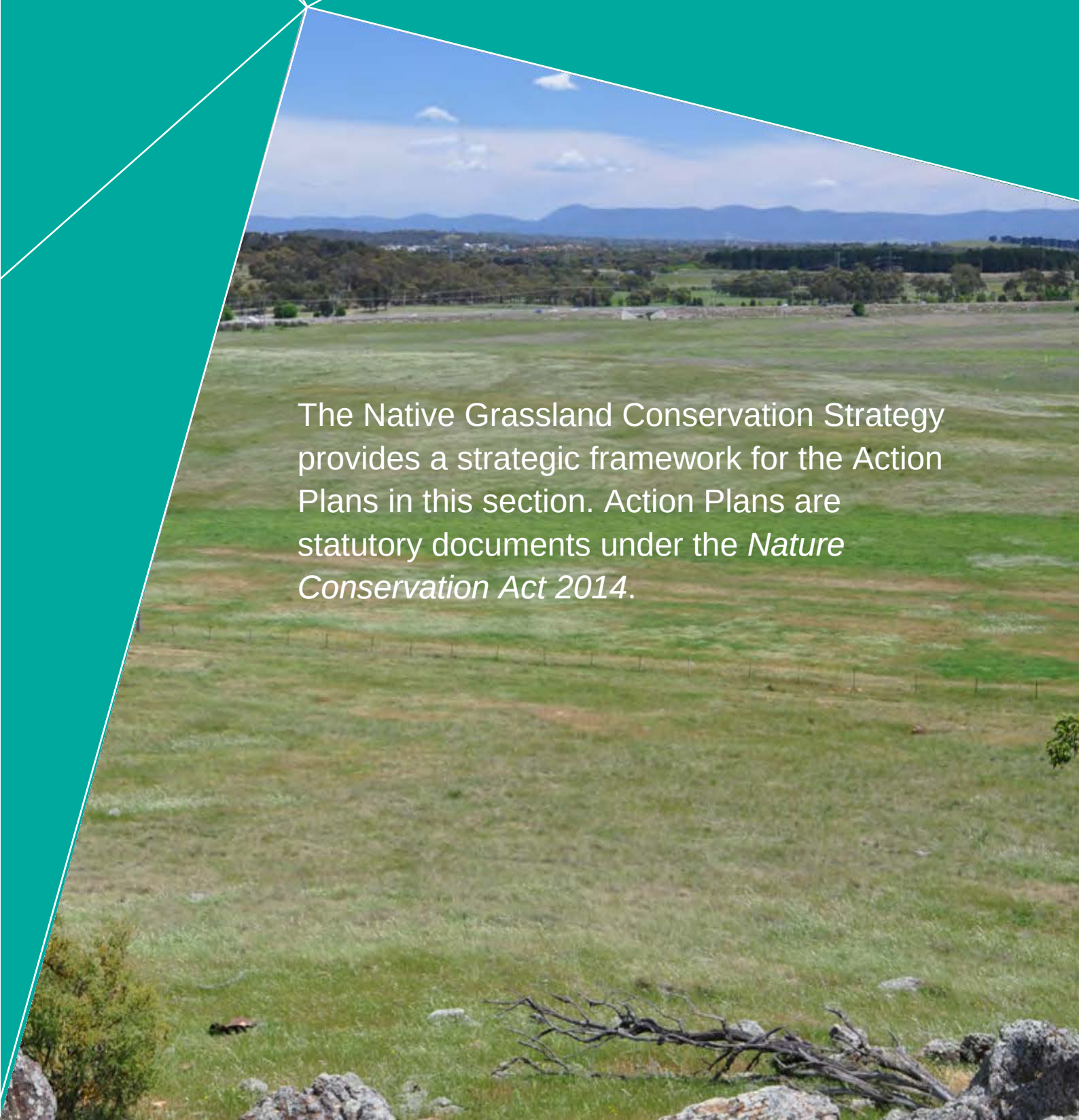
PART B
ACTION PLANS



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

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 ecological community was prepared in 1997 (ACT Government 1997). This revised edition supersedes all previous editions. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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 leptorhynchoides*) and Baeuerlen's Gentian (*Gentiana baeuerlenii*).

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.

The Commonwealth Natural Temperate Grassland listing may overlap with grassland components of the NSW-listed Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions ecological community.

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:

- Conserve all remaining areas of Natural Temperate Grassland in the ACT that are in moderate to high ecological condition.
- Retain areas of native grassland in lower ecological condition that serve as ecological buffers or landscape connections, or that are a priority for restoration.
- 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.

COMMUNITY DESCRIPTION AND ECOLOGY

DEFINITION AND DESCRIPTION

Native grasslands are vegetation communities dominated (> 50% cover) by native grasses and forbs where the cover of shrubs and trees is less than 10% (Eddy 2002).

Native grasslands include Natural Temperate Grassland, which is defined as follows:

Natural Temperate Grassland is a native ecological community that is dominated by moderately tall (25–50 cm) to tall (50 cm–1.0 m) dense to open native tussock grasses (*Themeda triandra*, *Rytidosperma* species, A*ustrostipa* species, *Bothriochloa macra*, *Poa* species). 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).

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. 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). Eastern Grey Kangaroos (*Macropus giganteus*) are the most abundant native mammalian herbivore in grasslands in the ACT, and through grazing can have a profound effect of the structure and composition of Natural Temperate Grasslands.

Threatened species found in Natural Temperate Grassland (Table 1) include three threatened grassland reptiles: 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, and a separate action plan has been prepared for this species (ACT Government 2017). Natural Temperate Grassland in the ACT is home to two threatened species of invertebrates: the Perunga Grasshopper (*Perunga ochracea*), and the Golden Sun Moth (*Synemon plana*).

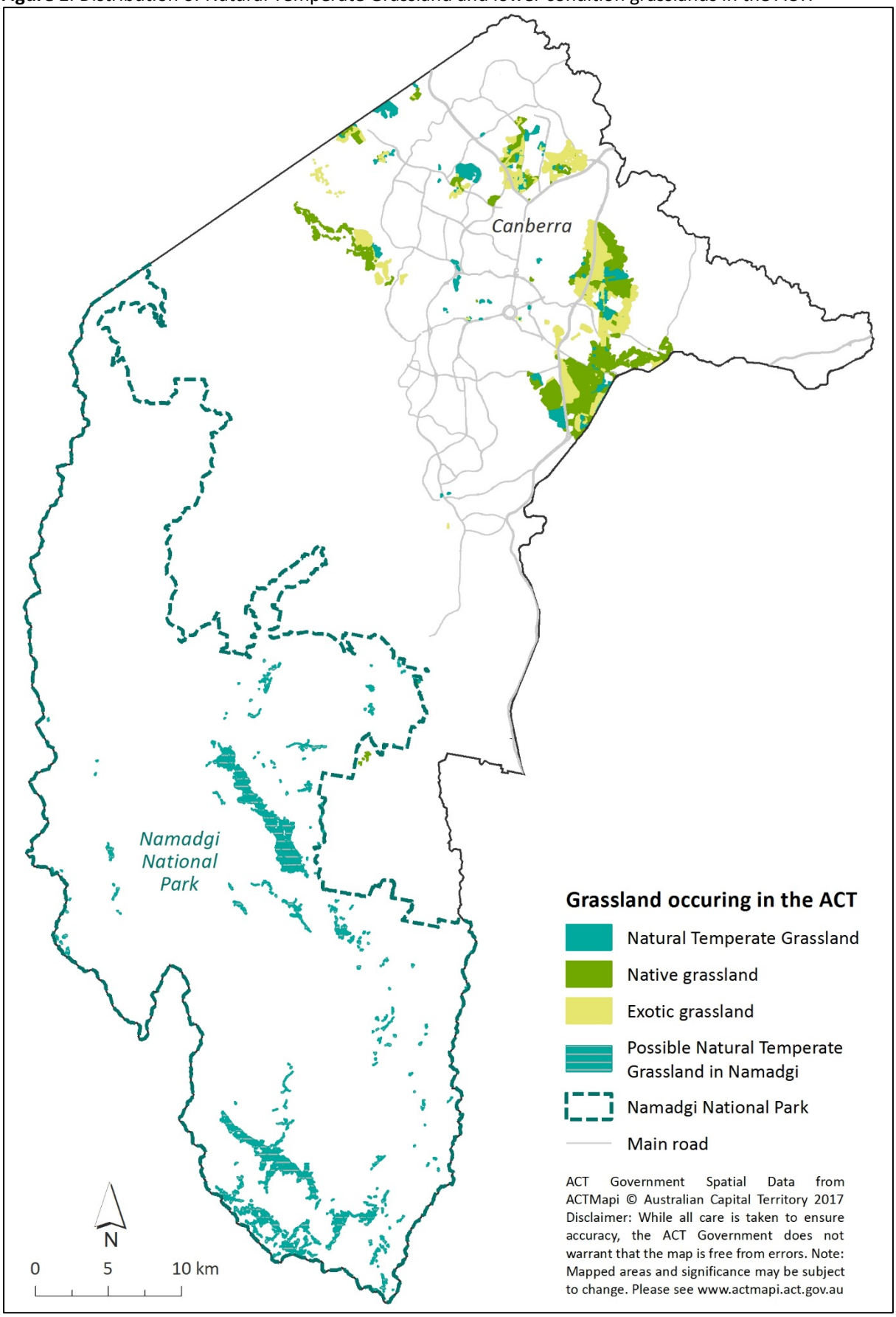
More detailed information on the description, habitat and ecology of native grasslands (including Natural Temperate Grassland), is given in section 8 of the strategy (Part A of this document).

