ARCHIVAL RECORD

REFERENCE No. 1

ACT Government 1998
Golden Sun Moth (*Synemon plana*):
An endangered species,
Action Plan No. 7, Environment ACT,
Canberra.

Threatened Species

Action Plan No.7

Golden Sun Moth *Synemon plana*

In accordance with section 21 of the *Nature Conservation Act 1980*, **the Golden Sun Moth (*Synemon plana*)** was declared an **endangered** species on 15 April 1996 (formerly Determination No. 29 of 1996 and currently Determination No. 7 of 1998). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration.

This is the Action Plan for the:

Golden Sun Moth *Synemon plana*

Preamble

The *Nature Conservation Act 1980* establishes the ACT Flora and Fauna Committee with responsibilities for assessing the conservation status of the ACT's flora and fauna and the ecological significance of potentially threatening processes. Where the Committee believes that a species or ecological community is threatened with extinction or a process is an ecological threat, it is required to advise the Minister for the Environment, Land and Planning and recommend that a declaration be made accordingly.

Flora and Fauna Committee assessments are made on nature conservation grounds only and are guided by specified criteria as set out in its publication *Threatened Species and Communities in the ACT,* July 1995.

In making its assessment of the Golden Sun Moth, the Committee concluded that it satisfied the criteria indicated in the adjacent table.

An Action Plan is required to ensure, as far as is practicable, the identification, protection and survival of the species or the ecological community, or proposals to minimise the effect of any process which threatens any species or ecological community.

While the legal authority of this Action Plan is confined to the Australian Capital Territory, management considerations are addressed in a regional context.

Criteria Satisfied

1.2 The species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the near future, as demonstrated by:
1.2.1 Current severe decline in population or distribution, from evidence based on:
1.2.1.1 Direct observation, including comparison of historical and current records; and
1.2.1.3 Severe decline in quality or quantity of habitat.
1.2.5 Continuing decline or severe fragmentation in population, for species with a small current population.

Links with other Action Plans

Measures proposed in this Action Plan complement those proposed in the Action Plan for Natural Temperate Grassland and other component threatened species, such as the Striped Legless Lizard (*Delma impar*), Eastern Lined Earless Dragon (*Tympanocryptis lineata pinguicolla*) and the Button Wrinklewort (*Rutidosis leptorrhynchoides*). Action Plans are listed at the end of this document.

Species Description and Ecology

DESCRIPTION

The Golden Sun Moth *(Synemon plana)* is a medium sized moth belonging to the family Castniidae, which is thought to be of Gondwanan origin (Edwards, 1990). The male has a wingspan of about 34 mm, larger than the female with about 31 mm wing span. The male having a larger wingspan than the female is unique in the Australian Castniidae. The upperside of the forewing of the male is dark brown with patterns of pale grey scales and the hind wing is dark bronzy brown with dark brown patches. The underside of both wings of the male is mostly pale grey with dark brown spots. The upperside forewing of the female is very dark grey with patterns of pale grey scales and the hind wing is bright orange with black submarginal spots. The underside of both wings of the female is silky white with small black submarginal spots. The adults are without functional mouthparts; they have strongly clubbed antennae and the female has a long extensible ovipositor. Coloured illustrations may be found in Common (1990) and Fraser and McJannett (1996).

