescue' (Pickup and Young 2008, Pickup *et al*. 2013). Small re-established populations appear to suffer the same constraints as small remnant populations, so management should aim to maintain population size above 200 plants to avoid the effects of loss of self-incompatibility alleles, and re-establishment projects should source seed broadly for the same reasons (Young *et al.* 2000b).

A study of local adaptation in relation to population characteristics in *R. leptorrhynchoides* also suggested that selecting seed from large, genetically diverse populations from environments similar to candidate sites is likely to provide the most appropriate seed sources for restoration (Pickup *et al*. 2012). Suitable candidate populations for this type of genetic enhancement would be small to medium sized populations (<1000 plants) showing poor seed set and seedling establishment below replacement rate on sites containing habitat suitable for expansion of the population. The National Recovery Plan nominates St Marks and Capital Hill as suitable recipient populations in the ACT (NSW OEH 2012).

Given the significant problems faced by populations with less than about 200 plants, the priority for management and research should be to increase the size of extant small (< 200 plants) populations.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1. Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve all large and medium size populations in the ACT. Protect small ACT populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).	Apply formal measures to protect all large and medium size populations on Territory-owned land. Encourage formal protection of all large and medium size populations on land owned by other jurisdictions.	All large and medium size populations are protected by appropriate formal measures.
	Protect all small populations on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect all small populations from unintended impacts.	All sites with small populations are protected by appropriate measures from unintended impacts.
	Ensure protection measures require site management to conserve the species on Territory-owned land. Encourage other jurisdictions to require site management to conserve the species on thier land.	Protection measures include requirement for conservation management.
	Identify other extant populations by maintaining alertness to the possible presence of the species while conducting vegetation surveys in suitable habitat.	Vegetation surveys in suitable habitat also aim to detect the species.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor populations and the effects of management actions.	Trends in abundance are known. Management actions are recorded.
	Manage habitat to maintain its suitablilty for the species.	Suitable habitat conditions are maintained by site management. Potential threats (e.g. weeds) are avoided or managed. Populations are stable or increasing.
3. Enhance the long-term viability of populations through management of adjacent grassland to facilitate expansion	Undertake or facilitate research and trials into techniques for increasing the size of small (<200 plants) populations.	Research and trials have been undertaken to increase the size of small populations. Small population(s) have increased in size.

Objective	Action	Indicator
of populations into suitable habitat. Establish new populations.	Undertake or facilitate research and trials into establishing new populations.	Research and trials have been undertaken to establish new populations. New population(s) established.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on appropriate methods for managing the species and its habitat (slashing/grazing/ burning etc.), lifecycle, germination, recruitment and genetics.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities and promotions.	Engagement and awareness activities and promotion undertaken and reported.

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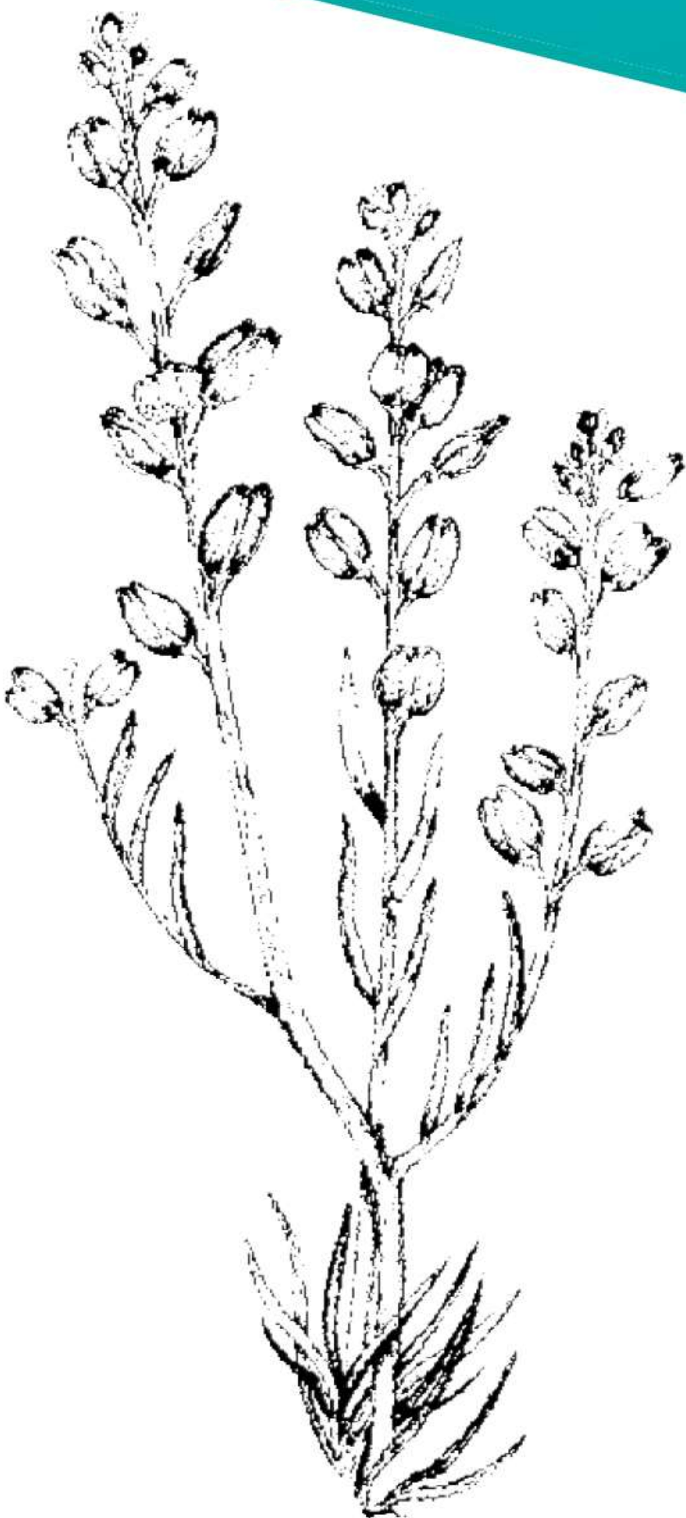
GINNINDERRA PEPPERCRESS

LEPIDIUM GINNINDERRENSE

DRAFT ACTION PLAN



PREAMBLE

The Ginninderra Peppercress (*Lepidium ginninderrense* N.H.Scarlett) was declared an endangered species on 4 September 2001 (Instrument No. DI2001-299 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 2003 (ACT Government 2003). This revised edition supersedes the earlier edition.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*), Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Golden Sun Moth (*Synemon plana*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Lepidium ginninderrense is recognised as a threatened species in the following sources:

National

Vulnerable species – *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) according to the following criteria: low population size, restricted area of occupancy, and no evidence of continuing decline (Department of Environment and Heritage 2016). A National Recovery Plan has been prepared (Environment ACT 2005), and about 20 hectares of the Lawson suburb has been added to the Register of Critical Habitat (Department of the Environment and Heritage 2005).

Listed Critical Habitat: Northwest corner Belconnen Naval Transmission Station, ACT - *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) according to the following criteria: Ginninderra Peppercress has a very restricted distribution and occurs at only one location. Therefore, the habitat is used to meet all essential life cycle requirements including seed dispersal processes, recruitment, etc. The only known population of *Lepidium ginninderrense* occurs in the habitat in the corner of Belconnen Naval Transmission Station in the suburb of Lawson in the Australian Capital Territory. Therefore, it is a key habitat for breeding, dispersal and the ongoing survival of Ginninderra Peppercress; and as 100% of the plants occur on this site, the habitat is critical to maintain genetic stock and potential long-term evolutionary development Criterion (e).

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*. Special Protection Status Species – *Nature Conservation Act 2014*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Ginninderra Peppercress (*Lepidium ginninderrense* N.H.Scarlett) is a perennial herb to a maximum height of about 20 cm, with one to six branched stems arising from a rootstock. Stems are striate and moderately papillose. Leaves are thick and fleshy, glabrous and shiny on the upper surface. Rosette leaves are widely spaced and very narrow (1.5–2.0 mm wide) and 15–55 mm long. Lower stem leaves are up to 35 mm long, broad lanceolate in outline and pinnatifid with 1–3 pairs of linear pinnae. Upper stem leaves are narrow and mostly unlobed. The inflorescence is an elongating raceme with a maximum length of 15 cm. Flowers are small, with four stamens, no petals and six nectaries. The four sepals are less than 1 mm long and about 0.5 mm wide, green and with scarious margins. Fruits are flat, bilocular, 2-seeded and bluntly obovate, 4–5 mm long and 3–3.5 mm broad and notched at the apex. Seeds are orange, obovoid and about 1.5 mm long (Scarlett 2001). *Lepidium ginninderrense* flowers in late spring. It sets seed mainly in December and the majority of seed is dispersed before August (Avis 2000).

DISTRIBUTION

There are two known extant populations of *L. ginninderrense*, both in the ACT. The larger population occurs in grassland in the north-west corner of the Belconnen Naval Transmission Station in the suburb of Lawson (the type locality).

This population is on flat ground near Ginninderra Creek at an altitude of 590 metres, near the estimated original boundary between Natural Temperate Grassland and Box–Gum Woodland (ACT Government 2005). The Lawson site includes over 100 hectares of Natural Temperate Grassland, most of which is surrounded by a security fence. The average number of plants recorded in six counts between 2000 and 2009 was 1715, with numbers varying considerably from year to year without obvious trends. The estimated area occupied over this period increased from 90 x 30 metres to about 200 x 100 metres (Avis 2000, ENSR 2008, AECOM 2009).

A second population was discovered in 2012 about 6 km north-north-east of Lawson in the Gungahlin suburb of Franklin (altitude 610 metres) in an 18 hectare paddock containing disturbed grassland and remnant Box-Gum Woodland (Taws 2013, Taylor *et al.* 2014). In spring 2012 this population occupied an area of about 9 x 4 metres and contained 50 plants (ACT Government, unpublished data). Three additional sub-populations were found at the Franklin site by environmental contractors in 2014. Staff from Conservation Research (ACT Government) surveyed the site in February 2015 and recorded 377 plants across 12 sub-populations.

There is an historical record from the suburb of Reid in 1952, between the Canberra Institute of Technology and St Johns Church. A subsequent search failed to relocate this population (M. Gray pers. comm. in Scarlett 2001) and it is likely that the site has since been developed.

Lepidium ginninderrense has only been recorded from these three sites in the ACT and is not known from outside the ACT. The species is spatially disjunct from the other four members of the allied section *Papillosa* in *Lepidium* that occur in south-eastern Australia, which are mainly ephemeral or annual herbs confined to the inland plains west and north of the Eastern Highlands (Hewson 1981, Scarlett 2001).

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

At Lawson, *L. ginninderrense* grows on the floodplain of the Ginninderra Creek, in and around slight depressions which are subject to winter inundation (Avis 2000, Scarlett 2001, AECOM 2009). The depressions may be natural or some may be former vehicle tracks (HLA 2006). Soil testing close to *L. ginninderrense* plants recorded a pale yellow brown silty clay loam layer to at least 300 mm deep, with the texture suggesting alluvium originating from Ginninderra Creek and the colour suggesting periodic inundation (AECOM 2009). The depressions carry little vegetation cover and the surface (with a dark microbiotic crust) cracks on drying (Rowell, pers. obs. 2009). The habitat has similarities with that of the endangered Winged Peppercress (*L. monoplocoides*), which occurs in inland NSW and Victoria (Mavromihalis 2010).

Native grassland species associated with *L. ginninderrense* at Lawson include Wallaby Grasses (*Rytidosperma* spp), Windmill Grass (*Chloris truncata*), Lemon Beauty-heads (*Calocephalus citreus*) and Fuzzweed (*Vittadinia muelleri)*. *Lepidium ginninderrense* is also often associated with low-growing annual exotic forbs and grasses which colonise the same habitat. It is generally not found among taller native and exotic grasses in the same area, which may out-compete *L. ginninderrense* for light and other resources (Avis 2000, HLA 2006, AECOM 2009).

The former Reid site was a flat area of grassland less than one kilometre from the Molonglo River, and the habitat description is similar: 'locally rather common, in depressions with little vegetation in grassland' (Scarlett 2001).

At the Franklin site the *L. ginninderrense* plants occur with other native grassland species in a number of small patches scattered across an otherwise weedy paddock. The plants are concentrated in and around bare areas that typically have a dark microbiotic crust. These bare areas are probably perched clay-lined depressions over rock or impervious subsoil.

The vegetation surrounding the *L. ginninderrense* patches is dominated by dense Phalaris (*Phalaris aquatica*) and Tall Speargrass (*Austrostipa bigeniculata*), but the species composition within patches themselves resembles that of Lawson; shorter Wallaby Grasses, Windmill Grass, Fuzzweed, Scrambled Eggs (*Goodenia pinnatifida*) and Lemon Beauty-head, the latter being a species typical of occasionally inundated grassland ('Ephemeral Drainage-line Grassy Wetland', DSE 2009) which is present at both sites.

Observation of changes in the density and distribution of the Lawson population suggest that *L. ginninderrense* is not an annual, which is supported by nursery experience where plants often survive more than a year (Taylor pers. comm. 2015).The species could be classified as either a biennial or (possibly short-lived) perennial or ephemeral (Avis 2000, ENSR 2008, ENSR-AECOM 2009, Taylor pers. comm. 2015). Recruitment often occurs in bare patches or where spring annuals have died down in summer (Avis 2000, HLA 2006).

Recent recruits (single-stemmed, not flowering, approximately 3 cm tall), new stems sprouting from the base of older plants and plants bearing flowers and fruits, have been observed in autumn surveys, and seed appears to be shed in autumn and winter (Avis 2000, HLA 2006), though viable seed has been collected as early as November (Taylor *et al.* 2014).

Lepidium is a large genus in which polyploidy is common, and material from the *L. ginninderrense* type locality has been determined to be tetradecaploid (14 sets of chromosomes, Dierschke *et al.* 2009). The genus is characterised by an autogamous mating system (plants self-fertilise), but the flowers of *L. ginninderrense* carry six nectaries, suggesting that insect pollination (and potential outcrossing) may also occur.

PREVIOUS AND CURRENT MANAGEMENT

The Lawson site is a former communication facility, currently managed by the Department of Defence (Defence). Defence has managed the site with advice from the ACT Government and specialist consultants, more recently under an environmental management plan (SMEC 2008).

Key components of management have been weed and biomass management and monitoring of kangaroo grazing pressure. In relation to *L. ginninderrense*, the environmental management plan prescribes continued monitoring of the size, distribution and viability of the population, appropriate weed control and management, maintenance of the surrounding grassland structure and diversity to favour *L. ginninderrense*, and management of the resident kangaroo population at a stable level compatible with maintaining the ecological values of the site (SMEC 2008).

The site was resumed from pastoral leases for Defence use in 1939, at which time it had not been ploughed, fertilised or sown with introduced pasture species. Low levels of sheep grazing continued, the site was slashed at least annually to meet Defence operational requirements, and clovers were sown around the base of some transmission masts (Crawford and Rowell 1995). In 1995 a small (10 metre x 10 metre) enclosure was erected around a small group of *L. ginninderrense* plants to protect them from sheep grazing. In 1997 sheep were removed, and the site was mown in accordance with a grassland management plan developed by Defence and the ACT Government (Avis 2000). Phalaris, Ryegrass (*Lolium rigidum*) and Subterranean Clover (*Trifolium subterranean*) are scattered across the Lawson site (AECOM 2009), suggesting some pasture improvement during this period.

Mowing became unnecessary as the kangaroo population enclosed by the security fence increased. By 2006 kangaroo numbers and grazing pressure were high and, in association with ongoing dry conditions, had the potential to damage the endangered Natural Temperate Grassland ecological community and the habitat of several threatened species (Cooper 2009).

Lepidium ginninderrense is not thought to be directly grazed by kangaroos at moderate densities when other feed is available, but in 2007 two exclosures were constructed to protect most of the population from trampling, the effects of overgrazing of the surrounding grasses and any risk of direct grazing (ENSR 2008). After kangaroo numbers were reduced in 2008, research was begun by the ACT Government on fertility control of the kangaroo population with the aim of maintaining their numbers within a range compatible with conservation of grassland values (SMEC 2008, ACT Government 2010). The gates to the exclosures were opened to readmit kangaroos, which then reduced the density of the grasses around the *L. ginninderrense* plants (AECOM 2009).

The Lawson *L. ginninderrense* population was counted nine times between 1997 and 2011, and the survey month and methods have varied (Table 1). The surveys between 2006 and 2009 used similar methods, with plants counted and mapped for each square metre of the known distribution.

These surveys showed considerable variation in plant numbers between years, as well as changes in the distribution of plants. Population estimates for Lawson have ranged from less than 50 plants to more than 3000 plants (Table 1). In some surveys dense clusters of single-stemmed plants were noted, suggesting that recruitment was occurring. These clusters of plants were not always found in subsequent years, indicating some mortality of young plants. The height and density of the vegetation surrounding the *L. ginninderrense* plants has also varied considerably in the last 20 years, in response to drought and years with heavier rainfall, and with variations in the number of kangaroos on the site.

The Franklin site is managed by the ACT Government, which undertakes slashing along tracks and fence lines. The site was previously under a grazing lease and the presence of clovers and Phalaris indicates previous pasture improvement of at least parts of the site. A lack of grazing by stock or kangaroos on this site often results in an accumulation of a large amount of vegetation (grass) biomass, and the ACT Government plans to undertake occasional biomass reduction activities (burning/slashing/grazing) to manage the vegetation biomass at this site.

Table 1. Number of *Lepidium ginninderrense* plants recorded in Lawson surveys, 1997 to 2011.

Date of survey	Number of plants	Reference
1997	<50	Environment ACT in Avis 2000
1999	80	Environment ACT in Avis 2000
April/May 2000	2243	Avis 2000
February 2005	875	HLA
April 2006	3523	HLA
February 2007	1181	HLA
February 2008	1328	ENSR-AECOM
Feb-March 2009	1137	ENSR-AECOM
November 2011	406	Taylor *et al.* 2014

EX-SITU CONSERVATION AND TRANSLOCATION

Existing plants of *L. ginninderrense* from Lawson were found to produce large numbers of viable seed, and the ACT Government has taken advantage of the opportunities this allows for translocation and ex-situ conservation, as recommended by Young (2001). These programs have been conducted according to the principles outlined in the Australian Network for Plant Conservation 'Guidelines for the Translocation of Threatened Plants in Australia' (Vallee *et al.* 2004) and 'Plant Germplasm Conservation in Australia' (Offord and Meagher 2009). The following has been undertaken:

- Australian National Botanic Gardens (ANBG) staff collected seed from most of the available plants at Lawson in 2008 and 2011 to capture the existing genetic diversity. The seed is stored under controlled conditions in the National Seed Bank by maternal line (Guja *et al*. 2013).
- Germination testing after four years of seed storage under controlled conditions resulted in 100% viability and germination (Taylor *et al*. 2014). Seed collection and replacement intervals will be determined by seed longevity. Seed longevity will be determined from germination trials of stored seed.
- In 2012 the ANBG grew 1589 plants from Lawson seed for seed production. The plants were grown on plant benches under shadecloth and good seed set was achieved, apparently without any significant insect activity (J. McAuliffe pers. comm. Sept 2014).
- In September 2013 most of the Lawson seed production plants held at the ANBG were translocated to selected sites at Crace (1093 plants) and Dunlop (487 plants) grassland nature reserves by Greening Australia and the ACT Government. Site preparation included raking away of thatch where necessary. Planting sites were selected for their similarity to the existing *L. ginninderrense* sites, i.e. flat or gently sloping

Ginninderra Peppercress

sites which might accumulate water, with sparse Wallaby/Speargrass grassland and Lemon Beauty-heads as a key indicator species. Significant rain (70 mm) fell in the week of planting, and plants were watered six weeks after planting. Dunlop Reserve was being grazed by sheep so the planting site was protected by temporary fencing that excluded sheep but not kangaroos (Cook 2013, N Taws pers. comm. September 2014). Subsequent searches of these sites in spring 2014 failed to locate any of the translocated plants or any seedlings derived from them (pers. obs. A Rowell, N Taws, J McAuliffe, October 2014). Follow up searches in February 2015 also failed to locate any surviving or germinated plants (pers. obs. E Cook, G Baines February 2015). The reason translocated plants failed to establish is not well understood but is probably related to unseasonably hot and dry conditions following translocation.

- At the time of writing, over 200,000 seeds were held in the National Seed Bank (Taylor *et al*. 2014), including over 500 from the Franklin population (Cook 2013).

THREATS

The main threats to the survival of the two populations (and therefore to the species) are likely to be habitat loss from urban development and habitat degradation from intended or unintended actions associated with land management and/or visitor activities.

The surviving (and one extinct) populations occur/occurred in areas where competing grass tussocks and other plant growth is short and open and, subsequently, there is little competition for space and light (Avis 2000, ENSR-AECOM 2009, HLA 2006, Scarlett 2001). The sites also appear to be occasionally or seasonally wet, either through periodic flooding (Lawson) or where rainfall collects (both sites). This wetting and drying may help maintain the open habitat and facilitate *L. ginninderrense* seed germination. Disturbance of the existing drainage patterns or inappropriate management may lead to changes in this open habitat that are not favourable for *L. ginninderrense* (including high levels of vegetation biomass and weed invasion), and it is important to identify and implement management practices that are conducive to the maintenance of the habitat in the appropriate condition. Individual plants may be quite short-lived, which could make the populations vulnerable to even short-term disturbances.