Table 1. Threatened species in ACT Natural Temperate Grasslands.

Species	Status	Natural Temperate Grassland Sites*
Button Wrinklewort (*Rutidosis leptorhynchoides*)	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 (Barton), Tennant St (Fyshwick).
Ginninderra Peppercress (*Lepidium ginninderrense*)	Vulnerable - EPBC Act 1999, Endangered - NC Act 2014	Lawson Grasslands (former Belconnen Naval Transmission Station), Franklin Grasslands.
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 Grassland, 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, Franklin Grasslands, Lawson Grasslands, Dunlop NR, Jaramlee, Lake Ginninderra, Lawson Grasslands, University of Canberra, Yarramundi Grassland, Limestone Ave, St John's (Reid), Lady Denman Drive, Dudley Street, Novar Street (Yarralumla), Black Street (Yarralumla), Kintore Street (Yarralumla), St Mark's (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 Grassland, 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.

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**Error! Reference source not found.**). Each grassland community type is differentiated by structure, dominant and co-dominant native grass species, native forb composition, and distribution across the landscape**Error! Reference source not found.**.

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 *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 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, and native vegetation characteristics 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 tenures, 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 Grassland).
- 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, Mulanggari Nature Reserve, Gungaderra Nature Reserve and Lawson Grasslands (former 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.

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

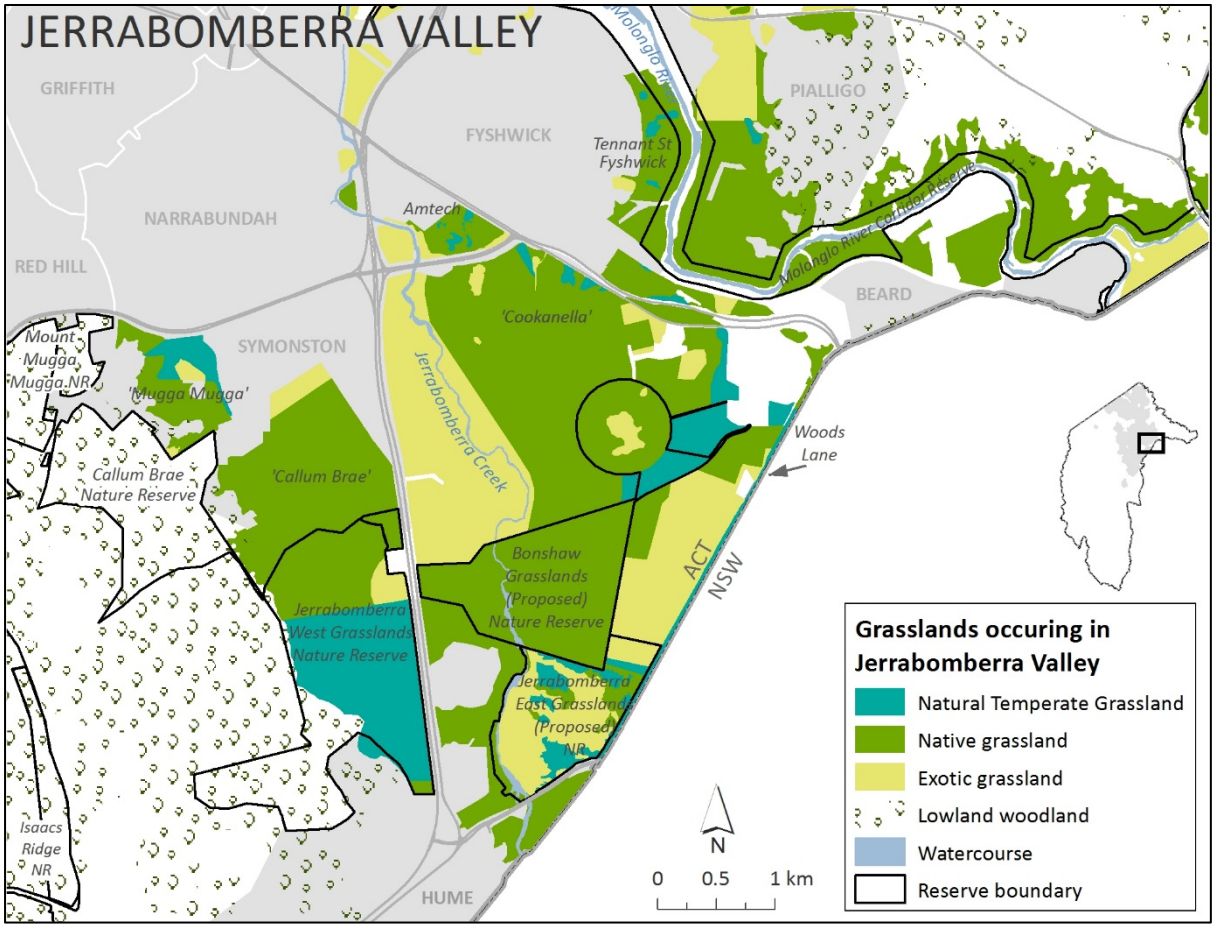


Figure 3. Natural Temperate Grassland distribution in the Majura Valley.