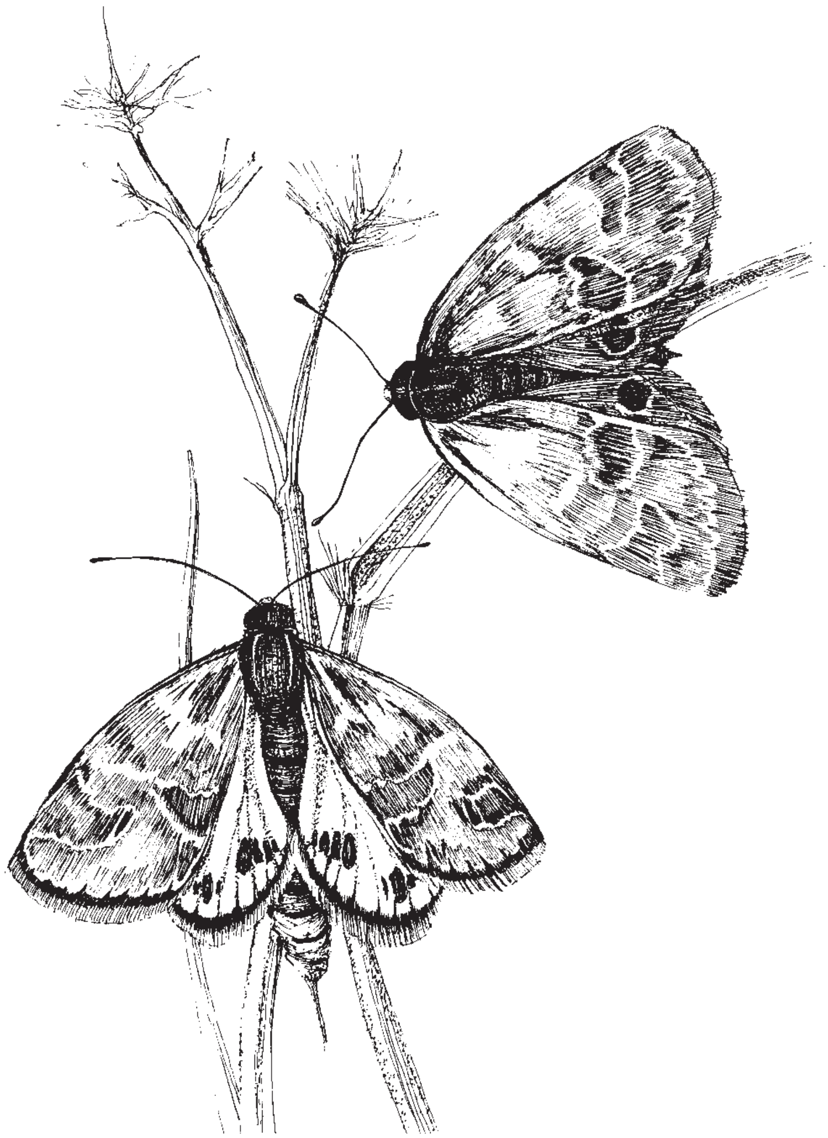

Figure 1: Golden Sun Moth (*S. plana*) - the female is on the bottom left and the male on the top right. Scale: 1.7 times natural size.

HABITAT

In the ACT, *S. plana* usually occurs in natural temperate grassland dominated by *Danthonia carphoides,* a wallaby grass. Some populations of the moth at Mulligans Flat occur in known grassy areas within an open woodland but all other sites are believed to have been treeless grassland prior to European settlement. In the ACT, these grasslands are not found at an altitude above 630 m.

Areas dominated by *D. carphoides* occur in grasslands containing *Danthonia* or *Stipa* associations, and may occur in patches in Dry *Themeda* grasslands (see the Action Plan for Natural Temperate Grassland for a more detailed description of natural temperate grassland associations). Wallaby Grass is a very low growing grass with tussocks usually separated by bare ground. These grasslands normally contain several species of *Danthonia* and the species actually fed on by the moth larvae are uncertain. It is not known what proportion of suitable *Danthonia* species must be present in a *Danthonia* or *Stipa* grassland to support *S. plana*. Nor is it known what factors are responsible for determining the proportions of *Danthonia* and *Stipa* in such a grassland.
In NSW, *S. plana* is also found in grasslands dominated by *D. setacea*.

In Victoria, *S. plana* may be found in grassland dominated by *D. setacea* (Douglas 1993) and *D. pilosa* (Britten *et al.* 1995). Recent field studies at Mt Piper have indicated that the habitat of *S. plana* was a native grassland dominated by *Danthonia*, in particular, *D. carphoides*, *D. auriculata*, *D. setacea* and *D. eriantha.* The percentage cover of *Danthonia* at all sites was greater than 40%, which was shown to be the minimum density required to sustain a *S. plana* population in Victoria (Dear 1997).

BEHAVIOUR AND BIOLOGY

Adult *S. plana* may be found in the ACT from about mid November until early January, but most usually fly in early December. There is some seasonal variation, with flights occurring earlier in a warm dry spring and later, and extending for longer, in a cool moist spring. In 1982 (a warm dry spring), moths were flying plentifully on 5 November and at York Park the flight period was nearly over on 25 November, whereas in 1992-3 (a cool moist spring), the flight commenced on 24 November and extended until 30 January (Cook and Edwards 1993). *Synemon plana* adults are day flying and are only active under sunny conditions. On days of bright sunshine they are active from about 11 am to 1 pm. The males fly rapidly at about one metre from the ground. Females rarely fly, unless disturbed. Compared with the males, they are relatively immobile and tend to walk from tussock to tussock to lay eggs. As the adults are unable to feed or drink, they must mate and lay eggs rapidly and are also short-lived. Five days is the longest recorded life span for the male, but one to two days is normal (Cook and Edwards 1993).

Eggs are laid between the tillers of a *Danthonia* tussock or between the tillers and the soil. They are inserted into the crevices by the long ovipositor of the female and each female is capable of laying up to about 200 eggs. The larvae feed on the underground parts of the *Danthonia*. Whether the larva needs a single tussock for development or must move between tussocks to complete its development is unknown. The length of the life cycle is unknown, but two years is the best current estimate.

The larvae remain underground throughout development and pupate underground after preparing a tunnel to the surface through which the pupa eventually emerges. The pupal stage probably lasts for about six weeks. The pupa partially emerges from the tunnel at the surface and the adult moth escapes, leaving the empty pupal shell protruding from the soil (Edwards 1991, 1994).

Predation of adults has been observed at York Park, Barton, by several species of birds including the Willie Wagtail (*Rhipidura leucophrys*), the Magpie Lark (*Grallina cyanoleuca*), the Starling (*Sturnus vulgaris*) as well as robber flies (*Colepia abludo* and *Brachypogon* sp.) (Cook and Edwards 1993, 1994). Some reptiles may also be predators. No parasites or predators of the early stages have been recorded.