MAJOR CONSERVATION OBJECTIVES

The overall objective of this plan is to preserve the species in perpetuity in the wild across its natural geographic range in the ACT. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve all ACT populations because the species is not known to occur outside the ACT.
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area, and by establishing new populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The Lawson and Franklin populations require protection as they are the only known populations of the species. The Lawson population of *L. ginninderrense* occurs on land under Commonwealth (Department of Defence) control. The population is currently afforded protection due to the land being surrounded by a man-proof fence and the Department of Defence restricting access to authorised persons. The Franklin population occurs on Territory land that is not formally protected in reserve but is managed by the ACT Government to conserve *L. ginninderrense* and other threatened species. The species is not known to occur outside the ACT and so all populations in the ACT require protection to help ensure the overall conservation objective is achieved.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents including the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. An environmental offsets assessment may result in a development being 'flagged'.

A flag identifies an area of land with significant protected matter values. If a proposed impact is flagged, it will require additional consideration by the Conservator of Flora and Fauna as to whether offsets are appropriate in the particular instance. The Ginninderra Peppercress has been determined as not able to withstand further loss in the ACT so offsets for this species are not appropriate. A development proposal which plans to impact on this species will be flagged for consideration by the Conservator.

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

It is possible that the species exists elsewhere in the ACT given the recent discovery of a second small population at the Franklin site. However, because the species is small and difficult to detect in grassland, surveys aimed solely at finding additional populations are unlikely to be practical. Discovery of new populations is likely to be through surveys for other plant species or from opportunistic observations from naturalists and other interested persons.

All known populations of *L. ginninderrense* will need to be monitored to determine population trends and to evaluate the effects of management.

Recovery of the species will rely largely on expanding the size/area of existing populations and establishing new populations. Research is required to determine optimal habitat conditions for the species (to maintain and expand existing populations) and how to establish new populations.

Priority research areas include:

- Improved knowledge of life history and ecology, such as plant longevity, seed longevity, conditions associated with germination and recruitment and effects of surrounding vegetation biomass.
- Methods for establishing additional populations, such as translocation of plants, in association with the Australian National Botanic Gardens, Greening Australia and other parties.
- Investigations of chemistry, composition and structure of soil at the known sites, to assist with identification of similar sites for establishment of other populations.
- Determination of the chromosome number in the small Franklin population. Due to the high frequency of polyploidy in *Lepidium* (Dierschke *et al.* 2009), this should take place before seed from this population is used in seed orchards with Lawson plants or for translocation.

MANAGEMENT

Due to the small size and fragmented distribution of the populations, management actions will be directed towards maintaining existing conditions and ensuring that activities occurring nearby do not adversely affect the sites. Management actions at the Lawson site need to take into account the presence of Natural Temperate Grassland ecological community (Endangered - *EPBC Act 1999, NC Act 2014*), the Golden Sun Moth (*Synemon plana*: Critically Endangered - *EPBC Act 1999*) and the Perunga Grasshopper (*Perunga ochracea*: vulnerable - *NC Act 2014*).

Priority management actions include:

- Manage vegetation biomass to maintain an open habitat structure.
- Control weeds if they pose a threat to the populations or the site.
- Manage grazing pressure, if it threatens the populations or the site, by reducing the

number of herbivores and/or fencing known *L. ginninderrense* populations.

- Avoid incompatible activities such as development of facilities, recreational use or access tracks in or near the sites, especially where these may alter drainage or introduce weeds.
- Maintain a low profile for the sites where the species is located; the appropriateness of signage and fencing will need careful consideration.
- Incorporate appropriate statements of management actions in relevant plans and strategies.
- Seek expert advice on best practices with regard to management of the species, particularly regarding maintenance of an open habitat and putting in place specific management actions as indicated by monitoring. Biomass management, hydrology and weed control are likely to be key issues for management consideration.
- Continue field collection of seed from the Lawson and Franklin populations for storage in the National Seed Collection, with seed replaced at appropriate intervals determined by seed longevity testing.
- Maintain an ex-situ ‘insurance’ population (plants and/or seed bank) while there is a high risk of extant populations becoming extinct.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 2. Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve all ACT populations because the species is not known to occur outside the ACT.	Apply formal measures to protect all populations.	All populations protected by appropriate formal measures.
	Ensure protection measures include requirement to conserve the species in the long-term.	Protection measures include requirement for conservation management.
	Maintain alertness to the possible presence of the species while conducting vegetation surveys in suitable habitat.	Vegetation surveys in suitable habitat also aim to detect the species.
	Maintain a seed bank as insurance against loss of extant population(s).	Seed bank in the National Seed Collection is maintained and seed collected at regular intervals (determined by seed longevity).
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor populations and effects of management actions.	Trends in abundance are known. Management actions are recorded.
	Manage habitat to maintain its suitablilty for the species.	Suitable habitat conditions are maintained by site management. Potential threats (e.g. weeds) are avoided or managed. At least 80% of plants are in suitable habitat. Extant populations are stable or increasing.
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and by establishing new populations.	Undertake or facilitate research and trials into increasing the size of populations or establishing new populations.	Research and trials have been undertaken to increase the size of populations or to establish new populations. Population size increased or new population(s) established.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on appropriate methods for managing the species and its habitat (slashing/grazing/ burning etc.), vegetation biomass, lifecycle, germination, recruitment and genetics.	Research undertaken and reported and where appropriate applied to the conservation management of the species.

5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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PERSONAL COMMUNICATIONS

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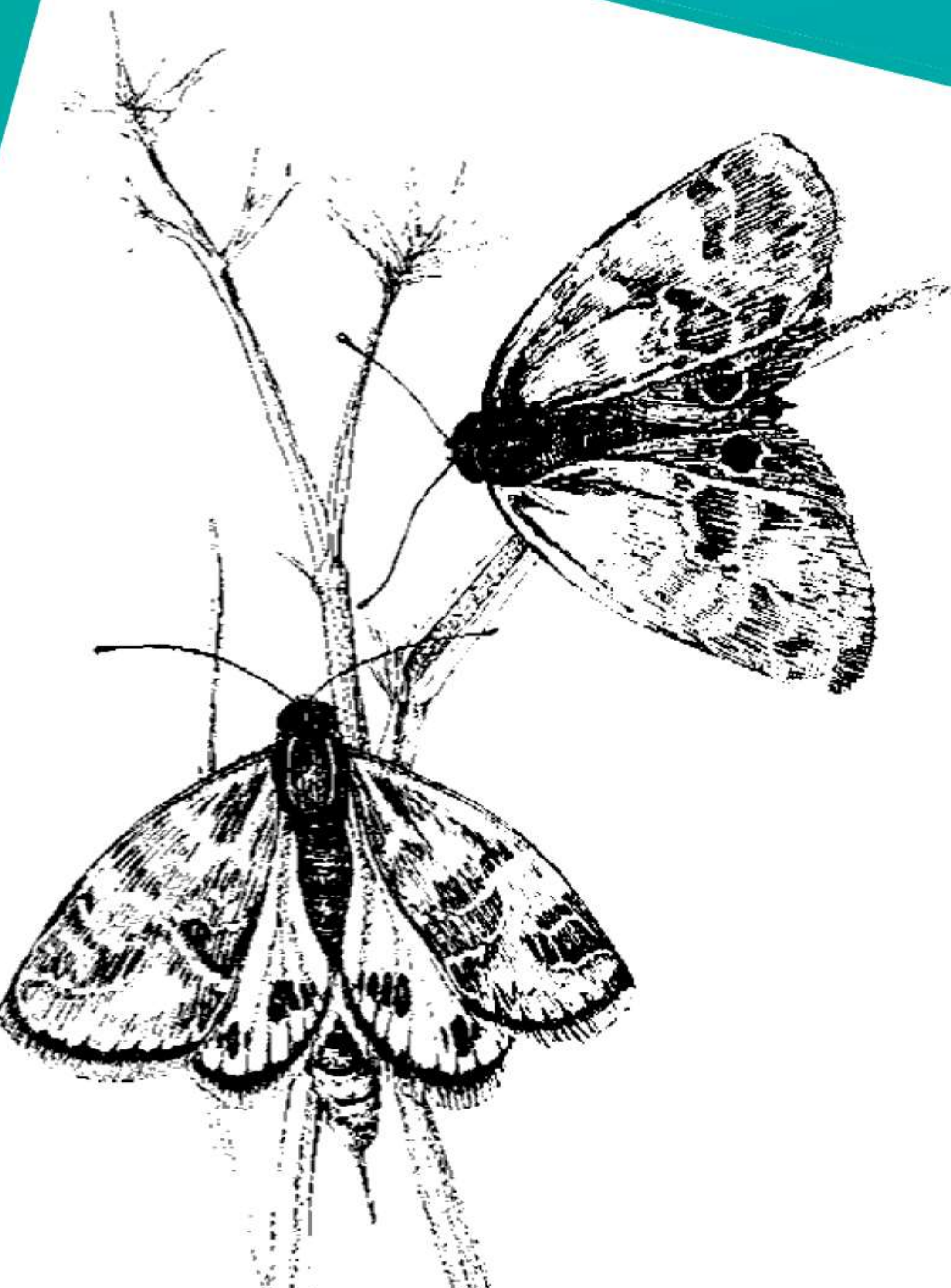
GOLDEN SUN MOTH
SYNEMON PLANA

DRAFT ACTION PLAN



PREAMBLE

The Golden Sun Moth (*Synemon plana* Walker, 1854) was declared an endangered species on 15 April 1996 (Instrument No. DI1996-29 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1998 (ACT Government 1998). This revised edition supersedes the earlier edition.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*) and the Grassland Earless Dragon (*Tympanocryptis pinguicolla*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Synemon plana is recognised as a threatened species in the following sources:

National

Critically Endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*.
Special Protection Status Species - *Nature Conservation Act 2014*.

New South Wales

Endangered – *Threatened Species Conservation Act 1995*.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Golden Sun Moth (*Synemon plana* Walker 1854) is a moth in the family Castniidae. Genera in this family are found in Central and South America and in Australia, suggesting a Gondwanan origin for the family (Edwards 1991). All adult moths in this family are diurnal, and their larvae feed on monocotyledonous plants (Common 1990).

Synemon plana adults are medium-sized, with clubbed antennae and no functional mouth-parts. In males, the upper side of the forewing is dark brown with pale grey patterning, the hind wing is dark bronzy brown with dark brown patches, and the underside of both wings is mostly pale grey with dark brown spots.

In females the upper side of the forewing is dark grey with pale grey patterning, the hind wing is bright orange with black submarginal spots, and the underside of both wings is silky white with small black submarginal spots. The male wingspan is about 34 mm, and the female wingspan is about 31 mm. The male having a larger wingspan than the female is unique in the Australian Castniidae. Females have a long extensible ovipositor.

Synemon plana eggs are just over 2 mm long, and the larvae develop underground where they are found associated with the roots of a few species of grasses or at the upper end of silk-lined tunnels below the tussock base (Richter 2010). Larvae are cream in colour, and late-instars have a red-brown head capsule. The empty red-brown pupal cases protrude from the ground, usually at the base of or close to a grass tussock. The pupal cases of female moths are larger than those of males, reflecting the larger size of the gravid female abdomen (Richter 2010).

DISTRIBUTION AND ABUNDANCE

Historically *S. plana* was widespread in south-eastern Australia and relatively continuous throughout its range, showing a close correlation with the distribution of temperate grasslands dominated by Wallaby Grasses (*Rytidosperma* spp., formerly *Austrodanthonia*) (Edwards 1993; O'Dwyer and Attiwill 1999).

Areas dominated by Wallaby Grasses probably occurred as part of a grassland mosaic, interspersed with patches dominated by other grass species. Museum records indicate *S. plana* was still common and widespread prior to 1950, with collections showing its distribution extended from Bathurst, NSW, through the Southern Tablelands of NSW and central Victoria to the South Australian border (Edwards 1993).

The area of temperate grassland in Australia at the time of European settlement is estimated to have been about two million hectares, though two centuries later this had been reduced to less than 1% of the original area (Kirkpatrick 1993), with the remaining remnants degraded by stock grazing and weed invasion.

A recent review of the status of *S. plana* across its range found that between the years 2000 and 2010 the known area of occupied habitat had increased from 10 km² to 150 km² due mainly to increased survey of areas proposed for development (Hogg 2010). Currently, the species is known from 100 (mainly small) sites north and west of Melbourne and in south-west Victoria (Brown and Tolsma 2010; Brown *et al.* 2011; DSE 2013), 48 sites in NSW (OEH 2012) and 78 sites in the ACT.

Most of the populations of *S. plana* in the ACT region are smaller than five hectares and lie within an area about 100 km long and 30 km wide, extending from the Queanbeyan district in the south-east to the Boorowa area in the north-west (Clarke and Whyte 2003; NSW Wildlife Atlas 2015). In the ACT the species occurs in lowland areas adjacent to the city of Canberra, and in mostly small sites within the city (Table 1).

Table 1 shows the area of habitat at sites where the species is known to occur in the ACT. These sites are defined as areas of contiguous, apparently suitable habitat, rather than by land ownership/management. For example, relatively large areas of habitat at Canberra Airport and the Majura Training Area are counted as one site because the habitat is continuous across the tenure boundary, while two small areas of habitat at the University of Canberra are counted as two sites because they are separated by more than 200 metres of non-habitat.

Because males are unlikely to fly more than 100 m away from suitable habitat (Clarke and O'Dwyer 2000), and females move even less distance, populations separated by 200 metres or more are likely to be isolated and are therefore treated as separate sites.

Populations of *S. plana* tend to have a patchy distribution (and density) within an area of apparently suitable habitat (and this area can vary between years), which means actual areas occupied by *S. plana* are likely to be less than the habitat areas shown in Table 1.

Table 1. Location of *Synemon plana* populations in the ACT

District	Number of sites	Habitat area (hectares)
Belconnen	9	355
Central Canberra	25	110
Gungahlin	32	812
Jerrabomberra	7	60
Majura	5	466
Total	**78**	**1803**

The area of apparently suitable (or potential) habitat for *S. plana* in the ACT is estimated to be about 1800 hectares, with individual sites varying in size from 0.055 ha to more than 300 ha, and a median size of 2.8 ha. There are large populations on Commonwealth Land at the Majura Training Area and Canberra Airport in the Majura Valley, at the Lawson Grasslands (former Belconnen Naval Station site) and at the West Macgregor offset area. Less extensive populations occur in the Dunlop Grasslands Reserve and Jarramlee Nature Reserve in Belconnen, in the Jerrabomberra Grasslands (east and west), and in the Mulanggari, Crace, Mulligans Flat and Goorooyarroo nature reserves in Gungahlin. Based on the known former distribution of Lowland Temperate Grassland in the ACT and areas surveyed for *S. plana*, it is unlikely any significant populations of the species remain undiscovered.

Numerous difficulties arise when attempting to estimate population size in *S. plana* (Gibson and New 2007). Flying adult males are the only life stage and sex that are readily detected and counted, but they are short-lived and emerge across a season of many weeks.

Counts or density estimates at a site on a single day will mostly reflect a single emergence cohort, and daily emergence and flight activity is affected by weather conditions. Daily emergence patterns between sites and across a site can also vary, with the flying season starting earlier on north facing sites, those with light ground cover and drier sites (Edwards 1994).

More adults emerge on hot dry days, making it difficult to detect the difference between long-term population trends and short-term seasonal effects at a site without surveying the whole site on every day of a season. Mark–release–recapture studies are labour-intensive and need to be carried out every day of the flying season in order to estimate the number of adult males present in the population.

Golden Sun Moth (photo K. Nash)

The length of the larval period is not clear, nor is it known if it can vary according to environmental conditions, so it is not known what proportion of the standing population is represented by the number of adults that fly in one season. Detecting and sampling larvae is difficult due to their patchy subterranean distribution and is destructive of larvae and their habitat. Late-season surveys of above-ground pupal cases can provide a useful indication of *S. plana* density as well as locations where larvae have developed underground because pupal cases are readily recognisable and have been found to persist in the field for longer than three weeks. However, pupal cases are likely to be more difficult to find on sites with denser vegetation or in wetter years (Richter *et al.* 2012; Rowell pers. obs).

Population estimates based on mark–release–recapture surveys have been undertaken four times for the small (0.4 ha) site at York Park in Barton. The number of flying males was estimated to be 520 (1992), 456 (1993) and 736 (1994) (Harwood *et al.* 1995), giving an average population estimate for those years of 1400 males per hectare This would be an annual adult cohort of about 2300 per hectare if the male:female sex ratio is 60:40 as suggested by Richter *et al.* (2012). A two or three-year life cycle would mean that double or triple the number of emerging adults estimated is potentially present on this site.

A similar survey at York Park in 2006 using a different analysis gave estimated male numbers of 440 (Rowell 2007a), with daily male population size during the peak flying period of about 55 to 65. A further mark–release–recapture survey in 2011 found similar daily male population sizes of 49 and 66 during the peak flying season (Rowell 2012).

Given the difficulties with measuring absolute population sizes for *S. plana*, measures of relative abundance or maximum daily abundance are likely be more practical for monitoring population trends. Counts of flying males have been undertaken at most ACT sites, but these have often involved different survey methods and years. Some ACT sites have been counted regularly, and others only once or twice. Richter *et al.* (2009) reported relative abundance of flying males at 28 sites in one season by using the highest number of individuals summed from 12 'rotational' counts (standing in one spot and counting all flying males within a defined radius whilst the observer rotates though 360 degrees) during 2–4 site visits, and characterised the abundance at each site from low (1–20 moths) to very high (several hundred). Richter (2010) conducted surveys at 24 locations over three seasons using counts along a 100 metre transect and found only a small number of sites had relatively high abundance (hundreds) of moths.

Hogg (2010) proposed three levels of *S. plana* activity (low, moderate, high) based on numbers of flying males counted during a standard time (fixed or transect counts) or distance travelled (walked transects and meandering traverses) and then rated the *S. plana* population size/activity at 56 ACT sites based on recent survey records. Mulvaney (2012) used the above and other data to apply the Richter *et al.* (2009) maximum moth count abundance classes to 73 ACT sites.

Standardised survey methods are detailed in DEWHA (2009) and have been developed by the ACT Government. These mainly cover transect, fixed point and fixed time counts of flying males, carried out in a way that allows some comparison of relative *S. plana* abundance between years and sites. Draft monitoring guidelines for the ACT include habitat monitoring methods to be used in conjunction with standardised moth counts.

Transect surveys covering some large ACT sites have been repeated in several seasons, mostly using transects across the site spaced 100 metres apart with numbers of flying males recorded per 100 metres of transect. These include:

- Belconnen Naval Transmission Station (Clarke and Dunford 1999; AECOM 2009),
- West Macgregor (Braby 2005; Biosis, 2015; Rowell 2015),
- Canberra Airport (Crawford 2001; Rowell and Bishop 2004; Biosis 2008; Rowell 2006, 2010, 2012),
- Majura Training Area (AECOM 2009, 2012).

Some general findings from the above surveys:

- Where it could be calculated, the average number of flying males per 100 metres for each site in the above surveys ranged from 0.2 to 34.
- When whole sites were taken into account, moth numbers were consistently highest at Canberra Airport (a site managed by regular mowing), but similar densities were recorded for the portion of West Macgregor dominated by grazed Chilean Needle Grass (*Nassella neesiana*).
- At West Macgregor, numbers of flying males were consistently higher on the creek flats dominated by Chilean Needle Grass than on the drier east-facing slope dominated by weedy native Speargrass (*Austrostipa* spp.)/Wallaby Grass (*Rytidosperma* spp.) pasture.
- There is a tendency for seasons to be characterised by either a high, moderate or low abundance of flying males at most sites across the northern ACT at the same time, with some local variation at particular sites (probably reflecting vegetation condition).
- A reduction in numbers of flying males between years appeared to be associated with excess biomass at one site and with overgrazing by kangaroos at another.
- The highest single count (per 100 metre sector) for a site is related to the abundance for the whole site, i.e. very high single counts occur in 'good' years when the count for the whole site is high.
- In seasons when males are abundant they may be detected across most of a site, but in poor years they may be found thinly scattered or have a patchy distribution which may match locations of high male abundance in previous seasons.
- Evidence of breeding (mating, oviposition, pupal cases) occurs in both Natural Temperate Grassland and native grassland, and is detected more often in areas and seasons of high male abundance.
- The number of females detected rises with the abundance of flying males, but rarely exceeds 1% of males recorded in walked transect surveys. This reflects the low probability of detecting females by the transect method.

The presence of flying males is a fairly coarse measure of breeding habitat, as they are able to fly some distance from their site of emergence and may also congregate in areas of low grass biomass (which may or may not contain the less mobile females), or shelter on the lee side of ridges on windy days (AECOM 2009; Rowell unpublished data).

Survey methods that detect females, pupae or larvae are valuable as they indicate more accurately the current and previous breeding and larval development sites, and allow better mapping and characterisation of breeding habitat. These surveys are more time-consuming and often less successful than surveys for flying males, but can be undertaken in a different time period to when males are flying. Surveys for females are best undertaken after the main period of male flying activity each day, when the females are more easily seen as they walk quickly from tussock to tussock to lay eggs.

Females are most readily seen on very hot afternoons (35–38°C) when they will perch on tall grass stems, presumably to escape the hot soil surface (Rowell, pers. obs). Searches of defined areas or timed searches for females can be combined with searches for empty pupal cases, as both require close inspection of the ground. Pupal case surveys are best undertaken towards the end of the flying season, when they will be more numerous, as they remain intact at the soil surface for several weeks under some conditions (Richter *et al.* 2012).

Unfortunately females and pupal cases are not easily found on sites with sparse or small *S. plana* populations. Surveys for larvae are destructive and require a permit to disturb the habitat, as tussocks are uprooted and the roots searched. There is no formal published description of the larvae, which need to be identified by an expert. Larvae are also patchily distributed in the habitat, possibly reflecting laying by individual females.