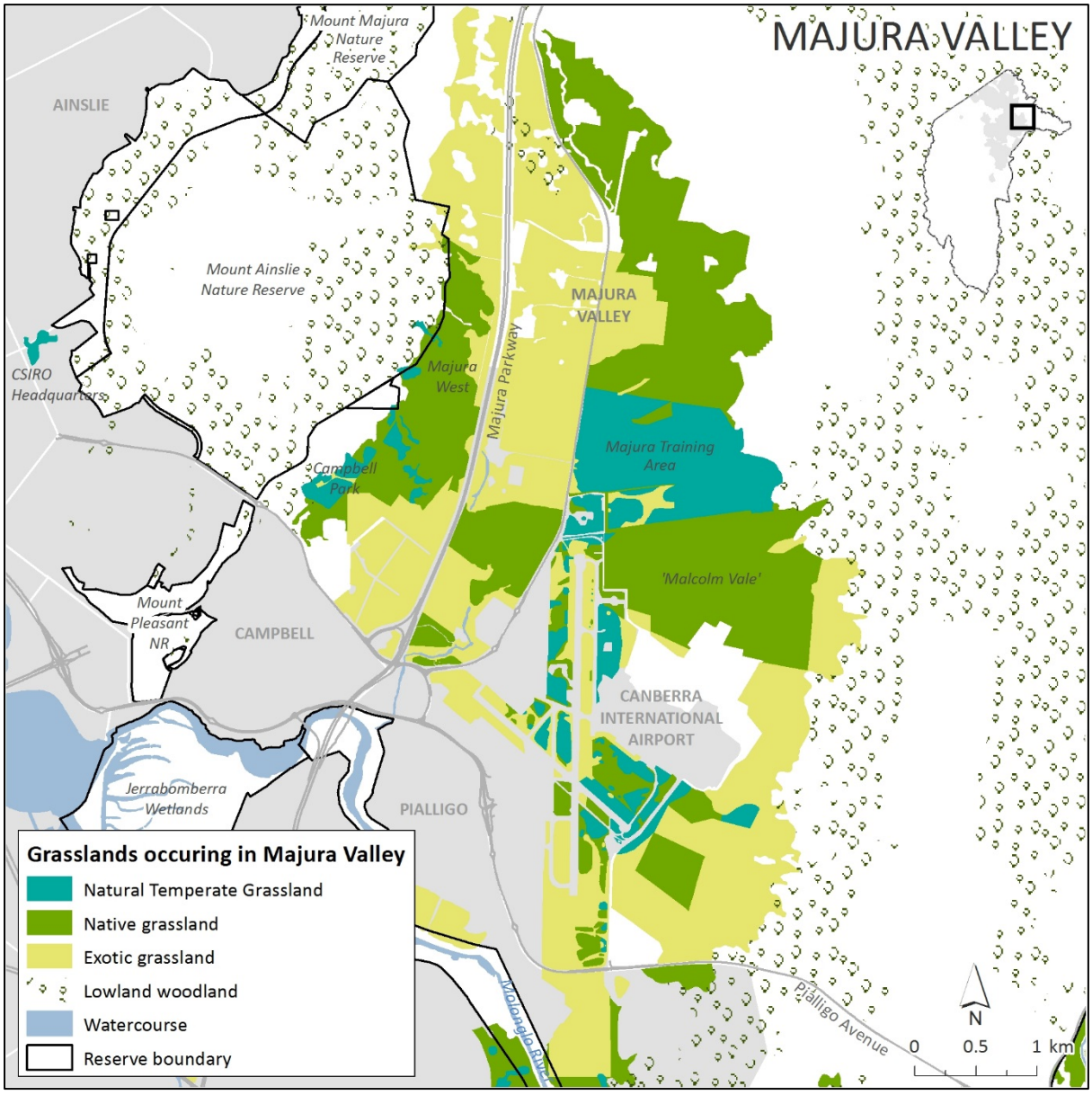
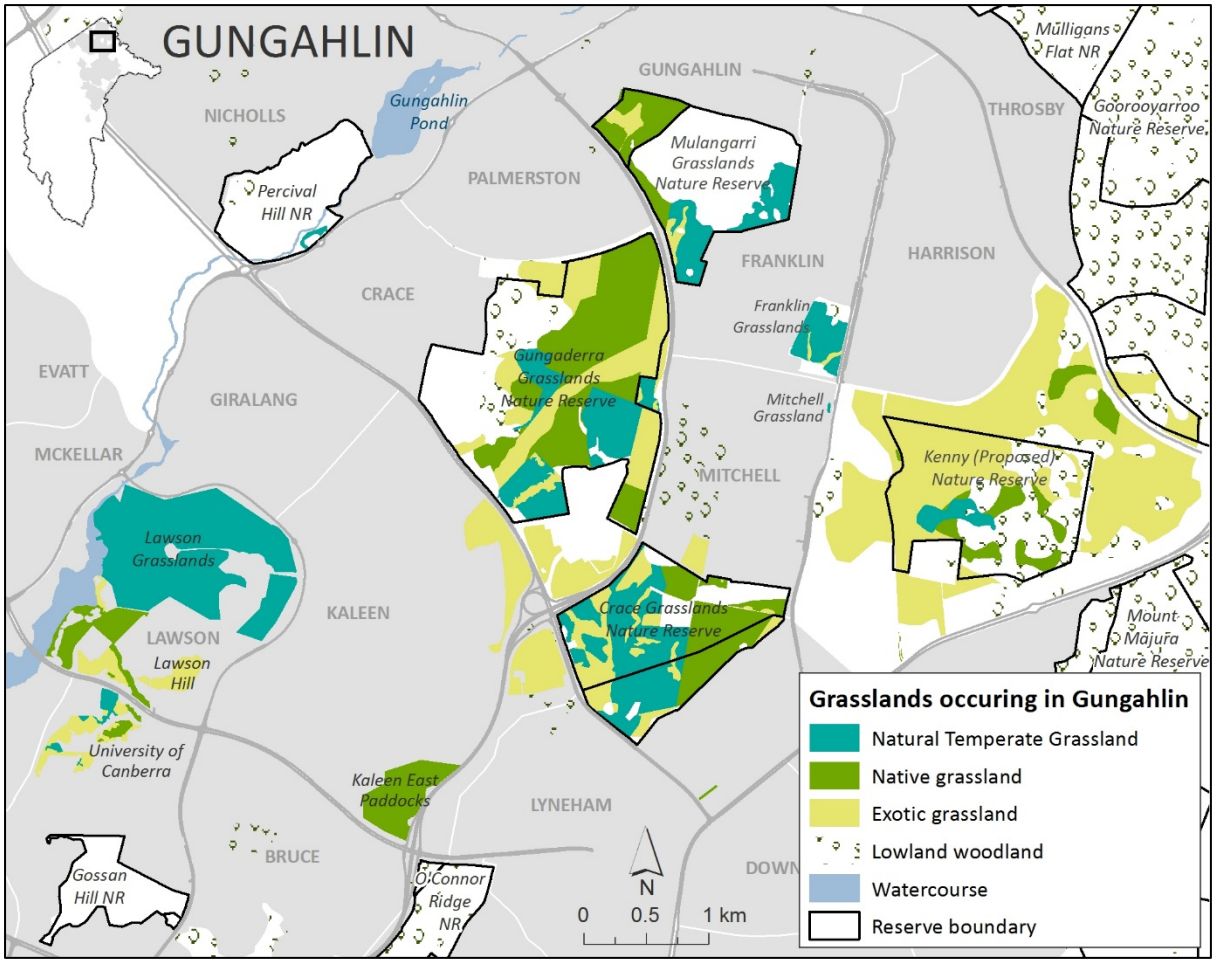


Figure 4. Natural Temperate Grassland distribution in Gungahlin.



Dry Tussock Grassland

Figure 5. Natural Temperate Grassland distribution in Belconnen.