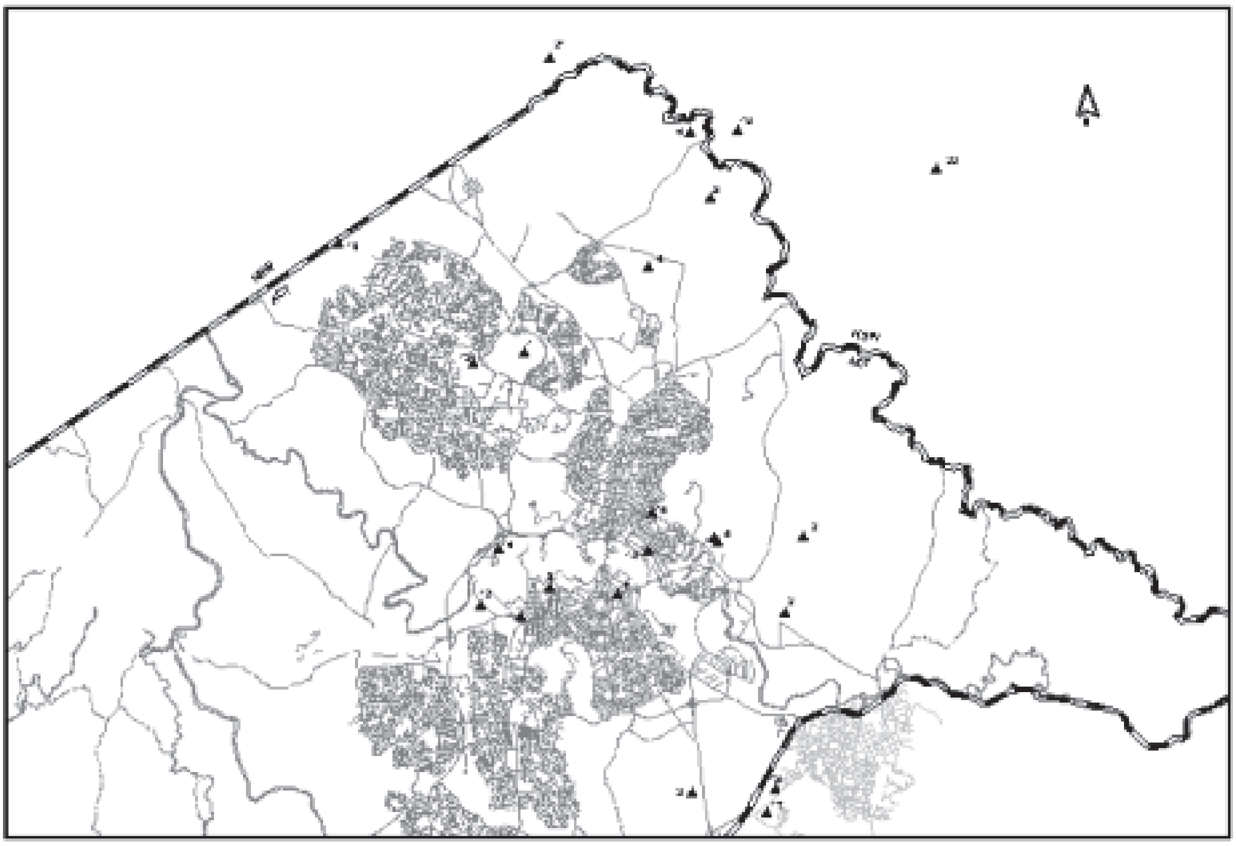

Figure 2: Known distribution of the Golden Sun Moth (*Synemon plana*) (▲ in the ACT (site numbers correspond to Table 1). Map produced by Environment ACT (Wildlife Research and Monitoring).
Note: Site 20 (Gundaroo Common) occurs outside the area shown on this map

Table 1. List of Locations with Conservation Ratings for *Synemon plana*

Population Number and Location	*Synemon plana* Conservation Value (Rating) 1=high; 4=minimal (see P.10 for explanation)	Area (ha) *	Grassland Action Plan Location No. (GAP) and Botanical Significance of Site (1=high; 5=low)	Other Significant Species in Vicinity	Proposed Protection Measure
ACT SITES:					
1. Belconnen Naval Station (Site A)	1	106.5	GAP 20: - 2	#	Reserve J
2. Majura Valley East: (Site A, Firing Range)	1	142.2	GAP 28: - 1(3)	Di, Tlp, Rl, #	Memorandum
(Site D, Airport)	1	47.1	GAP 28: - 2	Tlp, #	of Understanding
3. Jerrabomberra West (Site A, "Woden")	1	72.4	GAP 36: - 2	Tlp, Ap, #	Reserve J
4. Mulanggary Grassland Reserve (Site C)	1	82.8	GAP 6: - 3(5)	Di, #	Reserve
5. Campbell Park:					
Offices	2	3.3	GAP 27: - 3	Rl, Tlp, #	Reserve J
paddocks	2	9.0	GAP 27: - 3	Rl, Tlp, #	Reserve J
6 Mulligans Flat North	2	30.0 <			Reserve