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

Synemon plana is found in native grassland, native pasture, open woodland with a grassy understorey and 'secondary' grassland (open grassy woodland that has been cleared of trees). Occupied sites have generally not been pasture improved through the application of fertiliser, or ploughed (Richter *et al.* 2010). Sites are generally flat or gently sloping (< 5°), and in the ACT aspect does not appear to be a good predictor of habitat. Shading of habitat is generally minimal, with 88% of habitat in the ACT occurring in areas without trees or in very sparse woodland (Mulvaney 2012). Hogg (2010) suggested that populations of *S. plana* in open woodland and secondary grassland may be the result of the species spreading outside its preferred habitat (Natural Temperate Grassland) to adjacent woodlands following partial or complete clearing of the trees. This idea is supported by observations that habitat in secondary grassland and open woodland generally supports fewer moths than primary grassland.

Habitat for *S. plana* is characterised by the moderate abundance of larval food plants and the structure of the grassy layer. Sites occupied by *S. plana* tend to be open grasslands dominated by tussocks of *Rytidosperma* species (Wallaby Grasses), and to a lesser extent Tall Speargrass (*Austrostipa bigeniculata*) and Kangaroo Grass (*Themeda triandra*), that are generally low to moderate in grass height and have a moderate to high grass cover with areas of bare ground (inter-tussock space) (Clarke and Dear 1998; O'Dwyer and Attiwill 1999; Gilmore *et al.* 2008; Mulvaney pers. obs.; Rowell pers. obs.).

Edwards (1994) surveyed eight *S. plana* sites in the ACT and described six as containing patches of Wallaby Grasses in Tall Speargrass grasslands, while two had patches of Wallaby Grasses associated with *Themeda* grassland. Most sites were on low ridges, hillocks or low hills.

Richter (2010) surveyed 47 grassland sites within the distribution of pre-1750 Natural Temperate Grassland in the ACT, and found that 69% of sites containing *S. plana* were dominated by Wallaby Grasses with a smaller proportion of occupied sites dominated by Tall Speargrass, Kangaroo Grass or Chilean Needle Grass. Chilean Needle Grass is a Weed of National Significance and a declared pest plant in the ACT (DECCEW 2009), and has spread along creeks and roadsides and through urban parks. No sites dominated by Phalaris (*Phalaris aquatica*) contained *S. plana*.

A study of native pasture sites in NSW showed that *S. plana* is more likely to be found at sites with higher cover of Wallaby Grasses, provided that the tussock structure and inter-tussock bare ground is maintained, and suggested that while high grazing pressures might increase Wallaby Grass cover at the expense of other grasses, this is unlikely to favour *S. plana* due to the loss of tussocks (Gibbons and Reid 2013). Important structural features appear to be tussocks for shelter, egg-laying and larval development, and inter-tussock spaces for basking to increase body temperature and for females to display and attract mates (Edwards 1994; Gibson 2006; Gibbons and Reid 2013). Where vegetation height and density varies, male moths show a preference for flying over areas of relatively low open grassland with reduced grass biomass (Gibson 2006; Gilmore *et al.* 2008; Brown *et al.* 2011).

Adult moths emerge from pupal cases at the soil surface on warm dry sunny days during the breeding season. The adults have no functional mouth parts, so cannot feed or drink. Mark–release–recapture studies have shown that most live for only one or two days (Edwards 1993; Edwards 1994; Harwood *et al.* 1995; Rowell 2007a; Rowell 2012). In the ACT the flying period is usually between mid-October and early January with a peak from mid-November to early December, but varies according to seasonal conditions. Examination of 650 pupal cases from eleven ACT sites showed that the sex ratio on emergence was about 60% males and 40% females. This ratio was similar over two seasons, for native and exotic-dominated sites (Richter 2010; Richter *et al.* 2012).

The proportion of males detected in field counts and mark–release–recapture surveys is very much greater than this, probably due to behavioural differences affecting detectability (Edwards 1993; Edwards 1994; Harwood *et al.* 1995; Gibson 2006; Rowell 2007a; Rowell 2012).

Adult females contain up to 200 (mean 74) fully-formed eggs on emerging from pupation, and with their smaller wings are only able to walk or flutter for short distances (Edwards 1994; Richter 2010). Males are active fliers, able to move several hundred metres over suitable habitat (Richter *et al.* 2013). Males fly low and rapidly over the grassland during the late morning and early afternoon, searching for females. Males do not fly far from habitat, and usually turn back after 50 metres or less when they move into unsuitable vegetation. Females sit on the ground, exposing their golden hindwings when a male flies overhead (Edwards 1994; Gibson 2006). After mating, the females move from tussock to tussock, laying eggs into their bases. Field observations suggest females lay their eggs within a few metres of the mating site (Gibson 2006).

Synemon plana larvae are underground feeders, and are found in silk-lined tunnels closely associated with the roots of grasses (Edwards 1994; Richter 2010). Edwards (1994) suggested the larval period could be 1–3 years. Larvae collected just prior to adult emergence in October fell into three distinct size cohorts, which appeared likely to be one, two and three years old (Richter *et al.* 2013). In temperate climates, lepidopteran larvae can face a pathway decision between continuing development to the adult stage or entering diapause and delaying emergence until the following season (Gotthard 2008). It is possible that this occurs facultatively in *S. plana*, perhaps in larvae hatched from eggs laid late in the season or larvae which encounter poor conditions for development and growth, meaning that the larval period could be two and sometimes three years.

The main larval food plants are native C3 grasses, especially Wallaby Grasses and Speargrasses, and more recently the introduced Chilean Needle Grass (Edwards 1994; Braby and Dunford 2006; Gibson 2006; Gilmore *et al.* 2008; Richter *et al.* 2011, 2013; Sea and Downey 2014). Oviposition and pupal shells have also frequently been associated with these species (e.g. Edwards 1994, Gibson 2006; Braby and Dunford 2006; Richter *et al.* 2013). Larvae were more often found among the roots of Speargrasses or a mix of Speargrass and Wallaby Grass than with Wallaby Grass alone (Richter *et al.* 2013).

These are all C3 grasses, and there was no indication from the stable isotope studies of gut contents that any of the C4 grasses commonly found in and around *S. plana* habitat were eaten in significant quantities (Richter *et al.* 2011). However, only a few tussocks of C4 grass species were searched for larvae in that dietary study (Osborne pers. comm. 2015). C4 species commonly found scattered at or near *S. plana* sites include *Themeda triandra, Bothriochloa macra, Panicum effusum, Aristida ramosa* and the introduced African Lovegrass (*Eragrostis curvula*).

Further work is required to identify or eliminate other food species, and to find the density of food plants required to sustain a population of *S. plana*. Some features of *S. plana* suggest it may require a high density of larval food plants in its habitat. These features include the low mobility and very short life span of the female which must walk or flutter to tussocks suitable for oviposition, and the probably limited distance that larvae could move through the soil if unable to complete their development on the roots of a single tussock (Edwards 1994). A study of a relatively small number of sites in Victoria and the ACT found that that sites inhabited by *S. plana* had Wallaby Grass cover greater than 40% on soils low in phosphorous, with up to five species of Wallaby Grass present (O'Dwyer and Attiwill 1999), but areas occupied by *S. plana* at one larger Victorian site all contained less than 37% Wallaby Grass cover (Gibson 2006). Surveys at 66 occupied Victorian sites found that most sites containing *S. plana* had ≥10% Wallaby Grass cover (Brown *et al.* 2011; Brown *et al.* 2012).

One survey found that in two seasons there was a significant positive relationship between the cover of Wallaby Grass and the number of flying males recorded (Brown *et al.* 2012), but other surveys have not found such a correlation (Gibson 2006; Brown *et al.* 2011). Low numbers of *S. plana* have been reported where Wallaby Grasses occur as a minor component in grassland dominated by presumed non-food species such as Kangaroo Grass or some exotic grasses (e.g. Brown *et al.* 2012).

Synemon plana sites in the ACT region typically contain up to six species of Wallaby Grass, but their cover and distribution vary. EcoLogical (2012) reported Wallaby Grass cover of 25% or less in areas of high *S. plana* abundance at Mulligan's Flat Nature Reserve, but noted that Wallaby Grass density varied considerably at a small scale, with patches of high density scattered across the site. The Wallaby Grasses with highest cover are often the low-growing *Rytidosperma carphoides* and *R. auriculatum*, with *R. caespitosum* and *R. laeve* also often present (five NSW sites, Clarke and Dear 1998; eight ACT sites, O'Dwyer and Attiwill 1999; Belconnen Naval Transmission Station, AECOM 2009; York Park Barton, Rowell 2012; Majura Training Area, AECOM 2014; Canberra Airport, Rowell 2015).

A survey of two habitat areas at Canberra Airport found that both had the same mean percentage basal cover of Wallaby Grasses (3%), but that this was made up of 23 tussocks/m² at the site dominated by *R. carphoides*, and seven tussocks/m² at the site dominated by the larger *R. caespitosum* (Rowell 2009). The site with the larger tussocks contained more pupal shells and has also had consistently higher numbers of flying male *S. plana* in several annual surveys. This suggests the species of Wallaby Grass and/or the size of its tussocks may also be important in determining larval habitat quality. Tussocks with a large root volume may allow a larva to complete its cycle on a single tussock without the risk and energy cost potentially involved in moving through the soil to find another tussock.

Of 55 *S. plana* larvae collected from the roots of native grasses at ACT sites, 87% were associated with either Speargrass or Wallaby Grass, with twice as many associated with Wallaby Grass tussocks (Richter *et al.* 2013). Speargrass (mainly *Austrostipa bigeniculata*) are also a major component of *S. plana* habitat in the ACT.

Apparent oviposition has been observed into Speargrass tussocks (Gibson 2006; Richter *et al.* 2013) and larvae have been found among their roots. At York Park in Barton, a small well-studied site with high numbers of *S. plana*, the cover of Wallaby Grasses has been relatively low over several years (ca. 4-7% of the vegetation cover), while Speargrass cover has been around 30%. At Canberra Airport and the Majura Training Area, Speargrass cover in *S. plana* habitat over several years has also been consistently higher than Wallaby Grass cover (AECOM 2014; Rowell 2015) and at Belconnen Naval Transmission Station Speargrass and Wallaby Grass cover has been roughly equal (AECOM 2009).

Other surveys have found a strong association between *S. plana* and the introduced Chilean Needle Grass in the ACT and Victoria, with high numbers of flying males observed in areas dominated by this grass (Braby and Dunford 2006; Gilmore *et al.* 2008; Richter *et al.* 2009; Sea and Downey 2014), apparent oviposition into its tussock bases (Gibson 2006), many pupal cases protruding from them (Braby and Dunford 2006; Richter *et al.* 2010) and larvae being found among its roots (Richter *et al.* 2013; SMEC 2015). Larvae collected from the roots of this grass were found to weigh significantly more than larvae collected from the roots of native grasses in the same season (Richter *et al.* 2013; Sea and Downey 2014), and several larvae can apparently be supported by a single tussock (SMEC 2014, 2015).

ACT sites which contain *S. plana* and are dominated by Chilean Needle Grass are all adjacent to native grasslands (Richter *et al.* 2011).

Chilean Needle Grass is of South American origin, and is related to Australian *Austrostipa* species. It is a long-lived grass which readily invades disturbed sites or those with enhanced nutrients (Faithfull 2012).

Other grass species have been less often linked with *S. plana*, through the following observations:

- Weeping Grass (*Microlaena stipoides*, C3 grass): apparent oviposition, females probing with ovipositor but egg-laying not confirmed (Victorian site, Gibson 2006).
- Redleg Grass (*Bothriochloa macra,* C4 grass): apparent oviposition and pupal cases protruding from tussock (Reid ACT, Braby and Dunford 2006), larvae associated with roots (ACT sites, Richter *et al.* 2013).
- Purple Wiregrass (*Aristida ramosa,* C4 grass): larvae associated with roots (ACT sites, Richter *et al.* 2013).

Studies of *S. plana* populations across the range of the species show considerable genetic variation, which increases with the geographic distance between populations (Clarke and O'Dwyer 2000; Clarke and Whyte 2003). Five major genetic clusters have been identified, one encompassing the populations from the ACT and nearby NSW. These studies suggest the ACT/NSW cluster radiated from a small founding population that originated from Victoria in recent evolutionary time, and that populations in this cluster have recently undergone further genetic differentiation resulting from habitat fragmentation associated with the introduction of agriculture (Clarke & Whyte 2003).

PREVIOUS AND CURRENT MANAGEMENT

In the ACT *S. plana* occurs on land under a range of tenures and land management regimes. Sites where *S. plana* occur include land owned and managed by the Commonwealth Government, Territory land gazetted as nature reserve, 'Hills, Ridges and Buffers', urban open space, or broadacre, and Territory rural land leased for grazing. *Synemon plana* often occurs on sites that contain the endangered Natural Temperate Grassland community and other threatened grassland species, and sometimes with remnants of the critically endangered White Box–Yellow Box–Blakely's Red Gum Grassy Woodland and Derived Native Grassland community.

Currently occupied *S. plana* habitat in the ACT has generally had some regime of grass biomass reduction in the past, which may have helped to maintain the habitat in a condition that allowed the moths to survive. This has included grazing by sheep, cattle and/or kangaroos, occasional high slashing, occasional or frequent low mowing and occasional burning (planned and unplanned).

Parts of the Canberra Airport grassland have consistently high counts of *S. plana* (including 85 females counted in one year) despite being mown several times per year since the 1960s (Rowell 2010).

Some areas of the airport that currently support *S. plana* have previously been subject to earthworks (soil levelling), over-sowing with Subterranean Clover (*Trifolium subterranean*) and years of very close mowing associated with helicopter training (Canberra Airport pers. comm. 2015), indicating some resilience of *S. plana* to past incompatible land management practices. However, the loss of *S. plana* from Yarramundi Reach in the last 20 years appears to be associated with over a decade of sustained high grass biomass and weed invasion due to a lack of grazing or mowing (Sharp 2009, Faithfull 2012).

Small central Canberra grassland sites where conservation of *S. plana* is a primary aim, such as York Park in Barton (which has a site-specific management plan, Parsons and Brinckerhoff 2008), are mostly maintained by mowing or slashing which is timed to avoid the breeding period of *S. plana*, with weed control as required. However, *S. plana* also persists in small patches in urban open space (such as road verges, median strips and parks) that are slashed or mown annually (or more frequently), which may include during the emergence season. Other sites are grazed by horses, such as the North Curtin horse paddocks and the larger Yarralumla Equestrian Park, which has an offset management plan that aims to integrate *S. plana* conservation with the equestrian use of the site (Jessop 2014).

In Gungahlin the larger sites are mainly within the Crace, Mulligans Flat and Goorooyarroo nature reserves. These areas were formerly grazed by sheep and/or cattle, and are all now grazed by controlled numbers of kangaroos. Parts of Crace and Goorooyarroo nature reserves are grazed by cattle at times. Crace Nature Reserve also contains populations of Striped Legless Lizard (*Delma impar*) and Button Wrinklewort (*Rutidosis leptorrhynchoides*).

Mulligans Flat and Goorooyarroo nature reserves are mainly woodland and in some parts the ecological condition is being enhanced by kangaroo exclosures and the addition of coarse woody debris (Manning *et al.* 2013).

In the Majura Valley, much of the Canberra Airport habitat is regularly mown to about 10 cm for aviation safety reasons, while the adjacent large Majura Training Area site is mostly lightly grazed by regulated numbers of kangaroos.

The Majura West/Campbell Park grassland was formerly grazed by sheep, and is currently grazed by kangaroos. All three sites contain Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and Perunga Grasshopper (*Perunga ochracea*) populations, and the Majura Training Area and Majura West also have Striped Legless Lizard. The Majura Training Area has a grassland management plan that takes account of the threatened species present.

In Belconnen, the enclosed Lawson North (former Department of Defence naval transmission station) site was previously grazed by sheep, later slashed, and is now grazed by regulated numbers of kangaroos. This site has a grassland management plan that takes account of the threatened species on the site, which include the endangered Ginninderra Peppercress (*Lepidium ginninderrense*) and the Perunga Grasshopper. An area of *S. plana* habitat has been retained on Reservoir Hill within the South Lawson suburban development, and is subject to an environment management plan requiring grass biomass management, weed control, corridor retention and regular monitoring of *S. plana* and its habitat. West Macgregor, Jarramlee and the Dunlop Grasslands Nature Reserve are lightly grazed by kangaroos and (parts are) grazed by cattle for grass biomass control as required. Jarramlee (ACT Government 2013) and West Macgregor are subject to offset management plans, which aim to control grass biomass and weeds in *S. plana* habitat.

The Jerrabomberra West and East nature reserves were formerly grazed by sheep and are now grazed by kangaroos, with some areas protected by kangaroo grazing exclosures. These reserves also contain Grassland Earless Dragon, Striped Legless Lizard and Perunga Grasshopper populations, and small experimental patch burns are being undertaken at both sites.

THREATS

Synemon plana is a grassland specialist, being found in areas of Natural Temperate Grassland, native pasture, secondary native grassland or clearings in grassy woodland. A very high proportion of these grassy ecosystems have been cleared for agriculture and urban development, and most of the remnants are fragmented and degraded.

Further loss, fragmentation and degradation of habitat continue to be the major threats to *S. plana* (ACT Government 1998; DEWHA 2009; OEH 2012; ACT Government 2016).

Mulvaney (2012) reported that of the estimated 1800 ha of *S. plana* habitat remaining in the ACT, 22% has been approved or proposed for urban development, 23% is on Commonwealth land with an uncertain future, and 45% is in existing or proposed nature reserves or existing/proposed EBPC offset areas. Proposed urban development will most likely involve complete loss of some small sites and partial loss and fragmentation of some larger sites. Larger losses include clearance of habitat at Canberra Airport (airport development), South Lawson (urban development) and parts of Gungahlin (urban development). The proposed habitat loss at Gungahlin has been covered by the Gungahlin Strategic Assessment, which details the quality and area of *S. plana* habitat lost, the proposed avoidance and mitigation measures, and the offset strategy. Offsets include the creation of the Kinlyside Nature Reserve, addition of land to the Mulligans Flat–Goorooyarroo Nature Reserves, and adding land to the 'Hills, Ridges and Buffers' zone. Smaller losses are likely (or have occurred) at York Park, Majura West and West Macgregor for road building, and at Dudley Street in Yarralumla for housing (Mulvaney 2012).

Many *S. plana* sites in the ACT are small, and are therefore particularly vulnerable to invasion by weeds. It is likely that *S. plana* requires a high density of larval food plants in its habitat, and would therefore be susceptible to the dilution of food plants by weed species that are not food plants. Weeds also fill inter-tussock spaces and alter the low and open grassland structure favoured by *S. plana*. Invasive weeds of concern in *S. plana* habitat include:

- Perennial tussock grasses like Phalaris, African Lovegrass, Serrated Tussock (*Nassella trichotoma*) and Chilean Needle Grass.
- Tall annual grasses such as Wild Oats (*Avena* sp.).
- Some broad-leaved weeds such as St Johns Wort (*Hypericum perforatum*) and Saffron Thistle (*Carthamus lanatus*).

Chilean Needle Grass in *S. plana* habitat presents unusual issues. It is a Weed of National Significance but has become an additional food plant for *S. plana* larvae, and appears to pose both risks and potential opportunities for *S. plana* conservation.

At Canberra Airport, Chilean Needle Grass has invaded disturbed sites, e.g. former soil dumps, where soil has been disturbed by machinery, drainage swales and beside disturbed track and paved edges, especially where there is additional run-off. It has been slower to invade adjacent, well-drained intact Natural Temperate Grassland (Rowell, pers. obs.). Similar situations have occurred at Jarramlee, West Macgregor and the former Constitution Avenue site. Chilean Needle Grass can invade Kangaroo Grass dominated grasslands when they suffer tussock collapse and death due to lack of renewal through grass biomass reduction (grazing, mowing, burning), and this appears to have happened at Yarramundi Reach and part of the Dudley Street site (Faithfull 2012). At Dudley Street *S. plana* occupied the Chilean Needle Grass area, but at Yarramundi Reach the moth seems to have disappeared before the main invasion of Chilean Needle Grass. This may be due to the small amount of *S. plana* habitat originally present at Yarramundi Reach, and the years of excessive grass biomass that preceded the invasion of Chilean Needle Grass.

The spread of Chilean Needle Grass appears to have allowed the distribution of *S. plana* to expand into adjacent areas that previously may not have been suitable habitat. This may be the source of the apparently isolated population in the grassed roundabout on the northern approaches of Commonwealth Avenue Bridge. When Chilean Needle Grass invades disturbed sites which are not *S. plana* habitat, these are often relatively well-watered or fertile, and it may displace native grasses, native or exotic pasture, or the planted exotic dryland grass mix (Tall Fescue, White Clover). This process has led to linear infestations of Chilean Needle Grass along waterways such as Ginninderra Creek and Gooromon Ponds. The spread of Chilean Needle Grass is also facilitated by mowing, leading to a near monoculture on many roadsides, nature strips and traffic islands in central Canberra. Chilean Needle Grass is assisted in replacing other grasses by its ability to form cleistogamous seeds which can mature at ground level, thus producing fertile seed even under close mowing. This seed is also present and ready to germinate following the death of the tussock due to age, drought or herbicide use, while mowing inhibits seeding of taller grass species and restricts their contribution to the soil seed bank (Faithfull 2012).

The use of Chilean Needle Grass as a food plant by *S. plana* has allowed the moth to survive in disturbed habitats and to spread along roadsides and creeklines. This has the potential to connect populations which are currently isolated on native-dominated sites, e.g. the complex of sites at Ginninderra Creek, Gooromon Ponds, Dunlop Nature Reserve and NSW border properties near Hall, and at Yarralumla Equestrian Park, Lady Denman Drive, North Curtin horse paddocks, Dudley Street and Kintore Street. At the same time, these linear infestations of Chilean Needle Grass could act as invasion corridors for the weed to enter native grasslands.