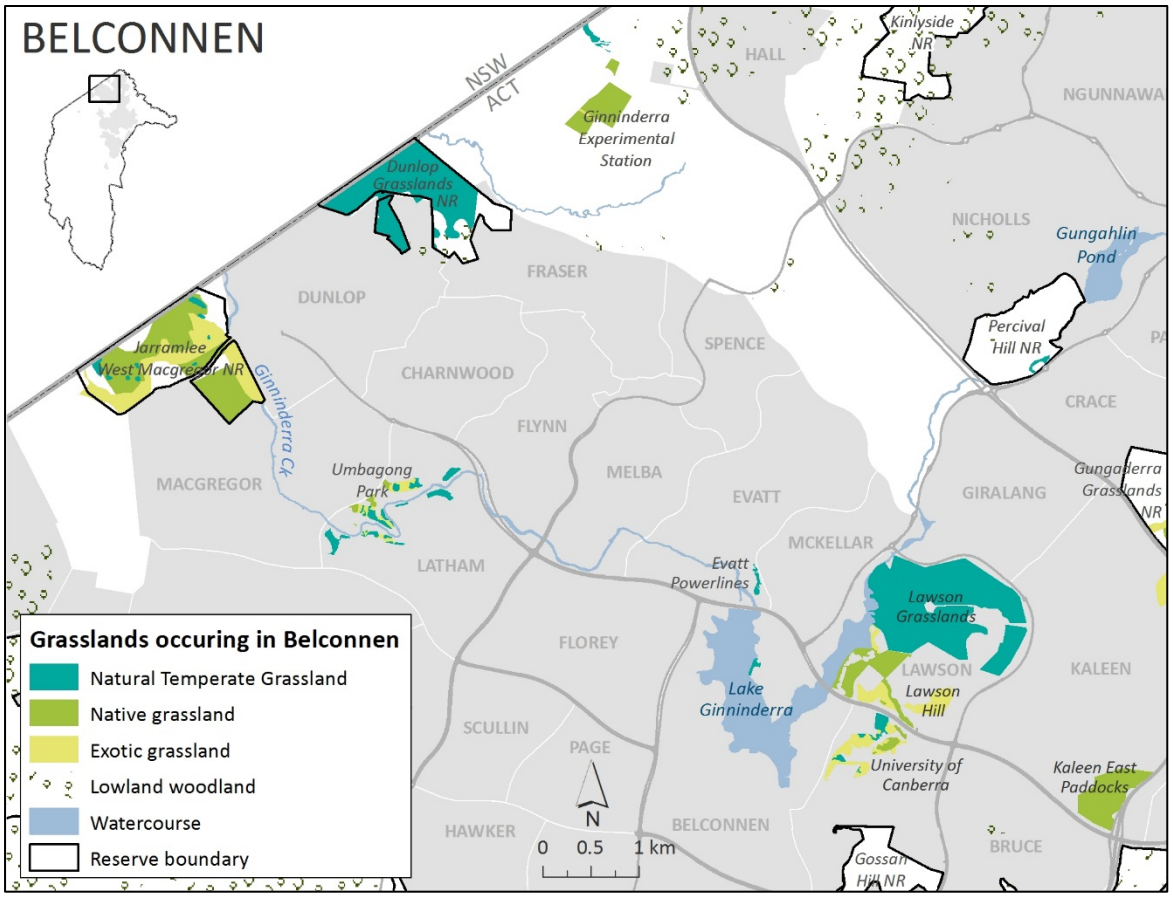


Figure 6. Natural Temperate Grassland distribution in West Belconnen.

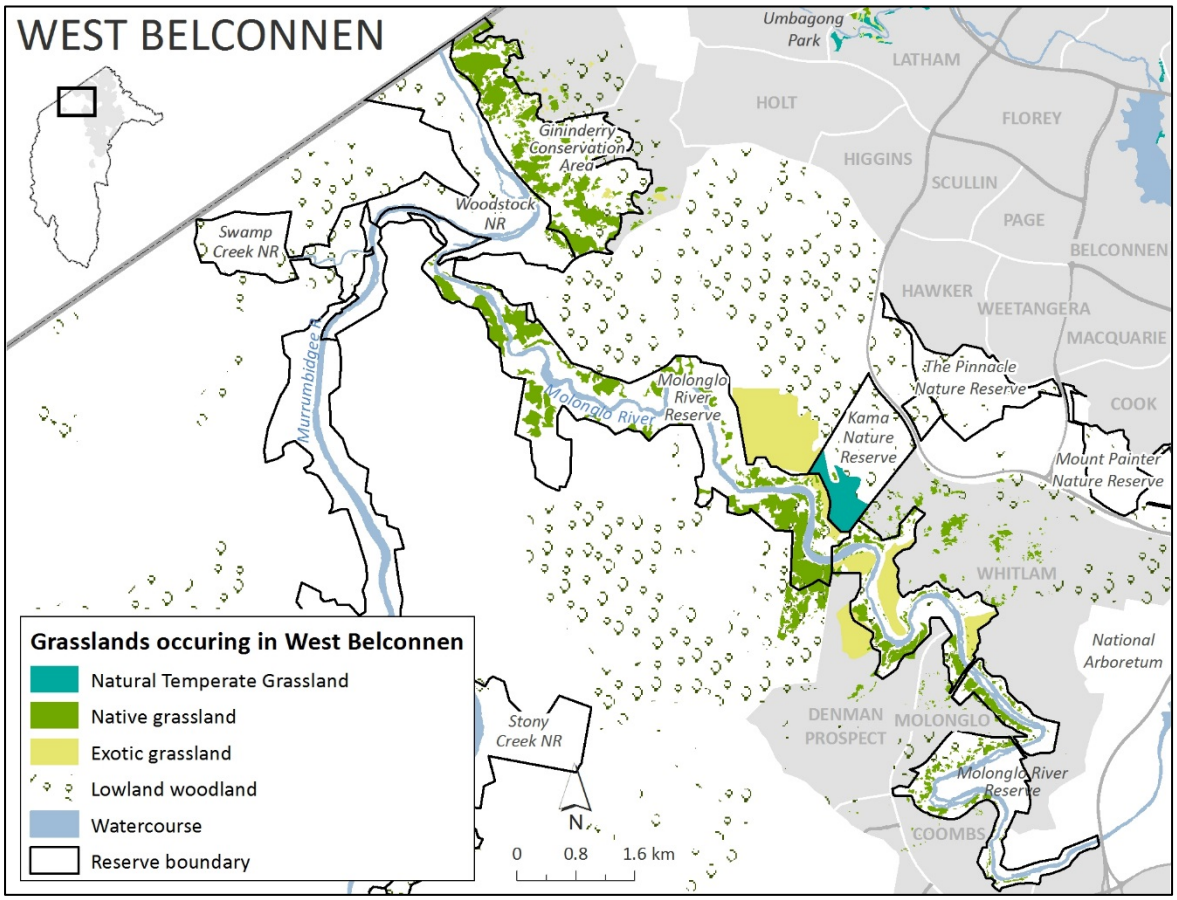
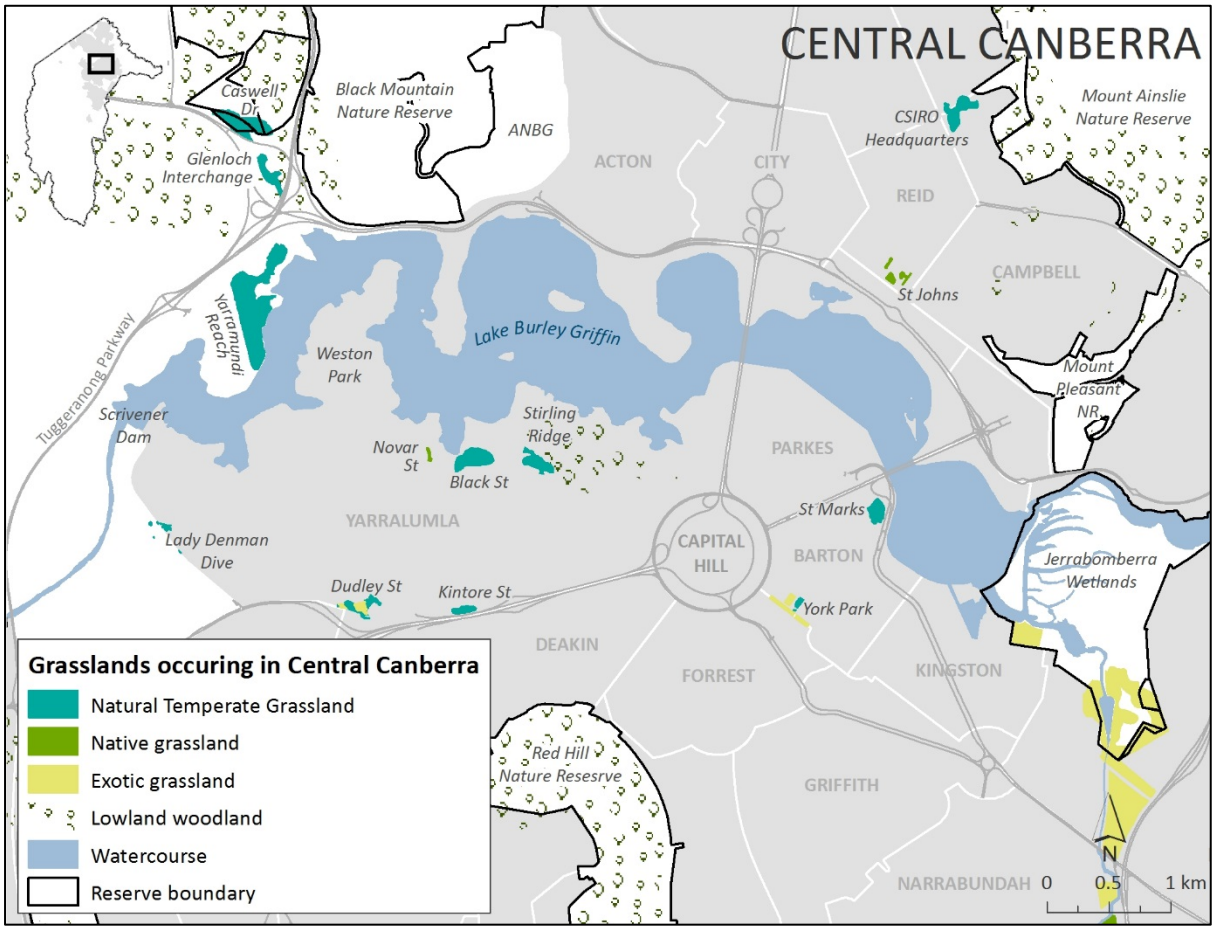