(a) Reserve					
(b) paddock	2			#	Urban Open Space
7. York Park, Barton	2	0.4	GAP 34: - 3		Memorandum of Understanding
8. Mulligans Flat South	2	20.0 <			Reserve
(a) Reserve					
(b) paddock	2				Urban Open Space
9. Black Street, Yarralumla	3	4.1	GAP 32: - 3		Urban Open Space
10. Dunlop Hills Grassland Reserve	3	20.0	GAP 3: - 3	#	Reserve
11. Dudley Street, Yarralumla	4	0.9	GAP 30: - 3		Urban Open Space
12. Lady Denman Drive, Yarralumla	4	2.5	GAP 29: - 3	#	Urban Open Space
13. Lake Ginninderra (Site A)	4	0.1	GAP 19: - 3		Urban Open Space
14. Constitution Avenue, Campbell	4	3.0	GAP 26: - 3	#	Urban Open Space
15. CSIRO Limestone Avenue, Campbell	4	2.8	GAP 25: - 3		Memorandum of Understanding
16. Yarramundi Reach (Site C)	4	1.0	GAP 24: - 4		Memorandum of Understanding
NSW SITES:					
17. "The Poplars"	(-)	1.0		Rl, Tlp	
18. Letchworth [a]	(-)	55.0		Rl	
19. Ginninderra Road [a]	(-)	91.0			
20. Gundaroo Common [a]	(-)	1.0			
21. Spring Range Road [a]	(-)	2.0			
22. Sutton [a]	(-)	1.0			

Shaded areas indicate sites that are Public Land - Nature Reserve.

[a] = Recently surveyed grassland sites near the ACT border (Clarke and Dear 1998). J = Reservation to be considered as part of further evaluation of planning and conservation issues.

*** = Areas indicated in column are for the general area for Natural Temperate Grassland. *Synemon plana* and *Danthonia* sp. may occupy all the area or part of the area where the grassland is dominated by *Stipa* or *Themeda*.**

< = The areas shown for *S. plana* occupation are an estimate only and cover both (a) and (b), which refer to the one population. Each of the two populations partially occurs within the Mulligans Flat Reserve and partially in an adjoining rural lease. However, there is much of Mulligans Flat which the species is not likely to occupy.

Key to species - Ap = *Aprasia parapulchella*, Di = *Delma impar*, Rl = *Rutidosis leptorrhynchoides*, Tlp = *Tympanocryptis lineata pinguicolla*, # = uncommon or declining species which are not formally listed.

GAP = Grassland Action Plan Location Number - this number is used as a location reference in the Natural Temperate Grassland Action Plan (Action Plan No. 1). Its use in Action Plans for component species, such as *S. plana* indicates that the habitat of the species in question more or less coincides with the natural temperate grassland site referred to.

Note: The Campbell Park and Majura Valley East sites are represented by two entries - this is because the two locations are subject to different land uses.

Population size estimates of males at York Park were 520 (1992-3), 456 (1993-4) and 736 (1994-5) or a mean for the three years of 571 (Harwood *et al.* 1995). The area of York Park is approximately 0.4 hectare and this gives a crude population of 1700 males per hectare. There is no information about the sex ratio in adult *S. plana* and the females are so much more inconspicuous than the males that no population estimates were attempted at York Park. A 1:1 sex ratio would give a population density of 3500 per hectare. A two year life cycle would mean that double the number of adults observed are potentially present but the genetic interchange between the odd and even cohorts may be low.

The observed population size may be very different from the effective population size which is the important parameter in terms of genetic criteria. Preliminary unpublished results by Dr Geoff Clarke (conservation biologist, CSIRO Entomology) suggest that, in the *S. plana* populations in the ACT, the effective population size (the number of individuals actually reproducing each generation) is much lower than the observed population size. This suggests that small sites may be less viable than the observed population size would indicate (G. Clarke pers. comm.).

DISTRIBUTION
Museum records show that the species was common and widespread prior to 1950. The known distribution of *S. plana* from museum specimens extended from Bathurst, NSW, through the Southern Tablelands of NSW and central Victoria to the South Australian border (Edwards 1993). There are about 30 localities in Victoria represented by museum specimens. Currently, the species is known from 16 sites in the ACT of various sizes, 11 sites in NSW, and five sites in Victoria. The NSW sites are at Boorowa, Binalong, Rye Park, Sutton, Gundaroo and areas immediately north of the ACT, and at Queanbeyan (Clarke and Dear 1998). The same survey has not located any populations in the Goulburn, Tarago and Bungendore areas, or on the Monaro (Bredbo, Cooma, Adaminaby and Dalgety). All are below 700 m which suggests that *S. plana* is a western species at the limits of its range (Clarke and Dear 1998).

In the ACT, the species occurs in lowland areas adjacent to the city of Canberra and within the city (Figure 2, Table 1). There are extensive populations within the Majura Field Firing Range and the Belconnen Naval Station. There are less extensive populations within large grassland sites at "Woden" Property in the Jerrabomberra Valley and in the Mulanggary Grassland Reserve in Gungahlin. Together, these make up the four sites of high conservation value. Smaller sites at Campbell Park, York Park in Barton, Mulligans Flat (North and South), Black Street in Yarralumla and the Dunlop Hills Grassland Reserve in Belconnen contain populations of high to moderate density (Edwards 1994). A further six sites contain very small populations, which may not be viable in the short to medium term.

Conservation Status

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

Australian Capital Territory
Endangered. - Section 21 of the *Nature Conservation Act 1980,* Determination No. 7 of 1998 (formerly Determination No. 29 of 1996).
Special Protection Status Species. - Schedule 6 of the *Nature Conservation Act 1980,* Determination No. 77 of 1996.