Synemon plana numbers are often much higher on Chilean Needle Grass-dominated sites where biomass is controlled by mowing or grazing than on adjacent native grassland (e.g. Constitution Avenue, West Macgregor/Jarramlee). This could be due to a number of factors:

- Chilean Needle Grass tussocks often form a continuous sward, providing a high density of food plants.
- More *S. plana* larvae can develop on a single Chilean Needle Grass tussock than on native grasses (Sea and Downey 2014; SMEC 2015).
- *Synemon plana* larvae which develop on Chilean Needle Grass are larger (Sea and Downey 2014).
- In Lepidoptera, large final body size often correlates with a high reproductive capacity (Gotthard 2008), because females produce more eggs and larger males may fly further and longer, and have greater mating success.
- Faster-growing larvae may lead to a shorter generation time in some Lepidoptera (Gotthard 2008).

The potentially enhanced reproductive success of *S. plana* using Chilean Needle Grass may be due to metabolic plasticity, but if these characteristics are genetically determined they have the potential to drive genetic change in *S. plana*, which could eventually lead to genetic barriers between isolated populations adapted to Chilean Needle Grass and those on native-dominated sites. For example, characteristics that enable *S. plana* to complete its life cycle under dry conditions in relatively sparse native vegetation on poor soils, could be lost in *S. plana* developing with more reliable food availability on fertile sites dominated by Chilean Needle Grass.

Other threats to *S. plana* populations or habitat include:

- **Wildfire or inappropriate fire regimes:** Lowland grasslands were regularly burnt by Indigenous people before European settlement (Nicholson 1981 in Lunt 1991) and virtually all perennial grassland plants resprout after fire in lowland grasslands (Morgan 2015). However, little information is available about the role of fire in low productivity grasslands of the type inhabited by *S. plana*, or of the effects of fire on *S. plana* in the ACT (Edwards 1994; ACT Government 1998). *Synemon plana* have been found to withstand burning of their habitat on some Victorian sites (Douglas 2004; Biosis 2010b), and flying males were observed in higher numbers on a previously burnt patch. However, it was not determined whether this was due to attraction of males to areas of low grass biomass, larvae surviving the fire, or reduction of the dominant *Themeda* grass exposing or allowing an increase in the growth of subdominant *Rytidosperma* grasses (Gibson 2006). Patchy ecological burns of *S. plana* habitat are seen as desirable for grass biomass reduction in Victoria, but the frequency and intensity of controlled burning needs to be planned and burns should be conducted outside the pupation and flight period (September–January) (Biosis 2010b). Edwards (1994) reported that ACT *S. plana* populations had survived well without fire for 50 years, and suggested that in the past they may have reoccupied burnt sites from surrounding areas rather than surviving fires, and that fires at small sites at certain times risked local extinction by killing vulnerable adults and eggs. Edwards (1994) also speculated that the mobilisation of the root reserves of grasses resprouting after fire could create a food shortage for *S. plana* larvae.
- **Grass biomass extremes:** Lack of grass biomass control on most sites is likely to lead to a shift from shorter *Rytidosperma* grasses to taller grasses, resulting in shading of the soil and reducing the availability of bare ground and open areas for basking, displaying and egg-laying. Excessive biomass removal by overgrazing or close mowing may cause soil compaction and reduce the vigour and root volume of the native grasses and hence lower the quality or availability of the larval food source, and possibly expose eggs or larvae to excessive soil temperatures and/or increase the risk of desiccation.
- **Cultivation and pasture improvement:** Ploughing is likely to damage or kill larvae and/or their food plants, and pasture improvement leads to loss of the native grasses that the moth depends on for habitat.
- **Herbicides and pesticides** have the potential to damage the moths and/or their food plants, and should only be used where necessary to protect the moths or their habitat.

- **Excess nutrients:** Addition or run-on of fertilisers is likely to favour exotic grassland species over the preferred native food plants of *S. plana*.
- **Shading:** As a grassland specialist, *S. plana* is presumed to have a life cycle adapted to unshaded sites, and in open woodland habitat it appears to be confined to large clearings. Planting of trees around small sites is likely to alter soil moisture, nutrients and temperature, and also the type and density of grasses, while shading by buildings is likely to reduce soil temperature, increase soil moisture and favour weeds. Such changes are likely to reduce the extent and quality of *S. plana* habitat.
- **Altered drainage:** Changes to drainage on or adjacent to *S. plana* sites have the potential to alter the vegetation and soil conditions preferred by the moth.

CHANGING CLIMATE

The predicted changes in climate in the next 50 years are likely to see the ACT become warmer and drier, with increases in extreme weather events and bushfire risk (ACT Government 2009). Species that tolerate such conditions will have an advantage over those species more sensitive to change. The likely direct effects on *S. plana* are not known, but plants advantaged by climate change are likely to include C4 grasses that are not thought to be *S. plana* larval food plants. Climate change may advantage some weed species, including African Lovegrass, which is an invasive C4 grass and is highly competitive on the low-nutrient soils that are typical of drier native grasslands in the ACT (Sharp 2011). Higher predicted CO_2 levels may also favour woody species over grasses, and lead to increased invasion of woody plants into grasslands (Berry & Roderick 2005; Morgan *et al.* 2007).

This effect could be hastened by rising temperatures in the ACT, where cold air drainage in winter is thought to be one environmental factor inhibiting the growth of trees in the local grassy valleys (ACT Government 2005).

MAJOR CONSERVATION OBJECTIVE

The overall conservation objective of this action plan is to maintain in the long term viable, wild populations of *S. plana* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve large populations in the ACT. Protect other populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

Populations of *S. plana* occur on land under a variety of tenures including nature reserve (Territory Land), rural leasehold Territory Land, Commonwealth owned and managed land (National Land) and unleased Territory Land. These sites are separated from one another by unsuitable habitat, roads and urban development. While there are some large areas of habitat, most sites are less than 5 ha and many sites are less than 1 ha.

Mulvaney (2012) rated the relative importance of known ACT sites using the following criteria:

- habitat size
- maximum moth count
- connection to other habitat patches
- main vegetation type
- understorey quality

- presence of other threatened species

There are very few *S. plana* sites on ACT-owned land where future land-use decisions (protection or development) are still to be decided. The majority habitat in large or highly ranked sites is, or is proposed to be, under conservation management. Mulvaney (2012) noted that while about 30% of the habitat at major ACT sites was approved or proposed for clearance in the next five years, 800 ha (57% of known ACT habitat) is likely to be under conservation management within the same time period. Highly ranked sites from each main area (Gungahlin, Belconnen, Jerrabomberra, Majura) are already either in nature reserves or under ACT Government management as offsets under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Many of these sites are also to be subject to long-term monitoring to ensure the protection of key populations (Rowell and Evans 2014).

Synemon plana occurs on Territory land managed as public open space (where current management practices, including regular grass biomass control though mowing or slashing, generally appear to be compatible with the persistence of the species at these sites), and leasehold rural land where it can be the subject of a Land Management Agreement or Conservator's Directions. Where the species occurs on Commonwealth land, the ACT Government will liaise with the Commonwealth Government and Canberra Airport to encourage continued protection and management of *S. plana* populations on their land.

Larger populations on larger sites should have highest priority for protection, as these are expected to have the greatest chance of long-term viability. Larger populations of the species are considered to be those containing 500 or more adult moths that occupy habitat patches of 50 ha or more. Medium-sized populations are considered in this plan to contain 200 or more adult moths (but do not meet the criteria for a 'large' population). A medium-sized population has the potential to be viable over the longer term if habitat quality is maintained though appropriate management. Small populations (less than 200 adults) can still form a significant contribution to the conservation of the species, particularly if small populations are connected by habitat so they function as a cluster of sub-populations or are connected by a habitat corridor to a larger population.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. The special offset requirements for *S. plana* is "no loss of habitat patches >50 ha AND supporting populations of more than 50 moths (population must be counted at a time when large populations are observed at nearby known sites)". Given this special offset requirement, a survey is required for this species for both the number of individuals as well as the extent of habitat in hectares.

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

Over the past two decades there have been numerous surveys in the ACT to determine the distribution of potential habitat and the presence of *S. plana* populations. Some of these surveys have been extensive and involved university researchers and Citizen Science volunteers (e.g. Richter *et al.* 2009), though the majority of surveys have been undertaken to identify ecological constraints to proposed urban development. There is now a good understanding of the distribution of *S. plana* and its habitat in the ACT and it is unlikely any significant populations of the species remain undiscovered. It is probable that smaller populations (less than 5 ha) will continue to be found, especially in good flying seasons and during pre-development surveys.

If Chilean Needle Grass continues to spread in Canberra, this may also extend the local range of *S. plana*.

Several key *S. plana* sites in the ACT are subject to regular or *ad-hoc* population and/or habitat condition monitoring, with the longest and most consistently monitored sites being York Park and Canberra Airport.

More recently, standardised monitoring of *S. plana* is being established at sites that include nature reserves and offset areas, as part of the ACT Government's management of offset areas under EPBC Act approval conditions (Rowell and Evans 2014). This monitoring includes quantitative surveys of flying male moths (which may be combined with searches for female moths and pupal cases), measurement of habitat parameters and photographic records. The long-term monitoring will include at least 100 ha of habitat in each of the main areas of occurrence (Gungahlin, Belconnen, Jerrabomberra, Majura), and sites containing Natural Temperate Grassland, native pasture, secondary grassland and open woodland.

Monitoring of a range of sites provides information on district-wide fluctuations in *S. plana* populations, trends at particular sites and the habitat parameters associated with these trends. This monitoring will also provide baseline information of assessment of other sites for which data is available from only one or a few seasons. Monitoring methods will need ongoing review to incorporate the results of research on *S. plana* ecology and habitat management, and to take account of new monitoring methods.

Soil survey methods have been trialled by SMEC (2014b, 2015), to determine the presence of Golden Sun Moth larvae outside of the flying season. Whilst this method can be destructive for larvae and habitat, it does provide information on density, age cohorts and feed species, which is not necessarily achieved from the flight surveys.

To date glasshouse and field trials undertaken since 2010 have indicated that Golden Sun Moths can be translocated, but long term survival in a new location is still being assessed by ongoing monitoring. The University of Canberra, in collaboration with the ACT Government and Forde Developments Pty Ltd, successfully translocated Golden Sun Moth larvae from West Macgregor into a glasshouse at the University of Canberra. The larvae were kept alive for nine months and then placed out in a new field location (Sea and Downey 2014). As part of the Majura Parkway environmental commitments, methodology was developed for harvesting Golden Sun Moth larvae and translocating soil containing larvae directly from a development area to translocation sites (SMEC 2016). Moths were subsequently recorded emerging from the translocation sites (Sea and Downey 2014, SMEC 2016). Soil searches at the larvae translocation site following the flight season resulted in the recovery of live Golden Sun Moth larvae (SMEC 2014a), and annual flight surveys at the soil translocation site have resulted in regular moth sightings (SMEC 2016). Translocation of soil with Golden Sun Moth larvae is more cost effective than individual larvae translocation, and has been repeated again in a 2016 transfer of larvae and soil containing larvae from the new proposed suburb of Taylor to the nearby environmental offset area of Kinlyside.

Research and adaptive management is required to better understand the life history and ecology of *S. plana*, habitat requirements and techniques to maintain the species' habitat. Specific research priorities include:

- Habitat management – optimal habitat requirements (grass species, structure, biomass) and techniques compatible with or required to maintain habitat condition, including regimes of grazing, fire, slashing/mowing.
- Habitat creation – development of methods to create *S. plana* habitat with the aim of increasing available habitat and facilitating connections between fragmented populations (e.g. Dunlop-Jarramlee grasslands, Canberra Airport).
- Habitat use – identify habitat characteristics that act as sources and sinks for adult moths, to reduce threats to the breeding population. Males are attracted to shorter areas and these can include areas where females might not be present, such as rock outcrops in tall grassy paddocks, mown areas (roadsides, median strips, fire breaks), golf course fairways, foot tracks, recently burnt areas).
- Food plants – further laboratory research is needed to clarify the grass species eaten by *S. plana* larvae, their relative dietary importance and density of food plants required to sustain populations of *S. plana*.
- Chilean Needle Grass – improved methods to control or manage the spread of this invasive

species and what role this food plant may play in the conservation of the species.

- Translocation – further development of reliable translocation methods to facilitate establishment of new populations (which could be within the urban open space, or newly created grassy areas in large roundabouts, playing fields etc.), to maintain genetic integrity of small or isolated ACT populations.

MANAGEMENT

Habitat requirements for *S. plana* are generally consistent with the requirements of other threatened grassland fauna including the Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Perunga Grasshopper (*Perunga ochracea*), which often co-occur with *S. plana*. Habitat management for these species aims to keep grass biomass within a moderate range to maintain tussock structure and inter-tussock spaces. The Striped Legless Lizard (*Delma impar*) occurs in grassland of intermediate to high grass biomass/height, and this threatened species may not be tolerant of shorter grass swards or management practices (regular mowing) that are compatible with the conservation of *S. plana*. Where the aim is to conserve multiple threatened species at a site, management will need to take into account any differing habitat requirements (see the ACT Native Grassland Conservation Strategy). This will most likely include maintaining or promoting a 'patchy' sward structure that contains a mosaic of habitat patches that differ in tussock height and/or density. Management of secondary grassland or open grassy woodland sites containing *S. plana* may be problematic, as the natural or assisted regeneration of trees and shrubs in these areas that favour conservation of bird, mammal, reptile, insect and plant diversity will most likely come at the expense of *S. plana*'s preferred open grassland habitat.

Based on current knowledge of the habitat requirements of *S. plana*, management actions should aim to maintain a native grass sward that is short to medium (5 cm - 15 cm) in height (i.e. the height of the bulk of the tussock leaves, not including the often few higher leaves and seed-bearing culms), has an intermediate density (cover) of tussocks, low weed cover and tussocks interspersed with areas of bare ground. Management should promote a sward that has a high proportion of known food plants, especially Wallaby Grasses.

Where possible, management activities should be undertaken outside the seeding period of major weeds, and should minimise disturbance and compaction of soil. The development of barriers within habitat areas such as areas of rank grass growth, dense weed patches, roads and linear tree/shrub plantings should be avoided.

Most grassland sites containing *S. plana* will require some management of grass biomass to maintain the habitat in good condition. The preferred method of managing grass structure and biomass is grazing by native herbivores (kangaroos), which are a natural fauna component of native grasslands. Kangaroo numbers will need to be managed on some sites, especially during droughts, to avoid overgrazing and loss of tussock structure.

Where kangaroo grazing may not be sufficient to maintain biomass within the desirable range, other methods of grass biomass control may need to be used, such as slashing or grazing by stock. If stock grazing is used, light or intermittent grazing is preferable, timed to avoid excessive trampling during the *S. plana* breeding period (late October to January). The average tussock height should not be reduced below 10 cm during grazing. Internal fencing will be required on some sites to allow control over grazing intensity in particular areas. On sites containing Chilean Needle Grass cattle are preferred to sheep as they are less likely to transfer seed, and grazing should take place in winter or early spring where possible, before the seeding period of the grass.

If slashing is used, tussock height should not be slashed below 10 cm, and slashing should be minimised between November and January to avoid the adult flying period.

Slashing should be undertaken before November but if the grass sward is tall and dense during the *S. plana* breeding season (little or no bare ground) then slashing is preferable to leaving a long, dense sward for the remainder of the breeding season. Machinery should be cleaned before entering *S. plana* sites, and after slashing on sites containing Chilean Needle Grass and other significant weeds. Slashing should avoid the seeding period of major weeds where possible and should not be undertaken when the ground is wet, to avoid soil disturbance. Mowing machinery should disperse the slashed material, or if windrows are produced, these should be raked and removed from the grassland.

Any burning in *S. plana* habitat should be patchy and low-intensity, and the effects on grassland composition and *S. plana* activity in subsequent years should be monitored.

Burning should be restricted to March–September to avoid the breeding and egg-hatching period, and to allow the grassland to start regrowing before the emergence of the next generation of adults. Post-fire weed control will be necessary on some sites.

Weed control on *S. plana* sites should, as a minimum, aim to eliminate woody weeds and control other high threat species. Preventing excessive reduction of biomass will make native grasslands more resistant to weed invasion. The strategic use of biomass control methods can assist in reducing seed set in some weed species. Perennial exotic grasses such as Chilean Needle Grass, Serrated Tussock and African Lovegrass can invade disturbed native grasslands. Where dense patches of these species have developed in or adjacent to *S. plana* habitat, they can be suppressed and contained if eradication and rehabilitation are not an option (DECCEW 2009). One method suggested for containment is to poison a barrier strip, then maintain a layer of deep, seed-free mulch between the native grassland and the weed-dominated areas, and manage the areas separately as far as possible (DPI 2007).

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra International Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 2. Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve large populations in the ACT. Protect other ACT populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).	Apply formal measures to protect all large populations on Territory-owned land. Encourage formal protection of all large populations on land owned by other jurisdictions.	All large populations protected by appropriate formal measures.
	Protect all medium size populations on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect all medium size populations from unintended impacts.	All sites with medium size populations are protected by appropriate measures from unintended impacts.
	Ensure sites where small populations occur on Territory owned land are protected from unintended impacts, where this contributes to broader conservation aims (such as protecting multiple threatened species at a site). Encourage other jurisdictions to undertake similar protection of small populations.	All sites with small populations are protected by appropriate measures from unintended impacts, where sites have broader conservation value.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor abundance at a representative set of sites, together with the effects of management actions.	Trends in abundance are known for representative sites, management actions recorded.
	Manage habitat to maintain its suitablilty for the species, including implementing an appropriate grazing / slashing / burning regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and herbage mass). Potential threats (e.g. weeds) are avoided or managed. Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations, or to establish new populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity. If suitable habitat exists, re-establish populations where they have become locally extinct.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant species composition). If suitable habitat exists, research and trials have been undertaken to establish new populations.

Objective	Action	Indicator
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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GRASSLAND EARLESS DRAGON

TYMPANOCRYPTIS PINGUICOLLA

DRAFT ACTION PLAN

PREAMBLE

The Grassland Earless Dragon (*Tympanocryptis pinguicolla* Mitchell, 1948) was declared an endangered species on 15 April 1996 (Instrument No. DI1996-29 *Nature Conservation Act 1980*, under the former name Eastern Lined Earless Dragon *Tympanocryptis lineata* pinguicolla). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1997 (ACT Government 1997). This revised edition supersedes the earlier edition.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*) and the Golden Sun Moth (*Synemon plana*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Tympanocryptis pinguicolla is recognised as a threatened species in the following sources:

International

Vulnerable – IUCN (2015).

National

Endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*.
Special Protection Status Species - *Nature Conservation Act 2014*.

New South Wales

Endangered – *Threatened Species Conservation Act 1995.*

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Grassland Earless Dragon *Tympanocryptis pinguicolla* is a small lizard in the family Agamidae. It was originally described as a subspecies of the more widespread and variable *Tympanocryptis lineata* (Mitchell 1948) and later recognised as a distinct species (Smith *et al.* 1999). Nelson (2004) noted morphological differences between animals from the Cooma district and the Canberra area.

Further genetic research, including studies of nuclear DNA microsatellites and mitochondrial DNA, has shown a clear genetic division between the extant populations in the NSW Cooma–Monaro and ACT–Queanbeyan areas, and that the ACT–Queanbeyan populations are also highly genetically structured (Melville *et al.* 2007; Scott and Keogh 2000; Carlson 2013; Hoehn *et al.* 2013). *Tympanocryptis pinguicolla* is found at higher altitudes and in cooler regions than any other earless dragon (Robertson and Evans 2009).

Most members of the genus *Tympanocryptis*, including *T. pinguicolla*, lack an external ear opening and a functional tympanum (ear drum) (Greer 1989, Cogger 2014). *Tympanocryptis pinguicolla* is a small lizard with a stout body and short robust limbs (Mitchell 1948), and is diurnal and cryptic in its grassland habitat. Total adult body length is usually less than 150 mm (Robertson and Evans 2009) with average snout-vent length of 55 mm (Smith 1994) and weight of five to nine grams (Robertson and Evans 2009).

The dorsal markings are distinctive, with a pale vertebral stripe flanked by alternating fawn/grey and dark brown irregular blocks between two pale (or yellow) dorso-lateral stripes. The pattern of the dark blocks is unique to each individual and does not change with age, and can therefore be used to identify individual animals (Nelson *et al.* 1996; Dimond 2010). There is usually a narrow pale bar on the head, between the anterior corners of the eyes, and two pale lateral stripes and scattered dorsal spinous scales (Cogger 2014).

The ventral surface is either intricately patterned with dark brown or grey markings, or immaculate white or cream. During the breeding season subadults and adults often have yellow-orange or reddish coloration on the throat, sides of the head and flanks, and this may be more common or prominent in males.

DISTRIBUTION AND ABUNDANCE

Prior to European settlement, *T. pinguicolla* was most likely distributed broadly in south-eastern Australia wherever suitable habitat (native grassland) was present. Pryor (1938) described *T. pinguicolla* as more common than the Eastern Brown Snake (*Pseudonaja textilis*) in the ACT, and animals were captured adjacent to Northbourne Avenue in the 1950s (Young 1992). NSW records show the species occurred in grasslands near Cooma in the Southern Tablelands (Mitchell 1948) and at Bathurst (Osborne *et al.* 1993a).

Most former records of *T. pinguicolla* in Victoria are from the basalt plains in the south of the state (Brereton and Backhouse 1993). The species was not uncommon at Essendon and the plains near Sunbury to the north of Melbourne late last century (McCoy 1889). There are also records from Maryborough and Rutherglen in central Victoria (Lucas and Frost 1894).

Recent records indicate *T. pinguicolla* has experienced a severe decrease in its geographic range. There have been no confirmed Victorian sightings since the 1960s, and no recent records north of the ACT, but populations still occur between Cooma and Nimmitabel in the Monaro region of NSW and there are some small populations near Queanbeyan, NSW (Queanbeyan Nature Reserve, The Poplars) (Robertson and Evans 2009).