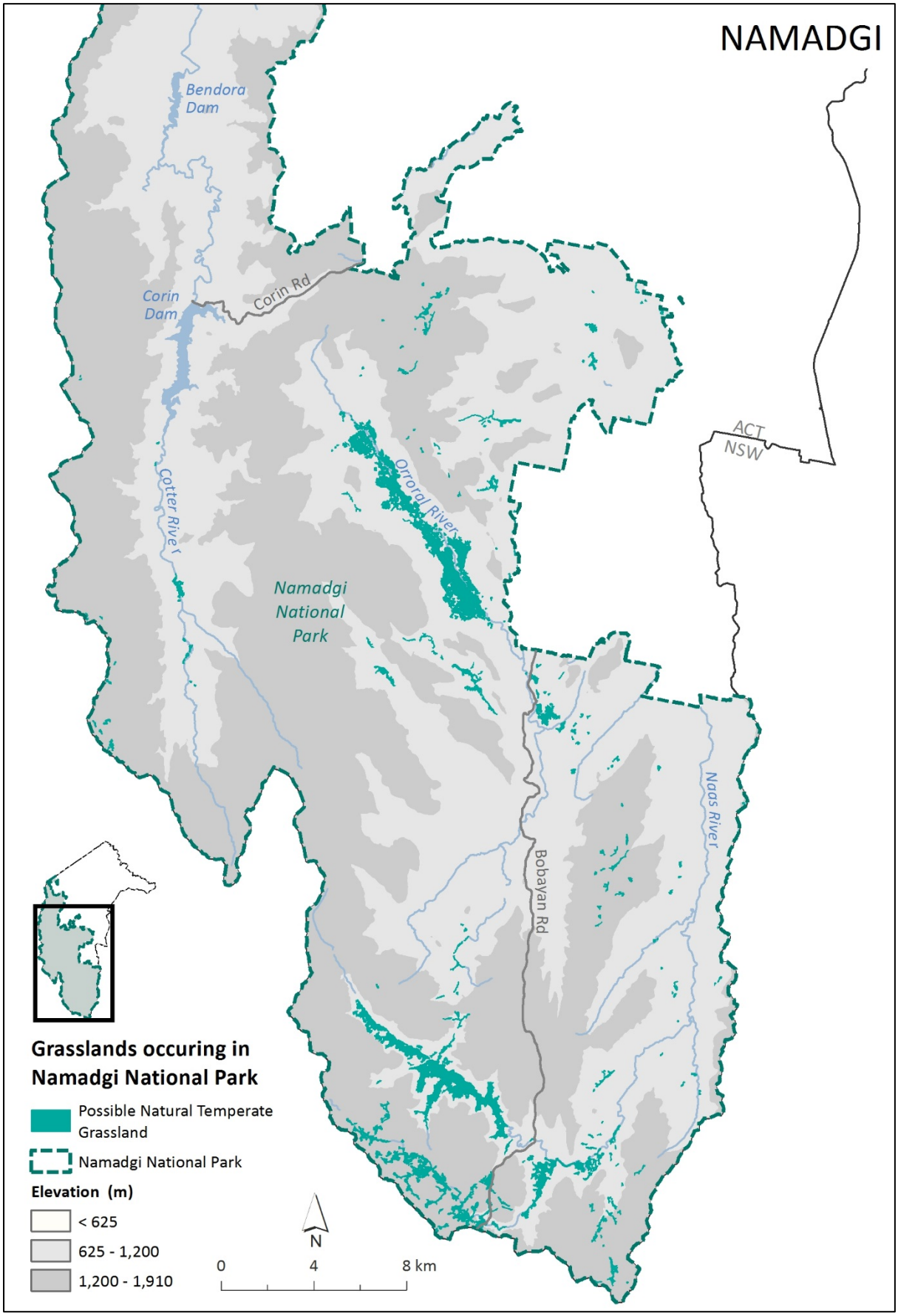
Figure 7. Natural Temperate Grassland distribution in Central Canberra.



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.



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. 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).

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 Grassland). 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 herbage mass, 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 Herbage Mass, Structure and Disturbance Regimes

The main methods for managing herbage mass 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 herbage mass 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 (2015). 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 Needlegrass (*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 Needlegrass (*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 herbage mass 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.

Further information and guidleines on restoration can be found in the National Standards for the Practice of Ecological Restoration in Australia and the framework within (SERA Standards Reference Group, 2016)

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:

The effects of historic habitat loss (such as fragmentation effects).

- Ongoing loss and modification of native grasslands, mainly due to agricultural and urban development.
- Invasive plants and animals.
- Ecologically inappropriate disturbance regimes, particularly a decline in disturbance frequency in productive grasslands.
- 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 herbage mass 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).

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 (Part A of this document) 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.

The FVS has been researched and developed by Rehwinkel (2015), with details provided in the ACT Native Grassland Conservation Strategy (Part A of this document). 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 2016a). 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), 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 herbage mass 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 Armstrong**Error! Reference source not found.**
- 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 herbage mass accumulation, degree of site modification and degradation, and history of land use in the ACT.

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 herbage mass 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 and cryptogams. 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 herbage mass 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, herbage mass 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 (Part A of this document).
- **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 herbage mass 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 herbage mass/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 herbage mass rather than maintaining grassland floristic diversity. In sites where fire and grazing is impractical, mowing/slashing can be used as a tool to reduce herbage mass 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 Needlegrass (*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).
- **Management of critical threshold sites.** Sites that are identified as approaching critical thresholds for ecological condition should be assessed for appropriate management interventions. Thes include, but not limited to, weed control, vegetation restoration, biomass and pest animal management, appropriate disturbance regime planning, and mitigation of threatening activites.
- **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 Native Grassland Conservation Strategy (Part A of this document).