New South Wales
Endangered. - Part 1, Schedule 1 of the *Threatened Species Conservation Act 1995* (NSW). Final determination made by NSW Scientific Committee (1996).
Victoria

Endangered. - CNR (1995). *Threatened Fauna in Victoria - 1995*. Department of Conservation and Natural Resources, Victoria.

Threats to Populations in the ACT Region

Loss or degradation of habitat is the major threat to *S. plana*. There has been a serious decline in the quantity and quality of habitat throughout its range including the ACT. About 5% or 1000 hectares of the natural grassland still exists in moderate to good condition and only a subset of this is dominated by suitable *Danthonia* species. The habitat continues to be in demand for urban, industrial and infrastructure development as well as being vulnerable to alteration by agricultural practices.

Fragmentation and isolation of the remaining areas results from the loss of extensive areas of habitat. Fragmentation has impeded the ability of the relatively immobile female to recolonise areas and therefore restricts gene flow.

The invasion of native grasslands by weeds and other introduced species has contributed to a decline in the quality of the habitat, and in numerous cases, to the effective destruction of the native grasslands.

Exotic species such as Toowoomba Canary Grass (*Phalaris aquatica*), Paspalum (*Paspalum dilatatum*), Serrated Tussock (*Nasella trichotoma*), Chilean Needle Grass (*Stipa neesiana*), Brome Grasses (*Bromus* spp.), Wild Oats (*Avena* spp.), Clovers (*Trifolium* spp.), Flatweed (*Hypochoeris radicata*), Fescue (*Festuca elatior*) and Plantain (*Plantago lanceolata*), pose a continuing threat to the surviving areas of *Danthonia* dominated grassland.

Natural grazing by native animals and grazing by introduced livestock under some agricultural regimes may have done little damage to *Danthonia* grasslands and *S. plana* populations. Indeed, light grazing may have increased areas of native grassland dominated by *Danthonia* (Sharp 1997). Cessation of, or changes in, these regimes may modify structure, lead to changes in species composition and result in degradation of the grassland. More intense agricultural practices involving fertiliser application, sowing introduced pasture species, or cultivation, are also destructive to native grasslands.
There is no evidence that predators have contributed to the decline in *S. plana*.

Major Conservation Objectives

The objective of this Action Plan is to maintain, in the long term, the existing viable populations of *S. plana* in their natural habitat, as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This is interpreted to include the maintenance of the species' potential for evolutionary development in the wild.

This objective is to be achieved by:

- Protecting and managing those sites where habitat of high conservation value remains.
- Developing detailed management strategies for remaining sites of lower conservation value where populations of *S. plana* remain viable.
- Continuing monitoring and research on the native *Danthonia* grasslands, and on the species and its biology, so that potential threats may be recognised and understood, with effective management practices implemented with minimal loss of habitat.

These objectives will be assisted by:

- Developing cooperative management arrangements (Memoranda of Understanding) between the Commonwealth Government and ACT Government on the two major sites that occur on land occupied by the Department of Defence.
- Negotiating with rural lessees for cooperative management arrangements (Property Management Agreements) for the other sites of moderate to high conservation value.
- Managing remaining sites to consider habitat requirements for the species.
- Supporting survey of further habitat in the ACT region.

Conservation Issues and Intended Management Actions

GENERAL

The *Danthonia* grasslands currently harbouring the species are subject to some low intensity management activities which serve to benefit low growing plants. Suburban sites are mown, rural sites are grazed and the Belconnen Naval Station is both mown and grazed. It is desirable that these areas continue to be managed in a manner similar to current practices with a view to maintaining *S. plana* populations. An adaptive management regime will need to be implemented, allowing for practices to be adjusted in accordance with greater scientific knowledge and future monitoring results.

Predators are not viewed as a problem and no steps need be taken to control or exclude pests, except weeds. Nor is human access to sites a problem so long as it is not so intensive as to damage the grassland. Indeed, human access may be encouraged, consistent with the need to ensure interested people are well informed of the purpose of, and activities at, a site.

The protection of Natural Temperate Grassland, an **endangered** ecological community, and other threatened species which inhabit this community, will allow for significant and complementary conservation actions.

- Issues, research needs and management actions set out in this Action Plan will be coordinated with the actions identified in the Action Plan for Natural Temperate Grassland, of which the species' principal habitat, the *Danthonia* grasslands, is a component.

Possible Management Conflicts
Some sites harbour *S. plana* and the Eastern Lined Earless Dragon (*Tympanocryptis lineata pinguicolla*) (also listed as endangered), notably the site on "Woden" Property and at the Majura Field Firing Range. Although reptiles may be predators of *S. plana,* there is no reason on the basis of current knowledge why a site should not be managed for the dual conservation of both *S. plana* and *T. l. pinguicolla*.