In the ACT, *T. pinguicolla* was rediscovered in 1991 after not being recorded in the area for 30 years (Osborne *et al.* 1993). It is now known to occur in the eastern Majura Valley (Majura Training Area, Canberra Airport), western Majura Valley (West Majura Grassland and Campbell Park Defence land) and the Jerrabomberra Valley (Harman/Bonshaw Defence land, Cookanalla, Callum Brae, Jerrabomberra West Grassland Nature Reserve and Jerrabomberra East Grasslands) (ACT Government 2005, Biosis 2012) (Table 1).

Genetic analysis indicates the ACT populations are highly genetically structured with little interchange of individuals between sub-populations. In particular the Majura Training Area and Jerrabomberra West populations are apparently insular and unlikely to provide or receive immigrants from the other populations, having been separated from the other populations for some time by natural and artificial barriers such as a river, creek, arterial road and/or developed land (Hoehn *et al.* 2013).

Monitoring of two main *T. pinguicolla* populations by Conservation Research (ACT Government) and the University of Canberra indicate ACT populations declined dramatically during the last decade (2005–2009), possibly as a result of lack of ground cover caused by drought and exacerbated by overgrazing (Dimond 2010; Dimond *et al.* 2012). The suggested mechanisms driving the decline are:

- Low soil moisture, increased exposure and dry conditions causing low production of, and high mortality in, eggs.
- Reduced plant growth during drought combined with increased grazing pressure from kangaroos (Eastern Grey Kangaroos) or stock, reducing ground cover and increasing the exposure of lizards (particularly hatchlings and juveniles) to predation.

Other factors related to drought and lack of ground cover might also be involved in the recent decline of *T. pinguicolla*, such as low availability of food (small invertebrates) or low availability of burrows for shelter (which would arise if the drought and ground cover conditions were also unfavourable for burrow-forming arthropods such as Wolf Spiders (*Lycosa* spp.) and Canberra Raspy Crickets (*Cooraboorama canberrae*).

The estimated density of the largest known population of *T. pinguicolla* (Jerrabomberra West), collapsed from 19.8 animals per hectare (ha) in 2006 to 2.4 in 2008. A population viability analysis suggested the Jerrabomberra population had a very high probability of extinction within 10 years and the regional decline places the species at severe risk of extinction (Dimond 2010).

Tympanocryptis pinguicolla has not been detected at two Symonston sites for several years and may no longer be present. These are north-west of the intersection of Hindmarsh Drive and Canberra Avenue in Symonston (Amtech East site: Osborne and Dimond 2008; Biosis Research 2011), and south-west of the intersection of Jerrabomberra Avenue and Narrabundah Lane (Callum Brae north: Fletcher *et al.* 1995; Rowell 2008; Dimond *et al.* 2010; Biosis Research 2012). The Amtech East site is relatively small and separated from the Cookanalla population by a major road.

Tympanocryptis pinguicolla was found in moderate numbers in the northern part of Canberra Airport in the late 1990s (ACT Government 2000), but numbers declined and it was not detected between 2005 and 2010. Numbers were still very low by 2015 (Rowell 2011 and unpublished data). The habitat at the airport was excised from the adjacent Majura Training Area in 1970 for a runway extension, and is now separated from it by an unsealed road with mown, relatively disturbed verges and two fences. This road is likely to form at least a partial barrier to movement between the sites (IAE 2013).

The airport grasslands are mown several times each year except during drought, in contrast to the Majura Training Area which was overgrazed by kangaroos during the first part of the 2002–2010 drought, then protected from kangaroo grazing from 2007. There have been no genetic studies of the airport population, but it may be reliant on occasional immigration from Majura Training Area for maintenance (IAE 2013).

Protection and enhancement of this potential movement corridor and appropriate management of the airport grasslands is likely be important for the survival of this small semi-isolated population.

Monitoring of *T. pinguicolla* populations at the Majura Training Area, Jerrabomberra West Nature Reserve and Jerrabomberra East grasslands suggests there is some post-drought recovery occurring in these populations (Cook *et al.* 2015).

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

In the ACT and nearby NSW, *T. pinguicolla* is found in Natural Temperate Grassland and native pastures, usually on well-drained sites dominated by Tall Speargrass (*Austrostipa bigeniculata*) and shorter Wallaby Grasses (*Rytidosperma* spp.), with patches of tussocks and open spaces between them (Osborne *et al.* 1993a; Robertson and Evans 2009). In the ACT these sites are frost-hollow grasslands and have usually had little or no ploughing or pasture improvement (Osborne *et al.* 1993a). At one ACT site, *T. pinguicolla* has been shown to use a broader range of grassland types, including denser and moderately degraded grassland (Langston 1996; Stevens *et al.* 2010).

Recent studies have found higher trapping rates of *T. pinguicolla* at artificial burrows set in areas where herbage biomass is naturally lower compared to adjacent grassland, or in patches where biomass is lower due to recent burning or grazing (Osborne et al. 2013; Cook et al. 2015; Osborne 2015). While it is not yet known whether this is due to differences in detectability or habitat preference of T. pinguicolla, maintaining a varied grassland structure and avoiding herbage biomass extremes is a management aim in order to maximise the range of shelter and thermal niches, and of prey types (Stevens et al. 2010; Taylor 2014; Evans pers comm.).

Table 1. Sites supporting *Tympanocryptis pinguicolla* in the ACT

Site Name	Habitat area (ha)	Land Jurisdiction	Land use policy
Majura Training Area (north of Airport)	139	Commonwealth	Military training area, includes Air-services Beacon paddock.
Majura Training Area (former grazing properties east of Airport)	90	Commonwealth	Military training area
Airport	22	Commonwealth	Airport, office accommodation and retail outlet
West Majura Grassland	104	Territory	Broadacre*, managed for conservation
Campbell Park	35	Commonwealth	Land attached to Defence offices
Jerrabomberra West Grasslands Reserve	180	Territory	Nature Reserve
Callum Brae (west of Monaro highway)	68	Territory	Grazing lease
Amtech east	12	Territory	Unleased land
Harman/Bonshaw	158	Commonwealth	Defence land with grazing lease
Jerrabomberra East Grasslands	71	Territory	Conservation Area
Cookanalla (east of Monaro highway)	164	Territory	Grazing lease

*Broadacre refers to agriculture and certain other 'large area' uses under Territory planning legislation.

Abandoned burrows of large arthropods appear to be an important feature of *T. pinguicolla* habitat in the ACT region. The species is known to use arthropod burrows as diurnal and nocturnal shelter sites in this region (Jenkins and Bartell 1980; Osborne *et al.* 1993b; Smith 1994; Langston 1996; Benson 1999; Rowell 2001; Stevens *et al.* 2010), and to shelter in tussocks (Langston 1996; Stevens *et al.* 2010). *Tympanocryptis pinguicolla* also shelters under rocks in NSW (Osborne *et al*. 1993b; McGrath *et al.* 2015), but rocks do not appear to be an essential component of the habitat for this species in the ACT (Langston 1996).

Capture data is characterised by a dominance of young animals and low recaptures of previous-year adults (Smith 1994; Langston 1996; Nelson *et al.* 1996; Dimond 2010), suggesting a predominantly annual turnover of adults with females able to breed in their first year. Some females survive into their second year, but most apparently only survive long enough to produce one clutch of eggs (Langston 1996; Nelson 2004). None have been found to be gravid in two consecutive years (Dimond 2010). As for many species, longevity of *T. pinguicolla* in captivity appears to be greater than in the wild, with one male held at Tidbinbilla Nature Reserve living for five years (Evans pers comm).

The female lays a clutch of three to seven (typically six) eggs in an arthropod burrow 10–13 cm deep in November–January, and backfills the burrow with soil and litter (Dimond 2010; Doucette unpublished data).

The burrows are created by large arthropods such as the Common Wolf Spider (*Lycosa godeffroyi*) and the Canberra Raspy Cricket (*Cooraboorama canberrae*) (Osborne *et al.* 1993b, Benson 1999). Females have been observed to visit nest sites daily during incubation (Doucette unpublished data).

Arthropod burrows are also used as mating sites (Nelson 2004) and appear to be important as thermal refuges for the animals from high and low daily ambient temperatures and during winter (Benson 1999; Nelson 2004; Doucette unpublished data), and as refuge from predators.

Hatching occurs in January–March (Langston 1996; Dimond 2010; Doucette unpublished data), and high abundance of invertebrate prey coincides with the juvenile recruitment period (Benson 1999; Nelson 2004). Juveniles grow rapidly and males mature earlier than females (Langston 1996; Nelson 2004). Nelson (2004) found seasonal and annual variability in population structure, and suggested that cool weather conditions in spring/summer may affect basking opportunities and food availability, and hence the rate of growth and maturation.

The relatively low fecundity and short life span of *T. pinguicolla* makes local populations vulnerable to the effects of wildfire, drought and other environmental changes on their habitat. This vulnerability is increased where fragmentation of habitat prevents recolonisation from surrounding areas.

A radio-tracking study of 10 adult lizards showed that they mostly occupied one or two natural burrows within a home range of 925–4768 m^2, and that there was some overlap in home ranges (Stevens *et al.* 2010). Adults and juveniles frequently move from one natural or artificial burrow to another (Benson 1996; Langston 1996; Nelson 2004; Stevens *et al.* 2010; AECOM 2014; Doucette unpublished data), with some movements of at least 230 m over longer periods (ACT Government 2000). *Tympanocryptis pinguicolla* takes shelter in burrows or tussocks when disturbed, so both of these features are likely to be important as refuge from predators.

The species relies on burrows as winter refuge sites, though animals can be active on cool sunny days and can move between burrows during winter (Benson 1996; Nelson 2004; Stevens *et al.* 2010).

Tympanocryptis pinguicolla is a sit-and-wait predator and eats a variety of small invertebrates, especially ants, beetles, spiders and moths (including larvae) (Howe 1995; Benson 1999; Dimond 2010).

Dimond (2010) found that although ants were frequently eaten, they were only taken in proportion to their abundance (i.e. were not selected for) and that beetles were preferred food items at three sites in 2007. Captive *T. pinguicolla* have been reported to eat crickets in preference to ants when both were offered, suggesting that the animals may have been selecting prey with a higher caloric value (Taylor 2014).

Grassland Earless Dragon (photo M. Evans)

PREVIOUS AND CURRENT MANAGEMENT

In the ACT *T. pinguicolla* occurs on land under a range of tenures and land management regimes.

The Jerrabomberra Valley, including sites where *T. pinguicolla* occurs, has a history of grazing by stock (mostly sheep, less so cattle and horses) and kangaroos. These areas include:

- Land previously owned and managed by the Commonwealth Government (Harman/Bonshaw Defence areas), now owned and managed by the ACT Government, which is generally lightly grazed by sheep and kangaroos.
- Broadacre Territory land (Amtech East Estate) with grazing agistment.
- Territory rural land leased for grazing (e.g. Cookanalla, North Callum Brae), which are grazed by stock (mostly sheep) and kangaroos.
- Land formerly leased (sheep grazing), that is now in nature reserve (Jerrabomberra West Grasslands), or set aside as a conservation area (Jerrabomberra East Grasslands), and are grazed by kangaroos. Management of the Jerrabomberra West Grassland Reserve and Jerrabomberra East Grassland conservation area is aimed at maintaining a heterogeneous grass sward mostly between 10 and 20 cm high, and includes grazing by kangaroos (with fencing to protect some areas from overgrazing), slashing along tracks and fence lines and, more recently, small-scale patchy burns to promote heterogeneity in the height and density of the grass sward.

In the Majura Valley *T. pinguicolla* occurs on the Majura Training Area (MTA) (Department of Defence land), where the species' habitat is managed for conservation and is generally only lightly grazed by kangaroos. A large area of habitat was fenced to prevent continued overgrazing by kangaroos in the 2002–2010 drought. Following the drought this area was opened to allow grazing by kangaroos. *Tympanocryptis pinguicolla* also occurs in the Airport Services Beacon paddock, a fenced area of about 10 ha that is contiguous with habitat on the MTA and has not been grazed for at least three decades. The species has been recorded intermittently in the northern section of Canberra Airport, which is subject to a slashing regime to maintain a moderately short grass sward. The grassland at Majura West is grazed by kangaroos and, in the past, has been grazed by sheep.

During the 2002–10 drought, some *T. pinguicolla* sites in the ACT were overgrazed by kangaroos and some by stock. Overgrazing was particularly severe in the Majura Valley at the MTA (kangaroos), West Majura (kangaroos and sheep), Cookanalla and Jerrabomberra East Grasslands. Sheep were removed from Majura West during the drought when overgrazing became evident, and stock numbers were reduced at Cookanalla. The height and biomass of the grass sward has since largely recovered at overgrazed sites.

Grasslands in the ACT, including *T. pinguicolla* habitat, are subject to planned and unplanned fire. An unplanned fire in the MTA in 1998 (Nelson *et al.* 1998b) resulted in several hectares of *T. pinguicolla* habitat being burnt. *Tympanocryptis pinguicolla* has been observed to use this and other burnt areas one year post-fire and in subsequent years, suggesting the species is capable of using grassland at least one year following fire if animals are able to disperse into the area from adjacent unburnt areas (Nelson *et al.* 1998b; Evans and Ormay 2002; Osborne *et al.* 2013; Cook *et al.* 2015).

Planned fire is used in grassland for ecological purposes and for fuel reduction. Recently, small-scale patch burning has been trialled in Jerrabomberra West Grasslands by the ACT Government with the aim of promoting heterogeneity of the grass sward to improve habitat for *T. pinguicolla*. Multiple burn patches (each several metres across) were used to create a mosaic of unburnt and recently burnt areas that differ in the density and height of the grass sward.

The small size of burnt areas means *T. pinguicolla* should be able to move a few metres to an unburnt area during the 'cool', slow burn. After the burn *T. pinguicolla* can forage in burnt areas and seek shelter in the unburnt habitat. Each burn patch was raked and closely examined immediately after burning for signs of dead lizards, but none were detected, suggesting no mortality of *T. pinguicolla* has resulted from this habitat management action.

THREATS

Tympanocryptis pinguicolla is a grassland specialist, being restricted to remaining fragments of native grassland. Approximately 99.5% of Natural Temperate Grassland (a nationally endangered ecological community, *EPBC Act 1999*) in Australia has been destroyed or drastically altered since European settlement (Kirkpatrick *et al.* 1995).

The major perceived threats to the continued survival of *T. pinguicolla* are:

- Loss and fragmentation of habitat through clearing of native grasslands for urban, industrial and infrastructure development and for agricultural purposes.
- Modification and degradation of native grassland habitat through incompatible and inadequate land management practices and weed invasion.
- Major ecological disturbances to grassland habitat such as widespread (unplanned) fire, drought and climate change.

Proposed future developments that may cause further loss and fragmentation of habitat for *T. pinguicolla* include:

- New roads through or adjoining habitat in the Majura and Jerrabomberra Valleys.
- Construction of a new taxiway at Canberra Airport.
- Very Fast Train in the Majura Valley.
- Urban or commercial development in the Jerrabomberra Valley.

Habitat fragmentation and degradation will exacerbate any effects on populations from climate change (Hoehn *et al.* 2013). Fragmentation increases the risk of extinction of isolated populations which suffer declines due to environmental disturbances such as wildfire and drought and can no longer be re-colonised by immigration from other populations. Fragmentation also exacerbates the loss of genetic diversity and increased inbreeding in isolated populations, which may compromise both short and long-term population viability by reducing individual fitness and limiting the gene pool on which selection can act in the future. Recent genetic research suggests:

- Majura and Jerrabomberra West populations are each genetically isolated from all other populations.
- There is limited gene flow between the Jerrabomberra East, Bonshaw and Queanbeyan Nature Reserve populations (Hoehn *et al.* 2013).
- Animals from Cookanalla show a high degree of relatedness, and the population may be at risk of inbreeding depression (Carlson 2013).
- The Monaro and ACT/Queanbeyan populations are genetically distinct and translocation and/or interbreeding should not be undertaken between these populations unless justified by rigorous research.

Degradation of ACT habitat may occur due to:

- **Weed invasion:** Weeds of most concern are African Lovegrass (*Eragrostis curvula*), Chilean Needle Grass (*Nassella neesiana*), Capeweed (*Arctotheca calendula*), Saffron Thistle (*Carthamus lanatus*), Paterson's Curse (*Echium plantagineum*) and St John's Wort (*Hypericum perforatum*) (Walker and Osborne 2010). These plants are aggressive colonisers and the grasses can form a monoculture by outcompeting native species for water, light and nutrients. The young forbs have rosettes that can fill inter-tussock spaces and obscure burrows, and the mature plants can shade the ground and release excess nutrients into the soil when they die at the end of the season. All may reduce the density of prey species and some of these plants can increase in abundance under grazing as they are avoided by kangaroos and/or stock (as they are unpalatable, toxic or spiny).
- **Cultivation and pasture improvement:** Ploughing is likely to destroy the arthropods that *T. pinguicolla* relies on to form burrows (Nelson 2004), and pasture improvement leads to damage similar to that described for weed invasion.
- **Overgrazing by kangaroos, rabbits or stock, or close mowing** leads to loss of tussock structure and excessive bare ground. A local study of ground-dwelling reptiles in grassy habitats showed that no species was more

likely to occur at high grazing intensities (Howland *et al.* 2014), however, this study did not include *T. pinguicolla*. High soil surface temperatures in summer require *T. pinguicolla* to retreat to burrows instead of feeding, and may contribute to loss of eggs and juveniles though overheating or desiccation (Nelson 2004; Dimond 2010; Doucette unpublished data). Excessive reduction in vegetation is also likely to lead to a reduction in prey (food) density and exposure of *T. pinguicolla* to increased predation. Overgrazing may reduce the number of burrowing arthropods that can be supported and burrow availability may then become a limiting factor for *T. pinguicolla*. Parts of three local *T. pinguicolla* populations were fenced to protect them from overgrazing by kangaroos late in the drought that ended in 2010.

- **Development of excessive vegetation biomass** due to insufficient grazing leads to a reduction in inter-tussock spaces for hunting and basking, a reduction in soil surface temperatures, and may increase the risk of wildfire. Recent analysis of kangaroo density and vegetation condition at many ACT grassy sites showed increased floristic diversity in moderately grazed grasslands due to the reduction in herbage biomass of more competitive plant species (Armstrong 2013). Moderate levels of kangaroo grazing are therefore required to maintain structural heterogeneity by preventing a few grass species from dominating the sward. Kangaroos have been allowed into the fenced Majura Training Area site since the drought ended, part of the Jerrabomberra East site is grazed by kangaroos, and monitored light sheep grazing is being trialled on part of Jerrabomberra West to keep herbage biomass within desirable limits (Cook *et al.* 2015).
- **Wildfire or inappropriate fire regimes:** Fire can be used to rejuvenate native grasslands and to maintain diversity in grassland structure, but widespread fire can also kill *T. pinguicolla*, reduce or alter habitat and temporarily reduce their food supply. There is a local record of *T. pinguicolla* both fleeing from and being killed by an unplanned fire (Osborne *et al.* 2009). Individuals have been recorded using an area in the year following a fire (Nelson *et al.* 1998b, Osborne *et al.* 2013) and in subsequent years (Evans and Ormay 2002, Cook *et al.* 2015). Small patch burning is being trialled at Jerrabomberra West Nature Reserve to promote structural heterogeneity in the sward.
- **Predation by cats, dogs and foxes:** Foxes are likely to be more numerous on the rural sites, and predation by domestic pets might cause increased predation rates where housing is developed close to *T. pinguicolla* sites.
- **Increased predation by native animals** due to: an increase in artificial perches (posts, fences, buildings) for birds such as magpies, ravens and raptors; exposure due to loss of groundcover; or enhanced shelter for snakes (e.g. through dumped materials or added logs/woody debris near *T. pinguicolla* habitat). Eastern Brown Snakes have been found to be efficient predators of *T. pinguicolla* (Doucette, unpublished data).

CHANGING CLIMATE

In addition to the above threats, the severe decline of *T. pinguicolla* during the 2002–10 drought suggests the species may be sensitive to the predicted effects of climate change. Recent modelling of the effect of climate change on reptiles predicts that by 2080 local reptile population extinctions could reach 39% worldwide, and reptile species extinctions may reach 20% (Sinervo *et al.* 2010). Warmer year-round temperatures are predicted for south-eastern Australia by the end of the century, with fewer frosts, more hot days and warm spells, and declining rainfall (especially in winter). These changes have the potential to affect reproduction and survival of *T. pinguicolla* as the structure of their habitat is sensitive to drought, and sparser ground cover will lead to higher ground temperatures.

Higher ground temperatures combined with drier soil may increase mortality of eggs and hatchlings through desiccation (Dimond 2010), thermal refuges may be less effective, and at high temperatures the daily activity period of *T. pinguicolla* is shorter, reducing foraging time (Doucette, unpublished data). The predicted temperature increase of 3–5 °C by 2080 could restrict activity sufficiently to prevent *T. pinguicolla* from obtaining adequate food to meet increased metabolic requirements during summer months (Doucette, unpublished data).

The temperatures experienced during embryonic development can determine the sex of some reptiles, but there is so far no evidence of this occurring when *T. pinguicolla* eggs are incubated at different temperatures in the laboratory (Doucette, unpublished data). There is a recent report of temperature-related sex reversal in females of another Australian Agamid (Bearded Dragon) in the wild, and subsequent controlled mating of normal males with sex-reversed females produced fertile offspring whose phenotypic sex was determined solely by temperature rather than chromosomes (Holleley *et al.* 2015).

MAJOR CONSERVATION OBJECTIVE

The overall conservation objective of this action plan is to maintain in the long term, viable, wild populations of *T. pinguicolla* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve all ACT populations.
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The known extant *T. pinguicolla* populations occur on land under a variety of tenures including nature reserve (Territory Land), rural leasehold Territory Land, Commonwealth owned and managed land (National Land) and unleased Territory Land. These sites are separated from one another by unsuitable habitat, roads and urban development.