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, 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 2. 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 and 3 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 and 3 NTG sites on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect Category 2 and 3 NTG sites from unintended impacts.	All Conservation Significance Category 2 and 3 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	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.

Objective	Action	Indicator
• conserve grassland biodiversity.	Implement site-specific management actions to maintain required habitat structure for threatened species.	Herbage mass 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.
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

G. Baines, Senior Ecologist ACT Government

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BAEUERLEN'S GENTIAN

GENTIANA BAEUERLENII

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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.

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*.

CONSERVATION OBJECTIVES

The overall objective of this action 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.

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 (Harden 2000) 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

Baeuerlen's Gentian

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.

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.

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 Namadgi National Park. Given this species' extremely limited distribution, offsets for this species are not appropriate and impacts are to be avoided

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.

T, similar habitat to where Baeuerlen's Gentian occurs.

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).
1. 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.
2. 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.

Objective	Action	Indicator
3. 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.
4. 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 LEPTORHYNCHOIDES

ACTION PLAN

PREAMBLE

The Button Wrinklewort (*Rutidosis leptorhynchoides* 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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

CONSERVATION STATUS

Rutidosis leptorhynchoides 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 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*.

CONSERVATION OBJECTIVES

The overall objective of this action plan is to preserve *R. leptorhynchoides* 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.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Button Wrinklewort *Rutidosis leptorhynchoides* (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 leptorhynchoides 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. leptorhynchoides* 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. leptorhynchoides* 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 Gungahlin. 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. leptorhynchoides* 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 leptorhynchoides* 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. leptorhynchoides* 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 leptorhynchoides 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 leptorhynchoides* 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. leptorhynchoides*, 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. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* restoration projects should be sourced from large genetically diverse populations (Pickup *et al.* 2013). Because most *R. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* 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 herbage mass. 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. leptorhynchoides* 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 Mark's site in Barton in 2009, with no reported ill effects on *R. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides* (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. leptorhynchoides*, 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. leptorhynchoides* 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. leptorhynchoides* seedlings.

Monitoring in spring 2011 recorded more seedlings in burnt plots, but results were patchy. By spring 2012 the number of *R. leptorhynchoides* 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. leptorhynchoides* populations in the ACT. Fuel reduction burning at Stirling Park will provide further opportunities for monitoring.

Population modelling for *R. leptorhynchoides* 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:

- An updated management plan has been prepared and implemented for Stirling Park and associated woodlands (Sharp 2016). 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 leptorhynchoides* 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.
- Herbage mass 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. leptorhynchoides* 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 leptorhynchoides 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. leptorhynchoides* populations, particularly through reduced germinant survival due to dry conditions and/or increasing intervals between rain events.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The long term conservation of *R. leptorhynchoides* 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. leptorhynchoides* on their land, in particular, Stirling Ridge and the Majura Field Firing Range.

Demographic modelling suggests that populations of *R. leptorhynchoides* 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. leptorhynchoides* (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. leptorhynchoides* 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. leptorhynchoides* 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.

SURVEY, MONITORING AND RESEARCH

While it is possible some small populations of *R. leptorhynchoides* 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. leptorhynchoides* 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

Button Wrinklewort (E. Cook)

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.

The Centre for Plant Biodiversity Research (CSIRO Division of Plant Industry) is conducting ongoing research into aspects of the population biology of *R. leptorhynchoides*, 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. leptorhynchoides* 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. leptorhynchoides* 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. leptorhynchoides*. 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 Needlegrass (*Nassella neesiana*). Control methods should take account of the characteristics of each site, and proximity to *R. leptorhynchoides* 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. leptorhynchoides* should be taken into account when determining the desirable level of kangaroo grazing at a site. Stock grazing may have an adverse effect on *R. leptorhynchoides* and its habitat, although the specieds has persisted for many years on sites with long histories of grazing. Any application of this form of grazing should be closely monitored. 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. leptorhynchoides* 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. leptorhynchoides* 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 (Barton) 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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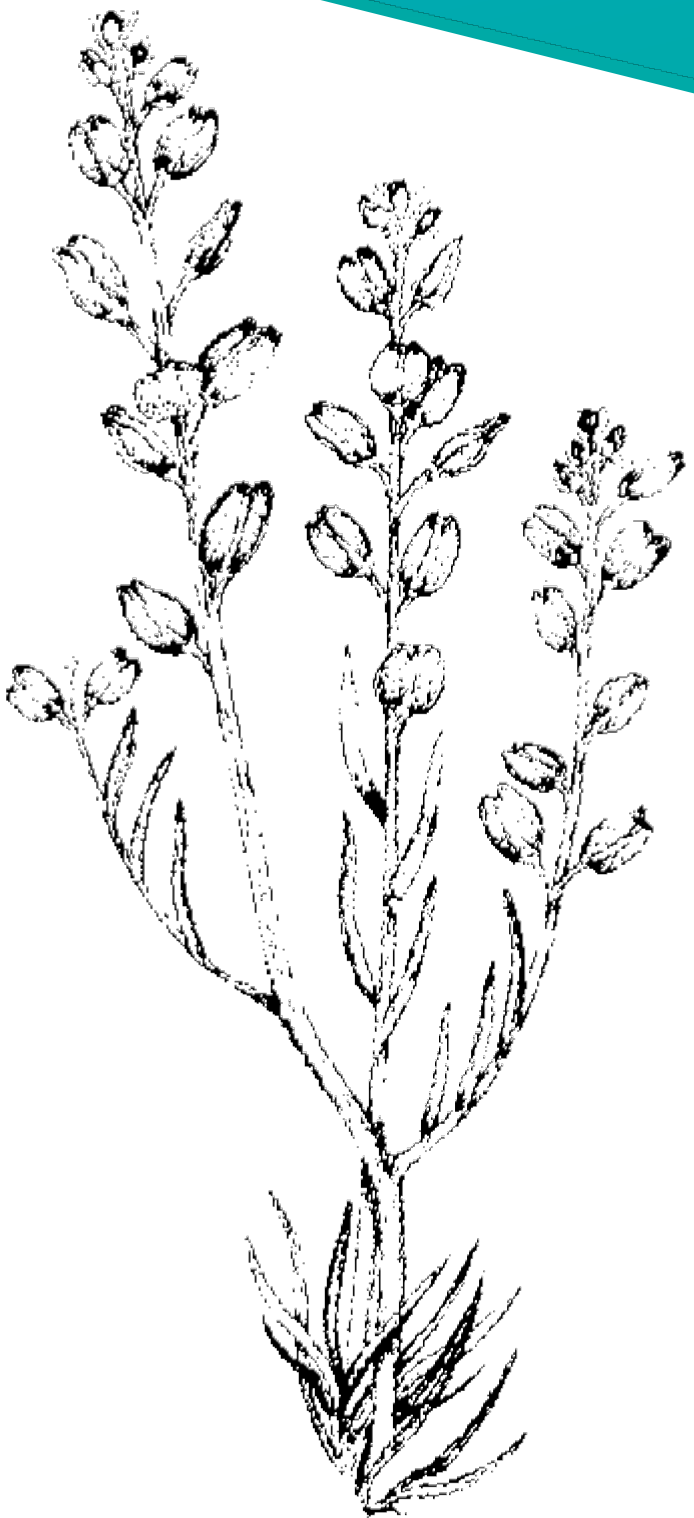
GINNINDERRA PEPPERCRESS

LEPIDIUM GINNINDERRENSE

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

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 of Lawson Grasslands (former 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 Lawson Grasslands 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).'

Note that the EPBC listing of the critical habitat was made in 2005 before the discovery of the smaller Franklin population.

Australian Capital Territory

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

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.

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 Lawson Grasslands (former 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

Date of survey	Number of plants	Reference
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.

Ginninderra Peppercress

- 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 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.