On the other hand, *S. plana* has been found in sites also inhabited by Striped Legless Lizard *(Delma impar)* (listed as vulnerable). *D. impar* requires a dense grass cover, which does not provide suitable habitat for *S. plana*. Some grasslands inhabited by both *D. impar* and *S. plana* may have been maintained in a suitable condition for *S. plana* by mowing or grazing. Changing management by reducing grazing or mowing intensity may make these sites more suitable to the Striped Legless Lizard, but less suitable to *S. plana*. It should be clearly determined how a site is to be managed for the moth and the Striped Legless Lizard. In a similar manner, the possibilities and conflicts in managing a grassland for *S. plana* and for the vegetation community, including uncommon or threatened plants, such as the Button Wrinklewort (*Rutidosis leptorrhynchoides*) will also need to be assessed. Management programs should be developed accordingly.

- Possible conflicts in conservation objectives will be resolved in the context of documented management arrangements for each location.

SURVEY
Surveys in November and December 1997 covered much of the potentially suitable grassland habitat in south-eastern NSW and located 10 new sites. These include five sites in close proximity to the ACT, two of which have areas greater than 50 ha (Ginninderra Road and Letchworth) and five in the area north-west of Yass, around Binalong, Boorowa and Rye Park (Clarke and Dear 1998). Additional small sites of lesser conservation value may not be currently known but it is likely that all significant regional sites are now recognised.

- Sites known to contain *S. plana* in the ACT will be surveyed to determine the extent of populations.
- Any additional sites in the ACT that contain the *Danthonia* vegetation association, which provide potential habitat for the species, will also be surveyed.
- Where additional site information becomes available, management and protection measures consistent with this Action Plan will be implemented.

Knowledge of the significance and viability of populations in the region is an essential prerequisite to placing the ACT information into a proper biogeographical context. This will enable the relative significance of different areas in the region to be assessed for their importance to the survival of this species and will assist regional planning for both development and conservation purposes.

- Environment ACT (Wildlife Research and Monitoring (WR&M)) will continue to liaise closely with the NSW National Parks and Wildlife Service (NSW NPWS) to ensure sharing of information, coordination, and a regional approach to the conservation of *S. plana*.

MONITORING
It is essential that the composition of the grasslands and *S. plana* populations of major sites continue to be monitored. This is because changes in management practices can lead to degradation of the grassland habitat. Invasion by weeds can damage and destroy a grassland without overt human activity. These changes can occur slowly, and unless monitored, may proceed too far before they are detected. Gaps in knowledge mean that changes in the *S. plana* population cannot be foreseen in any detailed way and direct observation is the only means of assessing the welfare of a population.

Intensive monitoring of the York Park population was conducted in the three seasons from late 1992 to early 1995 (Cook and Edwards 1993, 1994; Harwood *et al* 1995). This monitoring program involved marking individuals in a capture-mark-recapture procedure which permitted estimates of the population (males only) and estimates of longevity. These procedures are very labour intensive and not suitable for long term work, but could be used as an occasional quantitative check on a more practical procedure. Monitoring by a less rigorous method (outlined in Edwards 1994) is more practicable and should give an indication of the size of the population if conducted in optimal conditions. Monitoring by this method - ie. counting the number of males observed over a short period, has been continued by Environment ACT (WR&M) at the Majura Field Firing Range and at York Park since the more intensive studies ceased.

- Environment ACT (WR&M) will maintain a long-term monitoring program for *S. plana* to assist it in applying appropriate management strategies.
- The impacts of management practices on the *S. plana* and its grassland habitat will be monitored regularly. The impacts of changes to management practices will also be monitored.
- A program of periodic review of the results of all monitoring will be implemented. The review program will provide a mechanism for adjustment and modification to management practices to achieve conservation goals.

RESEARCH
There is a need for further ecological research on *S. plana*. Some ecological research is being undertaken at CSIRO Entomology in Canberra and at the University of Melbourne on Victorian populations. Important aspects of the species' biology where further knowledge would be helpful for management purposes include:

- biology of the larval stage;
- fecundity and dispersal potential;
- ecological requirements of the species, including its relation to *Danthonia* spp., other flora, soils, and ability to move between fragmented habitat; and
- genetic variability within and among populations: preliminary genetic analyses of six ACT populations have indicated relatively low levels of genetic variability, which suggests that the effective population size is considerably lower than the observed population size; further information should make it possible to rank populations on their amount and pattern of variability.
- Environment ACT (WR&M) will encourage research work directed towards an understanding of the key biological parameters of *S. plana* and their application to management related issues, requirements and constraints, particularly the:
    1. dynamic response of the species and its grassland habitat to management practices, including burning, grazing, mowing, and soil disturbance;
    2. impacts of grassland management on *S. plana* within reserves; and
    3. population viability.

MANAGEMENT
Provisional management recommendations have been prepared for the National Capital Authority (NCA) for the maintenance of the York Park site (Edwards 1995). These recommendations hold for small sites in a suburban setting. The issues addressed were:

- invasion by weeds;
- changes in water regimes;
- shading, edge effects and fire;
- soil disturbance;
- spoil from surrounding activities;
- fertiliser application;

- vegetation, mulch and exotic species; and
- public access and information.