Conservation effort for *T. pinguicolla* in the ACT is focused on protecting viable populations in functional native grassland habitat within two clusters of sites across its geographical range—the Majura Valley and the Jerrabomberra Valley.

Both provide the opportunity to also protect endangered Natural Temperate Grassland community and associated threatened species. Parts of a number of the ACT's *T. pinguicolla* sites are the subject of development proposals including an airport taxiway extension, the Very High Speed Train route, roads and urban development.

In the Majura Valley *T. pinguicolla* occurs on a relatively large patch (around 100 ha) of native grassland north of Canberra Airport on the Majura Training Area, which is Defence (Commonwealth) land. This area of high quality grassland is managed for conservation but is not formally protected.

The species has been recorded on the Majura Training Area to the east of the airport, which was a former property (Malcolm Vale) that was grazed. The species also occurs (at least intermittently) in grassland on Canberra Airport, which is not formally protected. Habitat on the airport is contiguous with habitat on the Majura Training Area. It is possible that the high quality grassland on the Majura Training Area north of the airport forms the core of the species' habitat on the eastern side of the Majura Valley and individuals disperse onto the airport during favourable years.

On the western side of the Majura Valley *T. pinguicolla* occurs in a large patch of native grassland (West Majura grassland) that adjoins woodland in the Mt Majura Nature Reserve. While not currently protected in reserve, this area is managed for conservation by the ACT Government and has been proposed for future formal protection. The species also occurs in adjacent grassland (Campbell Park) that is Defence (Commonwealth) land, which is not formally protected.

In the Jerrabomberra Valley some of the habitat is protected in nature reserve (Jerrabomberra West Grassland Reserve) and in a conservation area (Jerrabomberra East Grasslands). The species also occurs on Territory rural lands leased for grazing (Cookanalla), and on Territory land previously owned and managed by Defence (Harman/Bonshaw) that is not formally protected. The species has apparently become locally extinct from an area (about 20 ha) of unleased Territory land (AMTECH EAST Estate).

Protecting existing *T. pinguicolla* habitat in the ACT and preventing further fragmentation is important due to the limited known habitat for the species in the ACT and NSW, the genetic distinctness between the ACT/Queanbeyan and Monaro populations, and the recent rapid drought-associated decline in ACT and NSW populations.

The highest level of protection is in nature reserve, though populations of the species have been maintained on leased Territory land used for stock grazing, providing the grazing regime is compatible with maintaining suitable habitat. Where the species occurs on grazing land, an appropriate legislative mechanism should be applied to prevent habitat from being overgrazed or degraded. The ACT Government will liaise with the Department of Defence to encourage continued protection and management of *T. pinguicolla* populations on their land.

Given *T. pinguicolla* recently declined to extremely low or undetectable levels at some ACT sites, and that some recovery appears to be occurring, it should be assumed the species is present at any site where it has previously occurred since 1991 unless this is disproved by rigorous survey or the habitat has been destroyed. As a guide, Dimond (2010) determined that where population density was very low, 26 artificial burrows (Fletcher *et al.* 2009) would need to be checked for six weeks (18 checks, February–March) to have 50% confidence of detecting the species, with 167 burrows checked over the same time period for 99% confidence of detection.

The protection of *T. pinguicolla* habitat in the Jerrabomberra West Grassland Nature Reserve and Jerrabomberra East Grasslands has given protection to endangered Natural Temperate Grasslands and other threatened species in this community (Golden Sun Moth *Synemon plana*, Striped Legless Lizard *Delma impar*, Perunga Grasshopper *Perunga ochracea*). Management of all these species on the same site requires monitoring of their populations and their habitat, and integrated vegetation management strategies taking their different habitat needs into account.

While the Majura and Jerrabomberra populations of *T. pinguicolla* have a long history of separation by natural barriers, populations within each of the valleys have been fragmented into subpopulations by more recent anthropogenic land-use changes. Further fragmentation of habitat/populations is likely to increase the risk of localised extinctions and so should be avoided. There may be opportunities to promote expansion of *T. pinguicolla*

Grassland Earless Dragon (photo A Cumming)

populations into areas formerly occupied by the species. For example, appropriate management of grasslands (with the aim of restoring habitat) to the east of the airport, in north Callum Brae and in parts of Cookanalla might enable adjacent populations of *T. pinguicolla* to expand into these areas. There are currently significant technical and resource challenges to restoring native grasslands.

Even restoring grasslands to low or marginal quality habitat might enable *T. pingiuicolla* to colonise and occupy such areas during years when conditions are favourable for the species, and hence help maintain genetic diversity in the longer term.

There may also be opportunities to reconnect sub-populations. For example, maintaining a link between Jerrabomberra West Grassland Reserve and North Callum Brae, and linking populations on Cookanalla to Harman/Bonshaw. Habitat corridors linking sub-populations must be sufficiently large (wide) to enable movement between sub-populations and to not act as population 'sinks'.

Salvage, involving removal of animals from the wild, will be considered only as a last resort, and only in cases where the site is considered non-viable and an approved research project with identified facilities and appropriate research resources are available.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents including the ACT Environmental Offsets Assessment Methodology and the Significant Species Database.

An environmental offsets assessment may result in a development being 'flagged'. A flag identifies an area of land with significant protected matter values. If a proposed impact is flagged, it will require additional consideration by the Conservator of Flora and Fauna as to whether offsets are appropriate in the particular instance. *Tympanocryptis pingiuicolla* has been determined to have a high risk of local extinction in the event of further habitat loss in the ACT so offsets are not appropriate. A development proposal that is likely to result in impacts to this species will be flagged. Habitat for *T. pingiuicolla* has been mapped and must be avoided for development. The map provided on the ACT Government website (ACTMAPi) should be used to determine whether the species occurs on the site. If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

Over the past two decades there have been numerous, extensive surveys of potential habitat to determine the distribution of *T. pinguicolla* in the ACT. There is now a good understanding of the species' distribution but the area of occupancy of all suitable habitat at most sites has not been fully determined.

Further surveys should be undertaken at ACT sites where the abundance of the species across the site is not well understood. These areas include Majura West Grasslands, grassland on Defence land to the east of the airport (former Malcolm Vale property), North Callum Brae and Harman/Bonshaw.

Past surveys in potential habitat at a number of sites in the ACT did not detect the species. These sites should be revisited and the habitat assessed for quality and potential for presence of *T. pinguicolla*, and surveyed if appropriate (i.e. the area appears to contain habitat suitable for the species). Sites where surveys in potential habitat have not detected the species are:

- Belconnen Naval Base (surveyed in summer 1996, summer 2001)
- "Avonley" (surveyed in summer 1998)
- adjacent to Pialligo Avenue (surveyed in summer 1998)
- opposite airport on Majura Road (surveyed in summer 1998)
- RAAF Fairbairn (surveyed in summer 1998)
- "Dundee" (southern part of Majura Training Area, east of Canberra Airport, surveyed in Summer 1998)
- southern part of HMAS Harman (surveyed in summer/autumn/spring 2004–2006)

Regular abundance monitoring of the larger ACT *T. pinguicolla* populations has been undertaken since 2001 using fixed grids of artificial burrows. The Majura Training Area population has been monitored annually since 2001, the Jerrabomberra West Grassland Nature Reserve has been monitored since 2006 and the Jerrabomberra East grasslands since 2009. The Canberra Airport population (adjoining Majura Training Area) has also been monitored by the airport since 2007 (Rowell 2011 and unpublished data) and four monitoring surveys have been undertaken since 2007 for the Department of Defence at Bonshaw (adjoining Jerrabomberra Grassland Nature Reserve east) (Osborne *et al*. 2009, AECOM 2014). Monitoring has begun more recently at Cookanalla in the Jerrabomberra Valley.

This monitoring program has been undertaken by ACT Government staff from the Conservation Research section and, since 2005, has often been jointly undertaken with staff from ACT Parks and Conservation Service and researchers from the Institute of Applied Ecology at the University of Canberra. Prior to establishment of the monitoring program in 2001, these and other sites have been intermittently surveyed by ACT Government staff, and a number of university studies have been completed on the ecology of these populations.

Tympanocryptis pinguicolla populations can undergo major fluctuations in size, as evidenced by the severe decline to very low numbers towards the end of the 2002–10 drought, and subsequent increase. A representative set of sites with *T. pinguicolla* will need to be monitored to determine long-term population trends and to evaluate the effects of management. Key sites for population monitoring are those with an established long-term monitoring program (Majura Training Area, Jerrabomberra West Grassland Reserve, Jerrabomberra East Grasslands).

University research projects conducted on ACT *T. pinguicolla* populations and their habitat include undergraduate studies, honours projects, two PhD theses and post-doctoral research.

These studies have been undertaken in partnership with, or facilitated by, the ACT Government. Research projects have covered morphology, taxonomy, habitat investigations, population and species ecology (including thermal ecology), life history, population viability analysis, microhabitat use, diet, home ranges, genetic studies, captive breeding and studies of behaviour of wild and captive animals.

Research and adaptive management is required to better understand the habitat requirements for the species and techniques to maintain the species' habitat. Specific research priorities include:

- Optimal habitat requirements, particularly structure and biomass of the grass sward.
- Land management practices compatible with, or required for, maintaining suitable habitat (such as grazing, slashing, burning).
- Breeding requirements, oviposition sites, reproductive rates, and their relationship to habitat structure, seasonal conditions and predicted effects of climate change.
- Importance of availability and density of natural burrows, relationship between *T. pinguicolla* and burrowing arthropods, effect of burrow supplementation on sparse *T. pinguicolla* populations.
- Sensitivity of *T. pinguicolla* to weeds in its habitat, the weeds of major concern, and suitable control and revegetation methods.
- Techniques to maintain and breed the species in captivity (this knowledge will be required should captive insurance populations be required).
- Magnitude and significance of seasonal/annual *T. pinguicolla* population fluctuations (may require annual or biennial monitoring at key sites) and relationship to seasonal/annual conditions and habitat characteristics.

MANAGEMENT

Based on current knowledge of the habitat requirements of *T. pinguicolla*, management actions should aim to maintain grassland that has a well-defined tussock structure (i.e. tussocks with inter-tussock spaces). Tussock heights (i.e. the height of the bulk of the tussock leaves, not including the often few higher leaves and seed bearing culms) of the grass sward should be mostly between 5 cm and 15 cm, with well-defined inter-tussock spaces composed of shorter grasses, forbs and bare ground.

This structure can be achieved by maintaining intermediate levels of grass biomass. Management actions should avoid creating a grass sward that is uniformly very short (<5 cm) or uniformly very tall and dense (>15 cm high with very few inter-tussock spaces).

A 'patchy' sward containing grass tussocks of mostly intermediate height interspersed with patches of taller and shorter height tussocks with linked inter-tussock areas containing shorter grass and forbs (and which might include some bare ground), is likely to provide *T. pinguicolla* with a greater range of sites for shelter and thermoregulation, and a wider range and/or density of prey (Melbourne 1993, Stevens *et al.* 2010, Barton *et al.* 2011, Taylor 2014).

The arthropods which form the burrows used by *T. pinguicolla* also prey on invertebrates and are also likely to benefit from diversity in habitat structure.

From an ecological community perspective, a heterogeneous grass sward structure is likely to provide a greater range of habitat niches and hence support a greater diversity of grassland flora and fauna.

Maintaining a heterogeneous habitat is also an appropriate goal given imperfect knowledge of the long-term habitat requirements for *T. pinguicolla*.

Extensive survey, monitoring and research has been carried out on ACT *T. pinguicolla* populations since 2005. An adaptive management approach is being implemented as results of this work become available. Recent analysis of kangaroo density and vegetation condition at many ACT grassy sites has found increased floristic diversity in moderately grazed grasslands due to the reduction in biomass of more competitive species (Armstrong 2013). This suggests that moderate kangaroo grazing is likely to preserve structural heterogeneity in grasslands by preventing a few vigorous species from dominating the sward.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 2 Objectives, actions and indicators

Objective	Action	Indicator
1. Conserve all ACT populations.	Apply formal measures to protect all populations on Territory-owned land. Encourage formal protection of all populations on land owned by other jurisdictions.	All populations are protected by appropriate formal measures.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor abundance of key populations and the effects of management actions.	Trends in abundance are known for key populations. Management actions recorded.
	Manage habitat to maintain its suitability for the species, including implementing an appropriate grazing and fire regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and plant species composition). Potential threats (e.g. weeds) are avoided or managed. Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations, or to establish new populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity. If suitable habitat exists, re-establish populations where they have become locally extinct.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant species composition). If suitable habitat exists, research and trials have been undertaken to establish new populations.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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PERUNGA GRASSHOPPER
PERUNGA OCHRACEA

DRAFT ACTION PLAN

PREAMBLE

The Perunga Grasshopper (*Perunga ochracea,* Sjöstedt, 1921) was declared an endangered species on 19 May 1997 (Instrument No. DI1997-89 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1999 (ACT Government 1999a). This revised edition supersedes the earlier edition.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*), Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Golden Sun Moth (*Synemon plana*). This draft action plan includes any relevant parts of the Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Perunga ochracea is recognised as a threatened species in the following sources:

Australian Capital Territory

Vulnerable – Section 91 of the *Nature Conservation Act 2014.*

Special Protection Status Species - Section 109 of the *Nature Conservation Act 2014.*

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Perunga Grasshopper (*Perunga ochracea*) is the only described species in the genus *Perunga* (Orthoptera: Acrididae: Catantopinae – Spur-throated Grasshopppers), although the Australian National Insect Collection (ANIC) has specimens of an undescribed species (designated as *Perunga* sp. 1) known only from South Australia. *Perunga* belongs to the subtribe Apotropina of the tribe Catantopini (Rentz 1996). Members of the subtribe are characterised principally by the stout femur of the hind leg and the presence of an auditory tympanum on the anterior abdomen under the wings. In males, there is a furcula (a forked structure) near the tip of the abdomen.

Both sexes of *P. ochracea* are short-winged and flightless. The species is distinctive in having the pronotum (the dorsal surface of the first thoracic segment) wrinkled and slightly extended caudally.

There is a whitish dorsal streak extending from the keeled pronotum to the tip of the abdomen, and also a broad pale ‘X’ on the pronotum, which is the most useful field identification characteristic. The wings are shorter than the length of the pronotum and have many raised longitudinal veins. Adult females range in length from 26–35 mm and adult males from 15–20 mm. Females bear very short, stout cerci (the pair of appendages at the apex of the abdomen) and the dorsal ovipositor valves are strongly recurved. Males possess simple, elongate cerci, each with a blunt, rounded tip which is slightly deflexed (illustrated in Rentz *et al.* 2003). The dorsal background colour of adults is variable, and may be tan, grey-brown, or dull or bright green. The proportions of each colour morph can vary from year to year with a tendency toward grey-brown in dry years and greenish in wet years (R.C. Lewis pers. comm. in ACT Government 1999a). The ventral surface of the body is yellow and the upper surface of the tarsi is usually bluish. A colour photograph is found in Rentz (1996), and Rentz *et al.* (2003) has photographs showing nymphs (instars 1 to 5) and diagnostic features of adults.

DISTRIBUTION

Perunga ochracea was first described from a collection from Wagga Wagga in NSW. The ANIC contains ACT collections from 1941 onwards, but the early collections have poor location data. The early (pre-1970) NSW collections are from Uranquinty near Wagga Wagga, Boorowa and nearby Galong, and in areas adjacent to the ACT, including Jeir, Murrumbateman, north-west of Hall, and Queanbeyan.

More recent NSW records are from Gundaroo, Queanbeyan and Bungendore (ANIC, ACT Government records). In the ACT most records are from the northern lowland valleys, from the ACT border in the north to Tuggeranong in the south.

The southernmost ACT record is from the edge of Naas Road north of the junction of the Gudgenby and Naas rivers (R.C. Lewis pers. comm. in ACT Government 1999a). Some collection sites have since been developed for housing (Reid, Calwell, Gordon, O'Malley, Weetangera and Mt Jerrabomberra in NSW).

Invertebrate surveys and opportunistic sightings during routine monitoring of other species from 1997 onwards have shown that *P. ochracea* occurs at apparently low densities at a number of ACT sites, mainly in native-dominated grasslands. This includes Mulanggari, Gungaderra, Crace, Mulligans Flat and Gooroyarroo nature reserves in Gungahlin, several sites in the Majura Valley, Jerrabomberra West Nature Reserve and other sites in the Jerrabomberra Valley, on Lawson Commonwealth land (formerly Belconnen Naval Station), Lower Molonglo Nature Reserve, Red Hill Nature Reserve, and in the Murrumbidgee River Corridor in Tuggeranong.

Perunga ochracea appears to have a small range stretching 180 km east–west and 150 km north–south. However, the area of occupancy within much of this range is likely to be low because of the reduction in size or extinction of populations through habitat alteration and fragmentation. *Perunga ochracea* usually occurs at low densities and is mostly restricted to larger areas of remnant habitat. No population studies have been undertaken for *P. ochracea*, and so it is not possible to estimate population sizes.

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

In the ACT, *P. ochracea* has been found in Natural Temperate Grassland dominated by Wallaby Grasses (*Rytidosperma* spp.), Speargrasses (*Austrostipa* spp.) or Kangaroo Grass (*Themeda triandra*), and in other native grasslands (Stephens 1998, ACT Government records).

The species sometimes occurs in open woodland areas with a grassy understorey, including the endangered Yellow Box/Red Gum Grassy Woodland community, as suggested by earlier collections from the Black Mountain and Mt Majura areas, and more recent records from woodland at Red Hill Nature Reserve and Queanbeyan Nature Reserve West (ACT Government records).

Field observations suggest that *P. ochracea* uses grass tussocks as shelter spaces, and Farrow (2012) described occupied habitat at two sites as containing vegetation mosaics with tall tussock grasses, shorter grasses and forbs, and bare ground. The species has been recorded in heavily grazed habitats, where the availability of dense grass tussocks was low (Stephens 1998, ACT Government records). Stephens (1998) reported that in these instances the animals were found in or near grass tussocks, suggesting the need for these tussocks in the habitat.

Perunga ochracea is a cryptic grasshopper which is difficult to see unless first disturbed. When disturbed, the adult appears to actively seek shelter, jumping once or twice before burying itself into a grass tussock. It is a powerful jumper, covering distances of a metre or more. Nymphs hatch in late summer and autumn, and develop over the winter and early spring (Rentz 1996), with a first instar nymph recorded in late January (Stephens 1998). This life cycle is unusual compared with most other ACT grasshopper species which overwinter as eggs rather than nymphs. Adults of *P. ochracea* have been collected from late October to mid-February (ANIC specimens), and the life cycle is a single year. There are many more collections and records of adults than nymphs, which may mean that nymphs are more difficult to detect and identify.

Perunga ochracea is usually recorded as individuals or in low numbers (Stephens 1998, Farrow 2012, ACT Government records). This is the case for casual observations and targeted searches, and also for animals caught in pitfall traps, suggesting that *P. ochracea* is mostly sparsely distributed rather than just being difficult to detect. Population densities nevertheless vary among years and between sites (Farrow 2012, Rowell 2015).

There is little information on the diet of *P. ochracea*. It has been suggested the species has a dietary relationship with *Chrysocephalum* spp. (Rentz 1996), largely due to collection of the grasshopper at sites containing these forb species, particularly Common Everlasting Daisy (*Chrysocephalum apiculatum*). This plant occurs in native grasslands of varying quality and in open Box–Gum Woodland. Dietary analysis undertaken by Stephens (1998) of grasshoppers from ACT grasslands found that three more abundant grasshopper species in the same subfamily as *P. ochracea* (Catantopinae) showed a mixed forb-grass diet with a preference for forbs, while the six most abundant species in two other subfamilies collected (Acridinae, Oxyinae) showed a preference for a mixed forb-grass diet with grasses preferred over forbs.

Only six individuals of *P. ochracea* could be examined, and all had consumed forbs other than *C. apiculatum,* despite this forb being present at the collection sites. *Perunga* sp. 1, from South Australia, has been recorded eating the flowers and leaves of several species of forbs, and in feeding trials it fed on the petals and flowers of Capeweed (*Arctotheca calendula*), Wild Geranium (*Erodium* spp.) and Common Everlasting (P. Birks pers. comm. in ACT Government 1999a).

Although no work has been done to identify predators of *P. ochracea*, parasitic wasps *Scelio* spp. in south-eastern Australia have been shown to regulate some populations of other acridid grasshoppers (Baker *et al.* 1996). Vertebrate predators such as birds may reduce population numbers, as shown in studies of grasshopper assemblages (e.g. Belovsky and Slade 1993). Wolf Spiders (*Lycosa godeffroyi*), which are abundant in ACT grasslands, often eat other large grasshopper species (A. Rowell, pers. obs.).

PREVIOUS AND CURRENT MANAGEMENT

The management history of sites containing *P. ochracea* varies. Most sites were not grazed by stock when the species was first recorded, but many have subsequently had a history of grazing which has often been light or intermittent, and most sites have not been pasture improved. Most *P. ochracea* sites are not now grazed by stock, and grass biomass reduction is mostly by kangaroo grazing of varying intensity, or occasional slashing on a few sites. Two of three records of *P. ochracea* at Gungaderra Nature Reserve were made in the slashed fire break around the edges of an otherwise moderately dense and weedy grassland (ACT Government records), and Farrow (2012) did not find *P. ochracea* at a number of known sites when grass growth was very dense.

THREATS

Perunga ochracea is a grassland specialist, being found only in areas of native grassland or grassy woodland. Loss or degradation of habitat is the major threat to *P. ochracea*. About 99% of Natural Temperate Grassland (a nationally endangered ecological community, *EPBC Act 1999*) in Australia has been destroyed or drastically altered since European settlement (Kirkpatrick *et al.* 1995). About 5% or 1000 hectares of the original area of Natural Temperate Grassland in the ACT still exists in moderate to good condition (ACT Government 1997; 2005) and it is possible that as little as 3-4% of the original area of Yellow Box/Red Gum Grassy Woodland community in the ACT may remain in a relatively natural state (ACT Government 1999b). These native grasslands continue to be in demand for urban, industrial and infrastructure development as well as being vulnerable to alteration by weed invasion and agricultural practices.