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. The Ginninderra Peppercress has been determined as not able to withstand further loss in the ACT so offsets for this species are not appropriate.

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 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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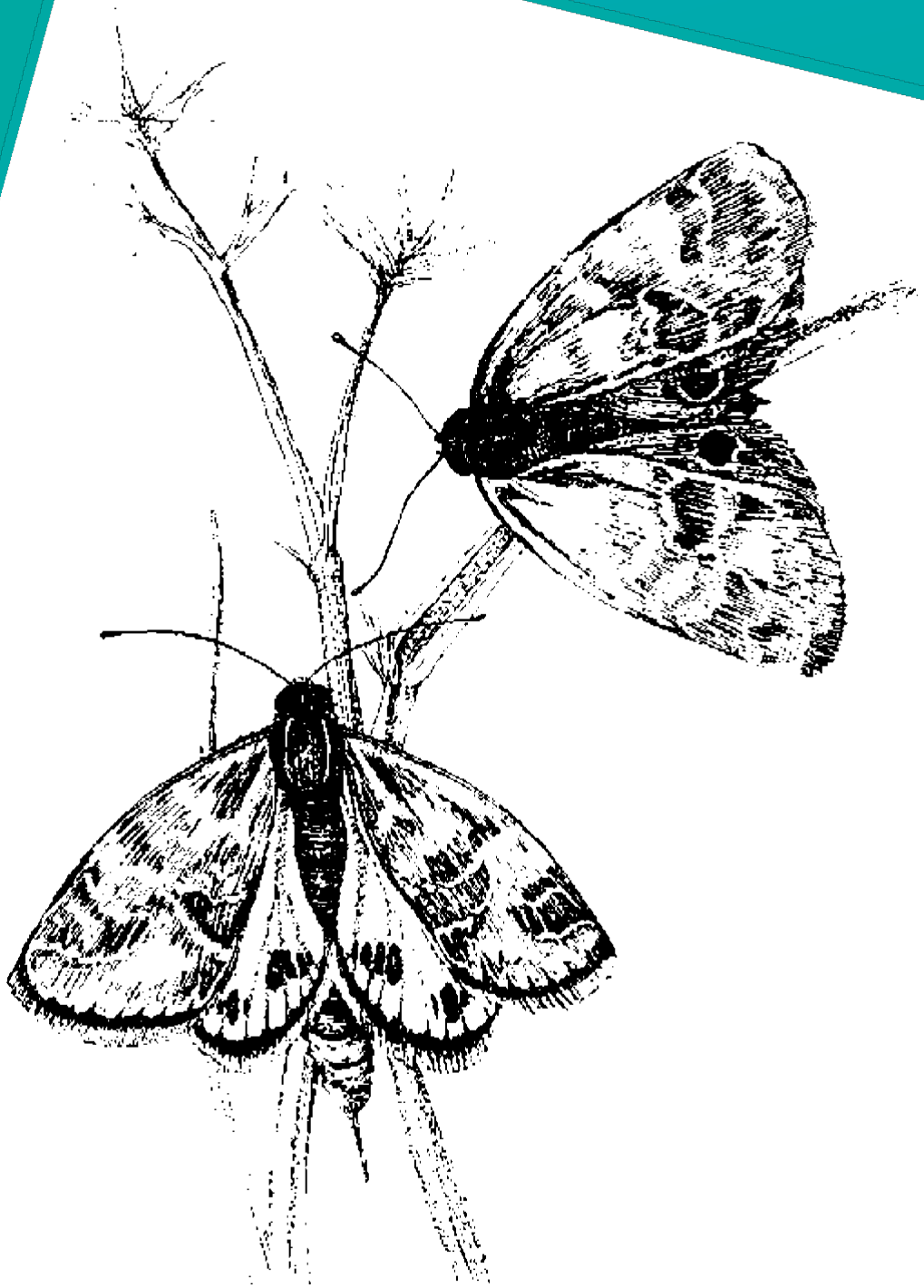
GOLDEN SUN MOTH

SYNEMON PLANA

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

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*.

CONSERVATION OBJECTIVES

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.

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 Transmission 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.

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.

Golden Sun Moth (photo K. Nash)

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:

- Lawson Grasslands (former 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 Needlegrass (*Nassella neesiana*).
- At West Macgregor, numbers of flying males were consistently higher on the creek flats

dominated by Chilean Needlegrass 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 herbage mass (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 Needlegrass. Chilean Needlegrass 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 herbage mass (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 Needlegrass (Edwards 1994; Braby and Dunford 2006; Gibson 2006; Gilmore *et al.* 2008; Richter *et al.* 2011, 2013; Sea and Downey 2014b). 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; Lawson Grasslands, 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 Lawson Grasslands 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 Needlegrass 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 2014a), 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 2014b), 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 Needlegrass are all adjacent to native grasslands (Richter *et al.* 2011).

Chilean Needlegrass 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 herbage mass 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 Grassland in the last 20 years appears to be associated with over a decade of sustained high herbage mass 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 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 leptorhynchoides*).

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 herbage mass 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 herbage mass control as required. Jarramlee (ACT Government 2013) and West Macgregor are subject to offset management plans, which aim to control herbage mass 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, such as Phalaris, African Lovegrass, Serrated Tussock (*Nassella trichotoma*) and Chilean Needlegrass.
- 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 Needlegrass 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 Needlegrass 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 Needlegrass can invade Kangaroo Grass dominated grasslands when they suffer tussock collapse and death due to lack of renewal through herbage mass reduction (grazing, mowing, burning), and this appears to have happened at Yarramundi Grassland and part of the Dudley Street site (Faithfull 2012). At Dudley Street *S. plana* occupied the Chilean Needlegrass area, but at Yarramundi Grassland the moth seems to have disappeared before the main invasion of Chilean Needlegrass. This may be due to the small amount of *S. plana* habitat originally present at Yarramundi Grassland, and the years of excessive herbage mass that preceded the invasion of Chilean Needlegrass.

The spread of Chilean Needlegrass 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 Needlegrass 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 Needlegrass along waterways such as Ginninderra Creek and Gooromon Ponds. The spread of Chilean Needlegrass is also facilitated by mowing, leading to a near monoculture on many roadsides, nature strips and traffic islands in central Canberra. Chilean Needlegrass 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 Needlegrass 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 Needlegrass could act as invasion corridors for the weed to enter native grasslands.

Synemon plana numbers are often much higher on Chilean Needlegrass-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 Needlegrass tussocks often form a continuous sward, providing a high density of food plants.
- More *S. plana* larvae can develop on a single Chilean Needlegrass tussock than on native grasses (Sea and Downey 2014b; SMEC 2015).
- *Synemon plana* larvae which develop on Chilean Needlegrass are larger (Sea and Downey 2014b).
- 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 Needlegrass 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 Needlegrass 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 Needlegrass.

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 herbage mass, 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 herbage mass 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.

- **Herbage mass extremes:** Lack of herbage mass 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, possibly expose eggs or larvae to excessive soil temperatures and/or increased 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).

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 of the 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 large 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 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 herbage mass 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.

Small populations at sites that contribute to research or public education related to the species (e.g. York Park in Barton) should be a priority for protection.

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.

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 Needlegrass 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 for 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 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 2014b). As part of the Majura Parkway environmental commitments, a 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 2014b, 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 Needlegrass – 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 herbage mass 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 herbage mass/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 herbage mass 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 herbage mass 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 Needlegrass 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 thoroughly cleaned before entering *S. plana*

sites, and after slashing on sites containing Chilean Needlegrass and other significant weeds. Slashing should avoid the seeding period of significant 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 Needlegrass, 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

Objective	Action	Indicator
		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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GRASSLAND EARLESS DRAGON

TYMPANOCRYPTIS PINGUICOLLA

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

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*.

CONSERVATION OBJECTIVES

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.

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, 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 indicates that 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; M. 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
Bonshaw	158	Territory	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

Grassland Earless Dragon (photo M. Evans)

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).