On larger sites and rural sites, invasion by weeds and fire management are the major concerns. Management to maintain low grassland structure by controlling tall species, including other native grasses and exotic plants, is the principal reason for grazing or mowing. Essentially, taller more vigorous weeds shade and compete for light with *Danthonia,* which is very low growing. Taller plants are more likely to be cropped by grazing and mowing, disadvantaging the weeds and encouraging the *Danthonia*. Mowing and grazing should be most effective in early to mid spring when the vigorous weeds make most of their growth. Mowing several times in spring may therefore be necessary, in fact, mowing even while the moths are flying is better than not mowing at all (Edwards 1995). Grazing should be most intense in spring, if possible, for best control of weeds but care should be taken to ensure that grazing is not so heavy as to prevent seeding of the *Danthonia*. This may conflict with requirements to restrict mowing or grazing in spring in order to enable native plants to set seed and for seedlings to establish.

The effects of fire are largely unstudied. In theory *S. plana*, except as adults, should be resistant to fire as it is underground. Observations on other species suggest that moths fly in normal numbers after a fire. However, there are observations suggesting that populations may fall in the years following a fire before they build up again. *Synemon plana*, as larvae, feed on the underground reserves of plants and as these reserves are mobilised following a fire, the reserves available to the species must be reduced. It seems likely that the effects of fire are not catastrophic and infrequent wildfires can be withstood (E. Edwards, pers. comm.). Regular burning, unless balanced by very positive advantages to the health of the grassland, will in general be detrimental. As a precautionary measure, care should be taken with fire used as a management tool so that only a small proportion of any site is burnt at any one time.

- An adaptive approach to management of habitat and species values (including fire regimes) will be developed. The approach will ensure that new knowledge, including results from research and monitoring studies, is used to adjust or modify management practice where necessary to achieve conservation outcomes.
- Environment ACT (WR&M) will develop management guidelines based on considerations discussed in this Action Plan to assist landholders to manage sites so as to conserve and maintain the moth habitat and population consistent with other land activities and other conservation requirements.

EDUCATION AND LIAISON

As with any threatened species, the importance of informing the community and people responsible for managing their habitat is substantial.

- Environment ACT will compile and distribute management guidelines and maintain contact with land managers responsible for areas on which populations presently occur.
- Environment ACT will closely liaise with regional bodies, including the NSW NPWS, NSW local councils and the management team for the Joint Regional Biodiversity Survey of Grassy Ecosystems Project.

Environment ACT (Parks and Conservation Service) and CSIRO Entomology have jointly produced a poster *Disappearing Insects of Native Grasslands*, funded by the Endangered Species Program, Environment Australia. This poster prominently features *S. plana.*

- Environment ACT will prepare and distribute to appropriate target audiences information about the species and its conservation - this will include providing information to the public on the conservation, management and research actions being undertaken, so that measures being implemented are understood and supported.

Protection

CONSERVATION VALUES

An approach to conservation planning for *S. plana* and its habitat is based on the grouping of all known ACT sites into categories of high (Rating 1), moderate (Rating 2), low (Rating 3) and minimal conservation value (Rating 4). Within these categories, each site is listed below in order of importance. The rating of sites is necessarily partly subjective but quantitative data were collected for the density of *S. plana* populations and the area and condition of most of the sites. The criteria used for establishing this ranking are:

- the size and density of the *S. plana* population; and
- the area and condition of the *Danthonia* grassland.

High Conservation Value (Rating 1):

- Belconnen Naval Station (GAP 20).
- Majura Valley East (Firing Range and Airport) (GAP 28).
- Jerrabomberra West (Site A, "Woden") (GAP 36).
- Mulanggary Grassland Reserve

(Gungahlin -Site C) (GAP 6).

Moderate Conservation Value (Rating 2):

5. Campbell Park Offices (GAP 27).
6. Mulligans Flat North (Reserve and adjacent agisted paddock), Gungahlin.
7. York Park, Barton (GAP 34) - the rating is increased slightly because of the scientific work which has been based on the site.
8. Mulligans Flat South (Reserve and adjacent agisted paddock).

Low Conservation Value (Rating 3):

9. Black St, Yarralumla (GAP 32).
10. West Belconnen (GAP 3 - Site C).

Minimal Conservation Value (Rating 4):

The sites in this group are so small that continued survival of moth populations is doubtful, even under optimum conditions.

11. Dudley St, Yarralumla (GAP 30).
12. Lady Denman Drive, Yarralumla (GAP 29).
13. Lake Ginninderra (Site A) (GAP 19).*
14. Constitution Ave, Campbell (GAP 26).
15. CSIRO Limestone Avenue, Campbell (GAP 25). *
16. Yarramundi Reach (GAP 24). *

Note: GAP refers to the site number in the Natural Temperate Grassland Action Plan. A fuller explanation is provided as a footnote to Table 1.

Conservation management of these areas may be implemented in recognition of their conservation values to other species or the natural temperate grassland community. Protection of the *S. plana* population may therefore occur as a result of other measures. Recent surveys by Dr Geoff Clarke, CSIRO Entomology, failed to locate *S. plana* at the three sites indicated by *.

MEASURES FOR PROTECTION

The known *S. plana* populations occur in remnant native grassland on land under a variety of tenures including Territory Land-Nature Reserve managed by Environment ACT, rural leasehold land, Urban Open Space, and Commonwealth owned and managed land (National Land). Grassland remnants are often small in size, and may be isolated from one another by areas used for urban, agricultural or other land purposes.