Fragmentation and isolation of the remaining areas has resulted from the loss of extensive, contiguous areas of habitat. *Perunga ochracea* appears to occur in only some of the larger remnants of these grassland communities. Movement between habitat fragments or recolonisation after local extinctions is likely to be limited because adults of *P. ochracea* are flightless.This relative immobility also restricts gene flow between populations. Where the sex of *P. ochracea* was recorded in the ACT Government Wildlife Atlas, about 60% of the animals were females; about 60% of the ANIC collections were also females. Stephens (1998) noted that *P. ochracea* is often found as single animals, and that parthenogenesis is known to occur in some species of grasshoppers when they are at low densities and females are unable to find mates. Eggs and nymphs produced by parthenogenesis have high mortality. If parthenogenesis does occur in *P. ochracea*, this could cause problems if populations are fragmented and density is naturally low.

The invasion of native grasslands by exotic plant species changes the floristic composition of the grasslands. The effect of weed invasion on the habitat and food plants of *P. ochracea* has not been investigated, but is likely to be detrimental given the apparent preference of *P. ochraea* for grasslands composed of native plant species.

Optimal habitat requirements of *P. ochracea* are not known, but management that reduces grassland structure/patchiness or the amount of native forb cover is likely to be deleterious. The effect that predators may have in reducing population numbers is unknown, but a large slow-moving flightless grasshopper is likely to be more vulnerable to predation on overgrazed sites, where ground cover is low. The effect of fire on *P. ochracea* is also not known, but large scale autumn/winter burning may endanger nymphs.

Climate change has the potential to affect *P. ochracea* at various life stages. Warmer year-round temperatures are predicted for south-eastern Australia by the end of the century, with fewer frosts, more hot days and warm spells, and declining rainfall (especially in winter). As an autumn-hatching grassland species, the nymphs of *P. ochracea* are adapted to low winter temperatures, and the adults mate and lay eggs before the hotter summer weather. A meta-analysis of studies that measured the ability of animals to deal with extremes of heat and cold found that terrestrial ectotherms such as lizards and insects have a limited ability to physiologically acclimate to higher temperatures, and species that are close to their heat tolerance limit will be most at risk from climate change (Gunderson and Stillman 2015). The limited mobility of *P. ochracea* also makes it less able to adapt by moving to accommodate habitat change. Maintaining high quality habitat might facilitate resilience of *P. ochracea* to changing rainfall and temperature regimes.

MAJOR CONSERVATION OBJECTIVES

The overall conservation objective of this plan is to maintain in the long term, viable, wild populations of *P. ochracea* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Protect sites where the species is known to occur in the ACT from unintended impacts.
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The long-term conservation of *P. ochracea* depends on protecting its native grassland and grassy woodland habitat. The difficulty in surveying for *P. ochracea* means little information exists on population sizes at sites, and hence conservation priority for sites. However, as for most species, larger areas of habitat are more likely to contain larger populations, and due to genetic and other considerations, larger populations are more likely to be viable in the long term. All sites where *P. ochracea* is known to occur should be protected from unintended impacts, with formal protection given to (the generally larger) areas of native grassland habitat that are likely to remain viable and functional in the longer term. The protection of Natural Temperate Grassland and Yellow Box/Red Gum Grassy Woodland (both declared as endangered ecological communities) and the protection of native grassland as habitat for other threatened species allows for significant and complementary conservation actions for *P. ochracea*.

The known *P. ochracea* populations in the ACT occur on Territory land (including nature reserve, urban open space and leasehold rural land) and Commonwealth land controlled and managed by the Department of Defence. The ACT Government will liaise with the Department of Defence to encourage continued protection and management of *P. ochracea* habitat on their land.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. *Perunga ochracea* does not have any special offset requirements. *Perunga ochracea* is a species identified for ecosystem credits through its association with the Natural Temperate Grassland Endangered Ecological Community.

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

The few surveys designed to search specifically for *P. ochracea* have not found large numbers even at known sites (Stephens 1998; ERM 2007; Farrow 2012). Most records are observations of single individuals and around half of the sites where *P. ochracea* has been recorded are from an observation of a single individual. The most frequent sightings have been at Canberra Airport where *P. ochracea* was recorded in five different years, all during monitoring and mapping of other threatened species and the grassland community. Most *P. ochracea* records in the ACT Government Wildlife Atlas are incidental observations made during vegetation and reptile surveys in native grassland, and there are often several years between sightings despite other surveys being undertaken at the same sites.

Perunga Grasshopper (photo E. Cook)

Perunga ochracea is small and cryptic and has proven difficult to survey. Stephens (1998) found *P. ochracea* was difficult to collect by standard sweep-netting methods, and recommended timed direct searching (flush counting) in spring and summer as the most effective method, albeit time consuming. Timed direct searching involves flushing grasshoppers by slowly walking through a pre-determined survey area for a fixed time and stopping often to search grass tussocks. *Perunga ochracea* has been opportunistically detected in standard quadrats (20 x 20 m or 20 x 50 m) used for vegetation surveys (AECOM 2011; ERM 2011; Rowell 2015), suggesting survey for *P. ochracea* could be combined with vegetation surveys.

The results of past direct searches indicate that ten such quadrats might be necessary to detect a sparse *P. ochracea* population, while a dense population might be detected with one or two quadrats, and hence it might be possible to detect large changes in *P. ochracea* density at a site with a low number of quadrats. Farrow (2012) searched for *P. ochracea* in favourable habitat at known sites in December for one hour in a random way and concluded that using habitat as a surrogate for determining the distribution of the species was more practical than extensive direct searches.

Direct survey for *P. ochracea* might be worthwhile as part of assessing the effect of grassland management (controlled burning, wildfires, firebreak slashing, extensive weed control or stock grazing), particularly if undertaken as part of an experimental design (treatment and control quadrats) which should also provide a better understanding of the habitat requirements of the species.

Because surveys aimed solely at finding additional populations appear to be impractical (Farrow 2012), discovery of new populations is likely to be through surveys for other plant and animal species or from opportunistic observations from naturalists and other interested persons. Determining and monitoring population sizes of *P. ochracea* at known sites is likely to face similar challenges to survey for the species. Monitoring the vegetation structure, condition and floristic composition of larger remnants of native-dominated grasslands and grassy woodlands as part of broader condition monitoring of these communities will assist in detecting habitat changes (such as weed invasion) at the key sites where *P. ochracea* occurs.

There have been relatively few records of *P. ochracea* in the ACT region and hence little is known about distribution and abundance of the species within sites, or its ecology and biology. Priority areas for research to assist conservation of the species include:

- improved knowledge of distribution and abundance
- micro-habitat requirements
- diet
- dispersal abilities
- soil requirements for oviposition site selection
- effects of various grassland management practices, particularly grazing
- possible competition with other forb-feeding grasshoppers, particularly those which are known to have high population numbers, e.g. *Phaulacridium vittatum*
- the effect of predators on *P. ochracea* populations
- nymphal survival requirements.

The management history of sites containing *P. ochracea* varies. Most sites were not grazed by stock when the species was first recorded, but many have subsequently had a history of grazing which has often been light or intermittent, and most sites have not been pasture improved. Most *P. ochracea* sites are not now grazed by stock, and grass biomass reduction is mostly by kangaroo grazing of varying intensity, or occasional slashing on a few sites. Two of three records of *P. ochracea* at Gungaderra Nature Reserve were made in the slashed fire break around the edges of an otherwise moderately dense and weedy grassland (ACT Government records). Farrow (2012) did not find *P. ochracea* at a number of known sites when grass growth was very dense.

MANAGEMENT

Perunga ochracea is known to be a specialist of native grasslands, though detailed habitat requirements are not well understood. Recorded sightings of *P. ochracea* suggest a preference for shorter grass and avoidance of tall, dense swards, though sightings might be biased if the species is more visible in shorter grass. The use of forb species as food plants suggests the need for openings (inter-tussock spaces) in the grassland for these forb species to grow.

In addition, many grasshopper species require open areas in which to bask and for females to lay their eggs (Urarov 1977). Fire can be important in creating gaps in Kangaroo Grass (*Themeda triandra*) grasslands, allowing the establishment of a number of forb species (Morgan 1998), which may be *P. ochracea* food plants. However, the effect of fire on adults and overwintering nymphs needs to be determined if extensive burning is to be used to manage grasslands in which they occur. The effect of grass slashing on *P. ochracea* (through direct mortality) is not known, though the species has persisted on Canberra Airport which is regularly slashed. Grass biomass/structure management by grazing (native or introduced herbivores) is likely to cause the least impact to the species from direct mortality.

Dennis *et al.* (1998) found that arthropod diversity and abundance in grazed grasslands was positively associated with floristic diversity and structural heterogeneity, and declined with grazing intensity, and that the reduction of arthropods with increased grazing intensity was buffered in grasslands with substantial patches of tussock.

Recent analysis of kangaroo density and vegetation condition at many ACT grassy sites showed increased floristic diversity in moderately grazed grasslands due to the reduction in biomass of more competitive plant species (Armstrong 2013).

Higher abundance and diversity of grassland beetles have been found to be associated with low to moderate kangaroo densities (Barton *et al.* 2011), and maintaining a mix of moderate and high grass height within reserves has been recommended for the conservation of reptile diversity (Howland *et al.* 2014). While the relationship between kangaroo grazing and the quality of *P. ochracea* habitat has not been determined, the apparent need of *P. ochracea* for structural variety suggests that low to moderate kangaroo grazing may also favour the species.

Results from a grassland enhancement trial at Canberra International Airport suggest that a sparse *P. ochracea* population can respond strongly to improved conditions. The trial area initially contained native-dominated grassland with few native forbs. Eight 20 x 20 m quadrats (0.32 ha) were monitored in spring 2011 before the trial began, and again in 2012 and 2013 after the vegetation treatments.

Half the quadrats were treated, which involved machine removal of impacted thatch, cutting and removing slashed material several times over two years, and planting of native forbs. The results of the treatment were a sharp but temporary increase in bare ground and *Chrysocephalum apiculatum* cover, a sustained decrease in litter, and higher native forb cover after two years. No *P. ochracea* were seen in any of the quadrats in spring 2011 or 2012, but in 2013, 29 *P. ochracea* were recorded in the treated quadrats and five in the controls which were adjacent to them. The increase in *P. ochracea* numbers was found to be confined to the treated area and adjacent control plots by monitoring eight more distant quadrats on untreated parts of the airport. No *P. ochracea* were found in these distant untreated areas in 2013, despite being occasionally recorded there in previous years. The vegetation changes associated with the trial apparently created preferred habitat for *P. ochracea*, possibly by increasing food availability and/or creating more favourable egg-laying sites.

The trial also showed that the effects of habitat changes on *P. ochracea* may need to be monitored over at least three seasons (Rowell 2015).

Until detailed habitat requirements of *P. ochracea* are known, management should aim to maintain native grassland habitat in good condition (such as controlling weeds) with inter-tussock spaces to promote native forb growth. Managing for a heterogeneous sward (patchy mosaic of short, moderate and long grass) within sites is likely to be an appropriate goal for native grasslands where a range of grassland fauna occur, including *P. ochracea*.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1 Objectives, Actions and Indicators

Objective	Action	Indicator
1. Protect native grassland sites where the species occurs from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).	Ensure native grassland sites on Territory-owned land where the species occurs are protected from unintended impacts. Encourage other jurisdictions to protect sites where the species occurs on their lands from unintended impacts.	All native grassland habitat is protected from unintended impacts by appropriate measures.
	Maintain a database of sightings of the species, and if available, record habitat information.	Records of sightings are maintained and used to determine the distribution of the species in the ACT.
	Identify other sites where the species occurs by maintaining alertness to the possible presence of the species while conducting vegetation surveys in suitable habitat.	Vegetation surveys in suitable habitat also aim to detect the species.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor the effects of management actions at a representative set of sites where the species is known to occur.	Management actions are recorded.
	Manage habitat to maintain its suitablilty for the species, including implementing an appropriate grazing / slashing / burning regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and herbage mass). Potential threats (e.g. weeds) are avoided or managed.

Objective	Action	Indicator
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant species composition).
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in, the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

ACKNOWLEDGMENTS

Alison Rowell contributed to the preparation of this Action Plan. The illustration of the species was prepared for the ACT Government by Kim Neubauer.

COMMUNICATIONS

Mr P.R. Birks undertook feeding trials on the only other species in the genus, the South Australian *Perunga* sp 1.

Mr R.C. Lewis surveyed grasshoppers in the ACT from 1974-1980.

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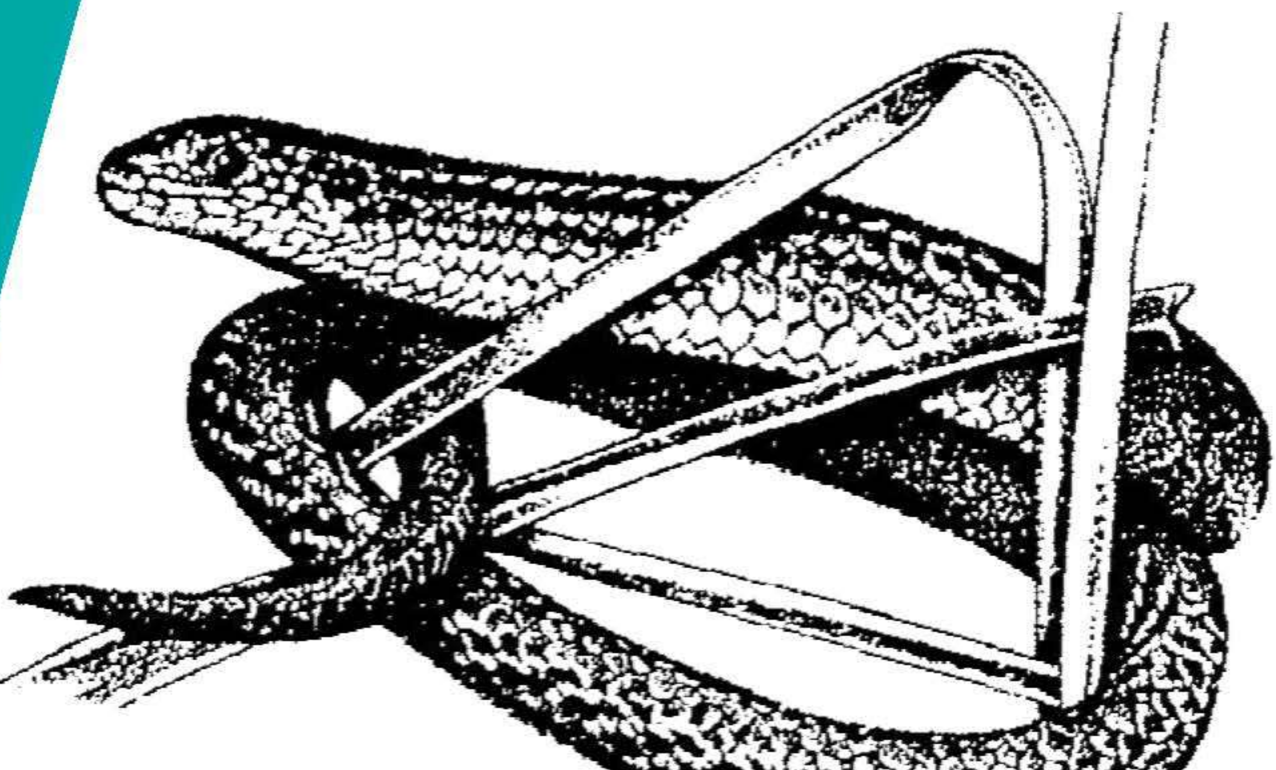
STRIPED LEGLESS LIZARD

DELMA IMPAR

DRAFT ACTION PLAN



PREAMBLE

The Striped Legless Lizard (*Delma impar* (Fisher, 1882)) was declared a vulnerable species on 15 April 1996 (Instrument No. DI1996-29 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1997 (ACT Government 1997) and the second in 2005 (ACT Government 2005). This revised edition supersedes the earlier editions.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Golden Sun Moth (*Synemon plana*). This draft action plan includes any relevant parts of the "Draft ACT Native Grassland Conservation Strategy.

CONSERVATION STATUS

Delma impar is recognised as a threatened species in the following sources:

International

Vulnerable – IUCN (2015).

National

Vulnerable – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Australian Capital Territory

Vulnerable – Section 91 of the *Nature Conservation Act 2014*. Special Protection Status Species - Section 109 of the *Nature Conservation Act 2014*.

New South Wales

Vulnerable – *Threatened Species Conservation Act 1995*.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988*.

South Australia

Endangered – *National Parks and Wildlife Act 1972*.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Striped Legless Lizard (*Delma impar* Fischer 1882) is a member of the family Pygopodidae, a group of lizards that lack forelimbs and have hind limbs reduced to small vestigial flaps (Cogger 2000). Legless lizards can be readily distinguished from small snakes by having a visible ear opening, fleshy broad tongue, the presence of remnant hind limbs (reduced to two small flaps near the vent) and a long tail that can be voluntarily shed.

Delma impar attains a maximum length of about 300 mm, of which the tail (when intact) comprises about two-thirds of the overall length. Fully grown *D. impar* attain a snout–vent length of around 90 mm–110 mm, though individuals are considered to be adults when they reach a snout–vent length of 70 mm (Banks *et al.* 1999), based on the minimum length of wild-caught gravid females in the ACT (Rauhala 1996, 1997). Adults average around 3–4 g but gravid females can weigh over 8 g (Hadden and Humphries 1994; Kukolic 1994; Osmond 1994; Coulson 1995).

Delma impar are usually pale grey-brown on the dorsal surface and white or cream on the ventral surface. As the name suggests, the species typically has a pattern of alternate dark and brown stripes running the length of the body on the dorsal-lateral and lateral surfaces, beginning at the neck and becoming diagonal on the tail. The stripes may be faint or absent in some individuals, particularly juveniles. The head is usually slightly darker than the body (slate grey to black), more conspicuously so in juveniles, and the sides of the face (from the posterior infralabial scales to around the tympanum) usually have a yellow flush (Coulson 1990).

The pattern of the head scales is unique to each individual and enables individuals to be identified. Some individuals have a salmon-pink coloration on the flanks that may extend to the ventral surface (ACT Government 1997). The ring of small scales around the eye is pale (almost white) in some individuals. The sexes are externally similar, though males may be distinguished by the presence of small, rounded, cloacal spurs under each hind limb flap (Rauhala and Andrew 1998; Robertson and Smith 2010). When handled, individuals often emit a high-pitched 'squeaking' vocalisation.

Delma impar can usually be distinguished from the Olive Legless Lizard (*Delma inornata*), a closely related species which also occurs in the ACT region, by the presence of stripes and the smaller size of adults.

DISTRIBUTION AND ABUNDANCE

Prior to European settlement, *D. impar* was most likely distributed broadly in south-eastern Australia wherever suitable habitat (native grassland) was present. Historic and current records of the species come from South Australia, Victoria, New South Wales and the Australian Capital Territory. Victoria encompasses the largest part of the known distribution; most records are from the central and western plains, with a few isolated records from the north-east of the state. The species is known to still occur at about 70 sites in Victoria, though many of these are small in area (such as road reserves) and only ten sites are protected in conservation reserves (Robertson and Smith 2010). In South Australia the species is known to occur in three areas, two of which are protected (one in a conservation reserve and another in a catchment reserve) (Robertson and Smith 2010). In New South Wales *D. impar* are known to still occur at seven locations, all of which are within 100 km of the ACT. Only one of these locations is protected (Kuma Nature Reserve).

In the ACT *D. impar* are known to occur in four discrete areas: the Gungahlin/Belconnen area, the Majura Valley in the vicinity of the Canberra International Airport, in Central Canberra on land adjacent to Yarrumundi Reach on Lake Burley Griffin and in the Jerrabomberra Valley.

These four populations are effectively isolated by geographic and anthropogenic barriers, and may represent genetically distinct sub-populations. The species occurs on a range of land tenures, including nature reserve and other land managed by the ACT Government, land owned and managed by the Commonwealth Government, and leasehold land.

In Gungahlin *D. impar* is protected in three reserves (Crace, Gungaderra and Mullanggari grassland reserves), which total over 500 ha and contain Natural Temperate Grassland, native grassland and areas dominated by exotic grasses. The boundaries of these reserves were determined on the basis of both the remaining fragments of Natural Temperate Grassland and the distribution of *D. impar*. Surveys in 2012 (Eco Logical 2013) indicate that each of the three Gungahlin reserves contains at least 1000 *D. impar*, representing some of the largest remaining populations of the species. *Delma impar* also occurs across a broad area (about 250 ha) in Kenny in the south of Gungahlin. This area was surveyed for *D. impar* in 2011 and 2012 (Biosis 2011b, 2012a) and is estimated to contain 1000 or more individuals. Other locations where *D. impar* occur in Gungahlin/Belconnen include in a patch of grassland (14 ha) to the north of the Mitchell industrial area (North Mitchell Grassland) and several small grassland fragments.

In the Majura Valley *D. impar* occurs in a large patch of native grassland (about 100 ha) on the Majura Training Area (Defence land), in a large patch of native grassland (about 150 ha) adjacent to Mt Majura Nature Reserve (Majura West grassland), and in grassland between Woolshed Creek and the Majura Parkway (Woolshed Creek grassland) (about 47 ha) (Biosis 2014). The species has also been recently recorded in grassland north of Majura Training Area (SMEC 2015) and in Piallago (Jessop 2014).