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 (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 2002–09 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 critically 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 Needlegrass (*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).

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 the 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 (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* 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 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.

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. 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.

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 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:

- Lawson Grasslands (former Belconnen Naval Transmission Station) (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 (former Defence land 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 herbage mass. 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

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

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.*

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.

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 Grasslands (Commonwealth land, formerly known as the Belconnen Naval Transmission 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 critically 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.

CHANGING CLIMATE

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.

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.

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 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

Perunga Grasshopper (E. Cook)

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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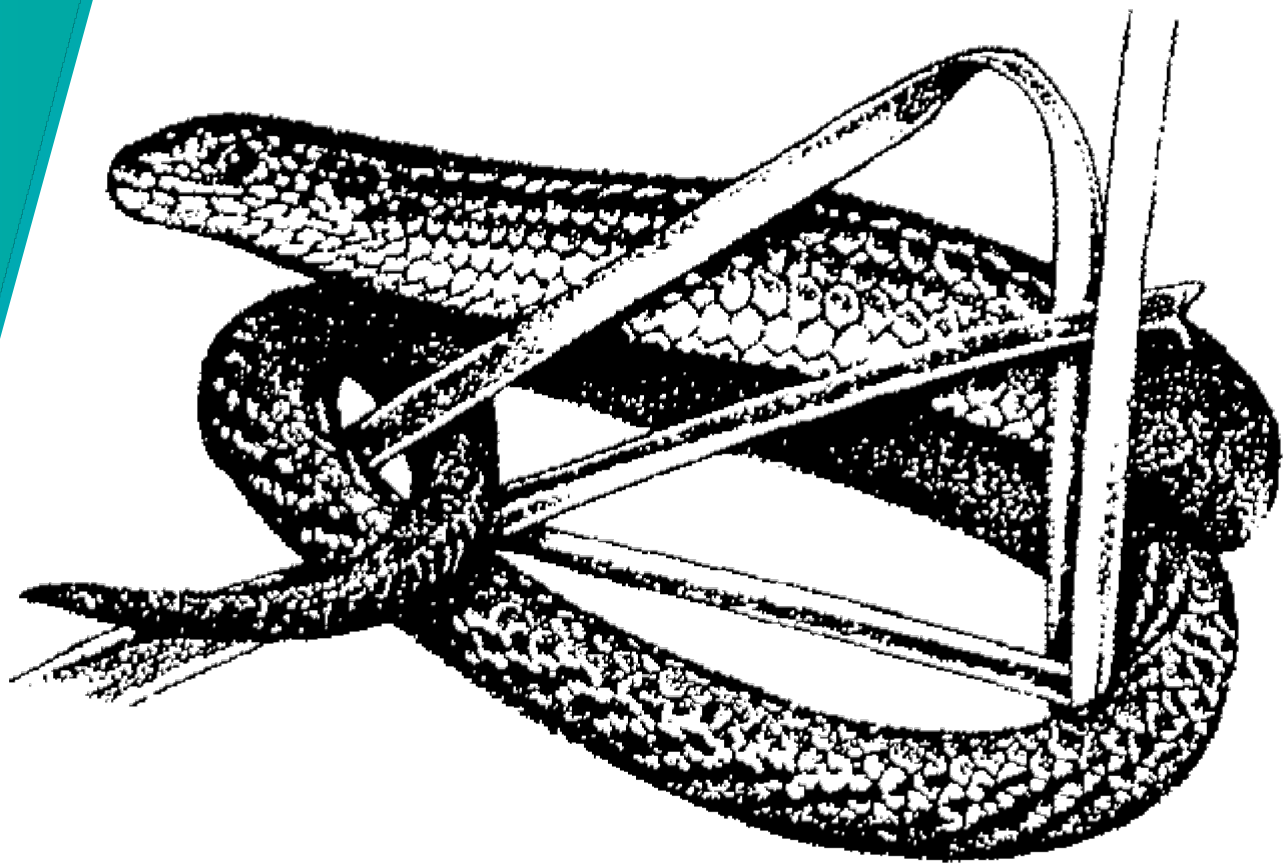
STRIPED LEGLESS LIZARD

DELMA IMPAR

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. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

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*).

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*.

CONSERVATION OBJECTIVES

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.

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 light 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. However, differences in nostril scales and pre-anal scales (Cogger 2000) are the most reliable features distinguishing the species.

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 Grassland 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 a patch of grassland (14 ha) to the north of the Mitchell industrial area (Franklin 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 Grassland 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

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.* 2016; SMEC 2015). These surveys have involved the use of pitfall traps and more recently the use of roof tiles as artificial shelters.

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 been recorded 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.* 2016). 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.

Delma impar has been found in areas with intermediate to tall grass, including surveys using roof tiles (Moore *et al.* 2010; Biosis 2012; EcoLogical 2013) and pitfall traps (e.g. Rauhala *et al.* 1995; Rauhala 1996, 1997, 1999). Pitfall trapping for the species during extensive

surveys in the 1990s found capture rates were highest in "extensive and intact swards and a well-developed grass thatch" (Williams and Kukolic 1991) and at sites where tussock leaf height was between 20 cm and 50 cm and projected foliage cover of tussocks was between 35% and 80% (Rauhala *et al.* 1995; Rauhala 1996, 1997, 1999).

In the peer reviewed papers by Howland *et al.* (2014; 2016) habitat preferences for *D. impar* were modelled and the researchers concluded 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. The role of intermediate levels of kangaroo grazing in maintaining habitat for *D. impar* is highlighted by Howland (2014, 2016).

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 of *D. impar* habitat in the ACT.

There is anecdotal evidence to suggest that 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).

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). Individuals are often caught in pitfall traps later in the day, rather than overnight or early in the morning (R. Spiers pers comm.). The highest detection rates for the species using roof tiles are in spring and early summer, though few individuals are found under tiles after December. 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). Field observations (Coulson 1990) suggest the animals are also diurnally active in the wild.

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 between 25 m^2 (5 m x 5 m) and 100 m^2 (10 m x 10 m) appears to be a reasonable generalisation based on pitfall and tile recapture data.

PREVIOUS AND CURRENT MANAGEMENT

In the ACT, *D. impar* occurs in areas with a variety of management regimes, which includes

Striped Legless Lizard

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 stock 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 Grassland has included slashing, occasional patch burns and weed control, which (at least over the past decade) has maintained generally moderate to high herbage mass. 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 stock.

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, though weeds, such as Saffron Thistle, remain abundant at some 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 critically 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.

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 *D. impar* are not known. Higher mortaility of

eggs buried in soil (due to dessication in hot dry periods) has been identified as a risk for Tympanocryptis pinguicolla, and is also likely to be a risk for *D. impar* eggs.

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 reptiles 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 *D. impar* also makes it less able to adapt by moving to accommodate habitat change. Maintaining high quality habitat (with adequate grass cover to provide shelter and to shade soil) might facilitate resilience of *D. impar* to changing rainfall and temperature regimes.

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 (East Jerrabomberra, Bonshaw, Cookanalla).

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 Franklin 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".

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 soil characteristics and invertebrates.
- 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.
- Continue to refine 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 herbage mass/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) (Bush Heritage and ANU) and to Kama Nature Reserve, ACT (PCS), to investigate methods for translocation and establishment of new populations of this species.

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). Whilst *D. impar* has been recorded in areas where the grass sward (or biomass) is high (such as areas dominated by Phalaris), Howland et al (2014, 2016) concluded from a habitat modelling study that *D. impar* prefers intermediate levels of grass structure and intermediate to high levels of grass cover. Such grass structure/cover characteristics tend to be most prominent at intermediate levels of herbage mass. 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 herbage mass 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 herbage mass/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 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-sized 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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The illustration of the species was prepared for the ACT Government by John Pratt.

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