In the Jerrabomberra Valley *D. impar* occurs across extensive areas of grassland in the central and eastern parts of the valley, mostly between the Monaro Highway and the ACT–NSW Border (SMEC 2015). The species also occurs in grassland (about 18 ha) on the AMTECH EAST Estate and in several grassland patches to the east of Fyshwick. The density of *D. impar* in habitat in the Jerrabomberra Valley is apparently lower than that of Gungahlin and the Majura Valley indicating lower quality habitat for the species in the Jerrabomberra Valley, which might be due to past or current land management practices.

The small patch of grassland at Yarramundi Reach in Central Canberra supports a small population of *D. impar* scattered across the site at low density (Kukolic 1994; ACT Government unpublished data). This patch of grassland also supports a small population of the related Olive Legless Lizard (*D. inornata*).

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal (Visit the ACTmapi website).

HABITAT AND ECOLOGY

The habitat of *D. impar* has been broadly described as naturally treeless grassland dominated by native, perennial, tussock-forming grass, particularly Kangaroo Grass (*Themeda triandra*), Wallaby Grasses (*Austrodanthonia* spp.) and Speargrasses (*Austrostipa* spp.) (Coulson 1990; Osborne *et al.* 1993; Hadden 1995). Although *D. impar* is largely restricted to areas that are (or were) lowland Natural Temperate Grassland, the species has also been found in grassland with scattered Eucalyptus trees (but not where canopy cover is high) and in grassland that has been derived from clearing of Eucalypts ('secondary grasslands') (Coulson 1990; Williams and Kukolic 1991; Osborne *et al.* 1993; Dorrough 1995; Hadden 1995; Howland *et al.* 2014). Records of *D. impar* in secondary grasslands are invariably from within two kilometres of the original boundary of the primary grasslands. *Delma impar* has also been found in degraded Natural Temperate Grasslands that are now dominated by exotic species such as Phalaris (*Phalaris aquatica*), Cocksfoot (*Dactylis glomerata*) and Serrated Tussock (*Nassella trichotoma*) (Coulson 1990; Williams and Kukolic 1991; Kukolic *et al.* 1994; Dorough 1995; Hadden 1995; Rauhala *et al.* 1995; Dunford *et al.* 2001; Biosis 2012; Howland *et al.* 2015). Degraded areas where the species has been recorded include a former quarry in Crace (Biosis 2012) that was converted to an asbestos dump and rehabilitated to grassland in the 1980s.

Surveys to better understand the distribution, abundance and habitat preferences of *D. impar* in the ACT have been undertaken since 1990 by the ACT Government (Conservation Research or contracted consultants) (e.g. Williams and Kukolic 1991; Kukolic *et al.* 1994; Rauhala *et al.* 1995; Rauhala 1996, 1997, 1999; Dunford 1998; Nelson *et al.* 2000; Dunford *et al.* 2001; Moore *et al.* 2010; Biosis 2011a, 2011b, 2012a, 2012b 2013, 2014; Eco Logical 2011, 2013; Jessop 2014; Howland *et al.* 2015; SMEC 2015). Habitat preference was initially described as being areas dominated by native tussock-forming grasses Tall Speargrass (*Austrostipa bigeniculata*) and Kangaroo Grass with "extensive and intact swards and a well-developed grass thatch" (Williams and Kukolic 1991). Kukolic *et al.* (1994) trapped *D. impar* in patches of *Juncus* species and Serrated Tussock during periods when native tussock-forming grasses in the same paddock had been heavily grazed, and concluded that it was the presence of a particular grass structure (tussocks) rather than species of grass that was probably essential to the long-term survival of *D. impar*. Unpalatable tussock-forming plants such as *Juncus* spp. and Serrated Tussock can apparently act as temporary refuge for *D. impar* during periods of heavy grazing, facilitating the species' recolonisation of areas of native grasses when stock are removed (Kukolic *et al.* 1994; Rauhala 1997).

Surveys involving pitfall trapping at up to 50 locations in ACT grasslands over a number of years (Rauhala *et al.* 1995; Rauhala 1996, 1997, 1999) found higher capture rates for *D. impar* (including gravid females) at sites where tussock leaf height was between 20 and 50 cm (with the two sites having the highest capture rates having a grass leaf height around 20–25 cm) and projected tussock foliage cover was between 35% and 80%. At the Majura Training Area, *D. impar* captures were relatively high in an area that had not been grazed for 25–30 years and tussocks were tall and dense, whereas captures were low in the adjacent paddock where grazing had resulted in a shorter and more open tussock structure. *Delma impar* was mostly absent from grazed areas where grass height was below 20 cm and almost no tussock structure existed. More recent surveys in the ACT using roof tiles as artificial shelter sites (Moore *et al.* 2010;

Biosis 2012; EcoLogical 2013) confirmed high densities of *D. impar* in areas with intermediate to tall grass, though no comparison was made with areas of low grass height. Howland *et al.* (2014; 2016), also using roof tiles, modelled habitat preferences for *D. impar* and found the species preferred grass swards of intermediate biomass rather than very low or very high biomass, and a structurally complex sward.

Grass structure and biomass are related; intermediate levels of biomass tend to be structurally complex (tussocks and inter-tussock spaces) whereas a grass sward that is very short, or very high and dense, tends to be more uniform in structure.

In Victoria, *D. impar* can occur in areas where the grass sward is short if deep-cracking soil or scattered surface rock is present as these are used as refuges (particularly for over-wintering) (Coulson 1990; Hadden 1995). Such habitats are not a feature for *D. impar* habitat in the ACT.

There are still large knowledge gaps in the life history and ecology of *D. impar*, which is partly a reflection of the difficulty in studying this shy, cryptic species. *Delma impar* are thought to reach breeding age at 2–3 years for males and 3–4 years for females (ARAZPA 1996). This is based on evidence for other lizard species and a single ACT record of a female captured at about one year old (based on snout–vent length) that was recaptured three years later in a gravid condition and subsequently laid eggs in captivity (ARAZPA 1996). From observations of *D. impar* laying in captivity (Banks *et al.* 1999) and data from other Pygopodids (Cogger 2000), only two eggs are produced, most probably each year (Coulson 1995; ARAZPA 1996). Cohabitation of wild gravid *D. impar* (Rauhala 1996) and communal clutches of up to 36 eggs (Robertson and Smith 2010) have been observed. There is some evidence that rocks are used as oviposition sites (Rauhala 1996), as well as soil cavities (including artificial arthropod burrows used to capture Grassland Earless Dragons (Osborne and Dimond 2008; M. Evans and E. Cook pers. obs.). Eggs are laid in December and January and, following a variable incubation period (38–47 days in Banks *et al.* 1999 and 35–60 days in Coulson 1995), hatch in January and February.

Longevity of individuals is not known, though adults in the wild have been recaptured almost seven years after first capture (Rauhala 1997) and adults have been held in captivity for 12 years (Robertson and Smith 2010). Based on data from other lizard species, it is likely that longevity of *D. impar* is between 10 and 20 years (ARAZPA 1996).

There have been a number of studies of the diet of *D. impar* (e.g. Coulson 1990; Wainer 1992; Nunan 1995; O'Shea and Hocking 2000) and these have shown that the lizards will eat a broad spectrum of invertebrates found in grasslands, with apparent preference (selectivity) for spiders, crickets, caterpillars and cockroaches. Prey types eaten to a lesser extent were grasshoppers, butterflies, moths, beetles and flies. Slaters, ants and bugs, while relatively common in the field, were rarely eaten.

Little information exists on the activity and movement of *D. impar* due to their cryptic behaviour and small size, which precludes using radio transmitters. Most movement and activity data come from trapping and mark–recapture studies. *Delma impar* are more readily caught in pitfall traps during spring and summer, particularly October to December (Kutt 1991; Kukolic 1993, 1994; Osborne *et al.* 1993; Osmond 1994). Gravid females are caught mostly from late November to early January (Kutt 1991; Kukolic 1993; Osmond 1994), with capture rates steadily declining through January and February (Osmond 1994). In captivity *D. impar* have been found to be active over a wide range of temperatures, with a preference for an ambient temperature of around 24–26^{0}C, and up to 29^{0}C for gravid females (Coulson 1990; Osmond 1994). Captive animals have been observed to burrow into soil during the late afternoon, re-emerge in the morning as temperatures increase and remain active during most of the day, including basking in sunshine (Martin 1972; Osmond 1994). The limited field observations suggest the animals are also diurnally active in the wild (Coulson 1990).

Distances moved by *D. impar* (and hence home range size) appear to be highly variable between individuals. Using pitfall traps, Kukolic *et al.* (1994) recaptured 13 individuals that had moved between 2.5 m and 62.5 m (mean 14 m) straight line distance between captures that spanned an interval of up to nine days. One individual travelled 60 m in two days. Rauhala *et al.* (1995) found no relationship between distance moved and number of days since recapture. Of the ten individuals recaptured by Rauhala *et al.* (1995), the two longest straight-line distances were 52 m and 58 m, which occurred over a short period (two days), whereas the shortest movement (5 m) occurred over a relatively long period of 20 days. Dunford (1998) recaptured an individual that was 160 m away from where it had been captured three years previously. Tracking individuals marked with fluorescent powder has revealed movements vertically and horizontally through grass tussocks and along the surface of the soil for distances up to 20 m in a day (Kutt 1993).

A survey using arrays of roof tiles (as shelter sites) to detect the species found most lizards were recaptured under the same tile, and less than 10% of recaptures were further than 10 m from the original capture location, though one individual was found to have moved 80 m (Eco Logical 2013). Home ranges have been conservatively estimated at 10 m^2 based on recaptures using tiles in Victoria (Robertson and Smith 2010), though a larger area of about 10 m x 10 m (i.e. 100 m^2) appears to be a reasonable generalisation based on pitfall and tile recapture data.

Striped Legless Lizard

PREVIOUS AND CURRENT MANAGEMENT

In the ACT, *D. impar* occurs in areas with a variety of management regimes, which includes grazed, slashed, occasionally burnt and relatively undisturbed. The species occurs in native grassland on the Majura Training Area (MTA) (Department of Defence land), which is managed for conservation and is generally only lightly grazed by kangaroos. *Delma impar* has also been recorded in the Airport Services Beacon paddock, a fenced area of about 10 ha that is contiguous with habitat on the MTA and which has not been grazed for at least three decades. In contrast, *D. impar* has not been detected in the adjoining native grassland on Canberra Airport, which is subject to a slashing regime to maintain a moderately short (10 cm high) grass sward. The grassland at Majura West is grazed by kangaroos and in the past has been grazed by sheep. The Woolshed Creek grassland (adjacent to the Majura Parkway) is part of a grazing lease and is subject to grazing by sheep and kangaroos.

Management of the three Gungahlin grassland reserves (Crace, Mulanggari, and Gungaderra) is aimed at maintaining a grass sward mostly above 10 cm height. These areas have been previously grazed by cattle. Current management of these reserves includes grazing by kangaroos, slashing along tracks and fence lines, and patchy fuel reduction burns.

Management of the small patch of grassland at Yarramundi Reach has included slashing, occasional patch burns and weed control, which (at least over the past decade) has maintained generally moderate to high grass biomass. Grassland habitat for *D. impar* in the Jerrabomberra Valley (most of which until recently was on land managed by Defence) is subject to generally light grazing by kangaroos and sheep.

During the 2001–09 drought, most sites where *D. impar* occur in the ACT were overgrazed by kangaroos and at some sites by stock. Overgrazing was particularly severe in the Majura Valley at the MTA (kangaroos) and West Majura (kangaroos and sheep). Sheep were removed from Majura West during the drought when overgrazing became evident. The height and biomass of the grass sward has since recovered at overgrazed sites.

Grasslands in the ACT, including *D. impar* habitat, are subject to planned and unplanned fire. Planned fire is used in grassland for ecological purposes and for fuel reduction. Burning in grasslands can cause direct mortality of *D. impar* (Kukolic 1994; Coulson 1995; Walton 1995).

Dunford (1998) captured *D. impar* in unburnt grassland and adjacent grassland that had been burnt by wildfire the previous year, suggesting the species is capable of using grassland at least one year following fire if animals are able to disperse into the area from adjacent unburnt areas. The species has continued to be present in the burnt area in subsequent years (Nelson *et al.* 2000).

THREATS

Delma impar is a grassland specialist, being found only in areas of native grassland or grassy woodland and nearby exotic pasture (Robertson and Smith 2010). Approximately 99.5% of Natural Temperate Grassland (a nationally endangered ecological community, *EPBC Act 1999*) in Australia has been destroyed or drastically altered since European settlement (Kirkpatrick *et al.* 1995).

The major perceived threats to the continued survival of *D. impar* are:

- Loss and fragmentation of habitat through clearing of native grasslands for urban, industrial and infrastructure development and for agricultural purposes.
- Modification and degradation of native grassland habitat through incompatible and inadequate land management practices, weed invasion.
- Other potential effects of urbanisation, including increased incidence of predation and frequency of fires.

Delma impar may persist for some time in modified (largely exotic) grasslands, but it can be eliminated from an area by extended intense grazing, pasture improvement, ploughing, drought or other heavy disturbance. Such areas may be recolonised by the species, but this is probably dependent on the availability of nearby undisturbed refuge areas (Robertson and Smith 2010).

It is likely that *D. impar* is preyed upon by a range of natural predators, including predatory birds and snakes, though the extent of such predation is unquantified. However, there is speculation that an increase in perching structures (electricity poles, fence posts) in and adjacent to *D. impar* habitat may lead to an increase in predation rates. *Delma impar* may also be susceptible to predation by introduced predators; there is anecdotal evidence to suggest foxes may prey upon the lizards (Robertson and Smith 2010) and domestic/stray cats could have a large impact on local populations where suburban housing abuts grasslands.

Overgrazing or drought resulting in lack of ground cover for this diurnal species would be expected to expose the lizards to increased predation.

The effect of fire on *D. impar* is not well understood. Fire has been observed to cause direct mortality of individuals (Coulson, 1995; Walton, 1995) and recently burnt habitat is likely to expose the lizards to increased predation. The species has been found to persist in areas that have been burnt in both short and medium timeframes (Roberson and Smith 2010). It is likely that intense, widespread fires have a greater impact on the species than low-intensity, patchy burns over small areas.

MAJOR CONSERVATION OBJECTIVE

The overall conservation objective of this action plan is to maintain in the long term, viable, wild populations of *D. impar* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species.

This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve large and medium-sized populations in the ACT.
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The long-term conservation of *D. impar* depends on protecting its grassland habitat as a cluster of sites across the geographic range of the species in the ACT. This cluster of sites should contain the larger populations of *D. impar* in formally protected areas, and medium-sized populations in areas that are managed to conserve the species.

Larger populations of the species are considered to be those containing 500 or more individuals that occupy habitat patches of 50 ha or more. As a general principle, populations of around 500 or more breeding individuals are genetically robust over the longer term. Larger areas of habitat are better buffered against edge-effects and provide populations with some resilience against planned or unplanned fire (there is less chance the whole area will burn because of natural vegetation patchiness). These areas can also protect against climatic extremes because of the greater heterogeneity of microhabitats likely to be present across the site. Thus, large populations, because of their size and the extent of their habitat, are expected to have the greatest chance of long-term viability. Sites likely to contain large populations of *D. impar* are Crace, Mullanggari and Gungaderra Nature Reserves, Kenny, Majura Training Area, Majura West and the large area of grassland habitat east of the Monaro Highway in the Jerrabomberra Valley.

Medium-sized populations are considered in this plan to contain 200 or more individuals (but do not meet the criteria for a 'large' population). A medium-sized population has the potential to be viable over the longer-term if habitat quality is maintained through appropriate management and threats (such as predation by foxes and cats) are also managed. Habitat for medium-sized populations that do not occur on a protected area should be managed to conserve the species through an appropriate mechanism such as land management agreement or Conservator's Directions. Medium-sized populations are likely to be present in the North Mitchell grassland, Jerrabomberra West Nature Reserve, patches of grassland in the Majura Valley (east of the Majura Parkway), in Fyshwick (east) and in the Woolshed Creek grassland.

Small populations (less than 200 individuals) can still form a significant contribution to the conservation of the species, particularly if small populations are connected by habitat so that they function as a linked cluster or a small population is connected by a habitat corridor to a larger population.

Protecting intact native ecosystems is generally preferable to protecting areas solely for a single threatened species. Priority should be given to protecting habitat for *D. impar* that results in broader conservation gains, such as conserving other threatened, declining or rare species, or conserving native grasslands with component native fauna.

In the ACT *D. impar* occurs on Territory land (including nature reserves and leasehold rural land) and Commonwealth land controlled and managed by the Department of Defence. The ACT Government will liaise with the Department of Defence to encourage continued protection and management of *D. impar* populations on their land.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. The special offset requirement for *D. impar* is "no loss of known habitat within Conservation Significance Category 1 grasslands as specified in the ACT Native Grassland Conservation Strategy".

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

SURVEY, MONITORING AND RESEARCH

Over the past two decades there have been numerous, extensive surveys to determine the distribution of *D. impar* in the ACT, and it is unlikely any large populations remain undiscovered. However, it is possible that small populations of *D. impar* persist in some of the numerous small fragments of grassland (many of which are dominated by exotic grasses) that have not been surveyed for the species. Knowledge of the distribution and abundance of *D. impar* in the ACT will be refined from data collected during surveys for other grassland fauna species or from opportunistic observations from naturalists and other interested persons.

A representative set of sites containing *D. impar* will need to be monitored to determine long-term population trends and to evaluate the effects of management.

Research and adaptive management is required to better understand the habitat requirements for the species and techniques to maintain the species' habitat. Specific research priorities include:

- Optimal habitat requirements, particularly structure and biomass of the grass sward.
- Land management practices compatible with, or required for, maintaining suitable habitat (including grazing, slashing, burning).
- Susceptibility to fires and seasonal effects of fires, optimum fire regimes, value and use of firebreaks.
- Seasonal home range area, movements, habitat use (including daily shelter sites, over-wintering sites and oviposition sites), dispersal ability.
- Efficient methods for monitoring abundance, absolute population size, long-term population trends and magnitude of seasonal/annual population fluctuations.
- Impact of barriers such as roads and cycle paths.
- Relative importance of predation by native, feral and domestic animals.

Current research includes:

- Trialling fire as a tool to manage grass biomass/structure in *D. impar* habitat (ACT Government).
- Translocating individuals from a proposed development site in Kenny to potential habitat in NSW (Scottsdale Bush Heritage property) to investigate methods for translocation and establishment of new populations of this species (Bush Heritage and ANU).

MANAGEMENT

Based on current knowledge of the habitat requirements of *D. impar*, management actions should aim to maintain a heterogeneous grass sward structure, with a grass sward between 10 and 20 cm high (i.e. the height of the bulk of the tussock leaves, not including the often few taller leaves and seed-bearing culms). While capture rates of *D. impar* can be high in areas where the grass sward (or biomass) is high (such as dense Phalaris grass patches), there is also some evidence that *D. impar* may prefer intermediate levels of grass structure and intermediate to high levels of grass cover (Howland *et al.* 2014, 2016). Such grass structure/cover characteristics tend to be most prominent at intermediate levels of grass biomass. Retaining patches of dense, taller grass might be important for providing refugia for the species during dry periods or when other parts of the habitat are heavily grazed.

A heterogeneous sward containing a mixture of tall and medium height tussock patches, with linked inter-tussock areas containing shorter grass and forbs, is likely to provide *D. impar* with a greater range of sites for shelter and thermoregulation, and a wider range and/or density of prey. From an ecological community perspective, maintaining a diverse (or 'patchy') sward structure across *D. impar* habitat is likely to provide a greater range of habitat niches and hence support a greater diversity of grassland flora and fauna. Maintaining a diverse (or 'patchy') sward with generally intermediate levels of grass biomass is also an appropriate goal given imperfect knowledge of the long-term habitat requirements for *D. impar*.

Until knowledge of the *D. impar* habitat requirements indicates otherwise, actions to manage grass biomass/structure (whether for ecological or fuel reduction purposes) should adhere to the following guidelines:

- Grazing is the preferred method for managing grass structure/biomass.
- Where slashing is determined as necessary, grass should not be slashed below 20 cm.
- Where burns are determined as necessary, burns:
  - must be patchy and low-intensity
  - should be conducted during the middle of the day or in the afternoon, rather than early morning when the lizards may be cold and slow moving
  - should be restricted to early spring (September–October), before the summer breeding season, or early autumn (March–April) to ensure sufficient regrowth of vegetation before winter.

Residential developments close to *D. impar* habitat are likely to contribute to disturbance (vehicle traffic, increased visitation by people and dogs, weed infestation, more frequent fires) and increase the risk of predation by uncontrolled roaming of domestic cats and, in some cases, dogs. Minimisation of these impacts will depend on responsible pet ownership or stronger controls and, where possible, buffer areas between residential development and grassland habitat.

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra International Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1. Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve all large populations in the ACT. Protect other ACT populations from unintended impacts (unintended impacts are those not already considered through	Apply formal measures to protect all large populations on Territory-owned land. Encourage formal protection of all large populations on land owned by other jurisdictions.	All large populations protected by appropriate formal measures.
	Protect all medium size populations on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect all medium size populations from unintended impacts.	All sites with medium-sized populations are protected by appropriate measures from unintended impacts.

Objective	Action	Indicator
an environmental assessment or other statutory process).	Ensure sites where small populations occur on Territory owned land are protected from unintended impacts, where this contributes to broader conservation aims (such as protecting multiple threatened species at a site). Encourage other jurisdictions to undertake similar protection of small populations.	All sites with small populations are protected by appropriate measures from unintended impacts, where sites have broader conservation value.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor abundance at a representative set of sites, together with the effects of management actions.	Trends in abundance are known for representative sites, management actions recorded.
	Manage habitat to maintain its suitablilty for the species, including implementing an appropriate grazing / slashing / burning regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and herbage mass). Potential threats (e.g. weeds) are avoided or managed. Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations, or to establish new populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity. If suitable habitat exists, re-establish populations where they have become locally extinct.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant species composition). If suitable habitat exists, research and trials have been undertaken to establish new populations.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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