Conservation effort in the ACT for *S. plana* will focus on protecting viable functional native grassland habitat in a cluster of sites occurring within the ACT. The four sites of high conservation value (Rating 1), located in Gungahlin, Belconnen, and the Majura and Jerrabomberra valleys, will be assigned the highest degree of protection. Their importance is based not only on the size and density of the *S. plana* population, but also on the botanical significance, representativeness and size of its habitat, along with the presence of other threatened species. The Majura Field Firing Range (GAP 28), the Belconnen Naval

Station (GAP 20) and "Woden" property (GAP 36) are all identified in the Natural Temperate Grassland Action Plan as being core natural temperate grassland sites warranting the highest degree of protection. In Gungahlin, the species is found in two reserved areas. The Mulanggary Grassland Reserve (Rating 1) contains significant populations and the Mulligans Flat Reserve (Rating 2) contains a small population in an open area within woodland and another small population in secondary grassland along the southern boundary. There is also a small population in the Dunlop Hills Grassland Reserve in West Belconnen. However, there is no formal protection for any of the other sites within the ACT. Consideration therefore needs to be given to the survival of the species, particularly at the other moderate to high conservation value sites at the Belconnen Naval Station and in the Majura and Jerrabomberra valleys.

The Belconnen Naval Station has been identified as an area to be transferred to the ACT Government on vacation of the site by the Navy.

In the Majura and Jerrabomberra valleys, there are opportunities to achieve protection coincidentally with that of grasslands and other threatened species, including the Striped Legless Lizard (*Delma impar)* and the Eastern Lined Earless Dragon (*Tympanocryptis lineata pinguicolla)*. In the case of the Majura Field Firing Range and the Campbell Park Offices in the Majura Valley, protection measures may also serve to protect a sizeable population of the endangered Button Wrinklewort (*Rutidosis leptorrhynchoides)*.

Protection of *S. plana* Populations

Protection of S*. plana* in native grassland habitat will be achieved through the provisions of the *Land (Planning and Environment) Act 1991*, the Territory Plan and Memoranda of Understanding with Commonwealth agencies. The mechanisms available to the Territory are reservation under the Territory Plan and Property Management Agreements (PMAs) with rural lessees. The Conservator of Flora and Fauna also has powers under the *Nature Conservation Act 1980* to protect threatened flora and fauna. Measures for effective protection of *S. plana* are identified through an assessment of the conservation values of the species and needs of each native grassland habitat site. Where specific measures have been identified for the protection of natural temperate grassland sites (see the Natural Temperate Grassland Action Plan), these are given as the recommended protection for *S. plana.*

The areas identified in the following tables generally refer to the size of the area containing the natural temperate grassland; in most instances the exact extent of *S. plana* populations within these areas has not been ascertained.

(I) Territory Plan - Hills, Ridges and Buffers with Public Land Overlay of Type Nature Reserve

Reservation is generally recognised as the mechanism for ensuring that sites of high conservation value are not eventually converted to a land use incompatible with their natural values (Caughley and Gunn 1996). Reservation is therefore an important mechanism for the protection of *S. plana* and its habitat. Reservation does not exclude the option of managing controlled grazing to achieve conservation objectives through agistment arrangements with local rural landholders.

The Commonwealth owned component of the Campbell Park grasslands, along with the Belconnen Naval Station, are included as they are recommended for transfer to the ACT Government, with consideration for reservation, based on further evaluation of planning and conservation issues (refer to the Natural Temperate Grassland Action Plan).

Areas already set aside, together with those to be considered as Nature Reserve, are listed in Table 2.

Table 2. Hills, Ridges and Buffers:
Public Land - Nature Reserve.

Location and site	GAP No.	Area (ha)	Cons. Rating	Current Status
Gungahlin: Mulanggary	6	82.8	1	Reserve
Mulligans Flat North & South (reserve)	N/A	*	2	Reserve

Dunlop Hills Reserve	3	20.0	3	Reserve
Reservation to be considered as part of further evaluation of planning and conservation issues				
Jerrabomberra West: "Woden"	36	72.4	1	Rural Lease
Belconnen Naval Station	20	106.5	1	National Land
Campbell Park: Offices Paddocks	27	3.3 9.0	2 2	National Land

The shaded area indicates sites that are Public Land - Nature Reserve.
* = Areas for the Mulligans Flat populations cannot be precisely determined as they overlap in part with adjoining rural leases.
Note: GAP No. = Grassland Action Plan Number. This number is used as a site reference in the Natural Temperate Grassland Action Plan.

(ii) Memoranda of Understanding
Memoranda of Understanding (MOU) provide another means of ensuring that sites with high conservation value will be managed so as to maintain their conservation value in perpetuity while enabling other compatible land uses, as identified in the MOU, to occur. An MOU with the Commonwealth does not preclude the possibility of the land being reserved in the future under Commonwealth legislation.

MOU are appropriate for Commonwealth-owned or occupied land, or other land where long-term land uses will not compromise conservation values (for example, land used for Defence purposes or communication facilities). Areas of National Land supporting *S. plana,* for which an MOU will be negotiated, are listed in Table 3.

In order to provide protection at the highest level for the sites of high conservation value (Rating 1), interim management arrangements will be put in place between land managers and Environment ACT until reservation or Memoranda of Understanding are achieved.

Table 3. Memorandum of Understanding to achieve protection equivalent to reservation.

Location and site	GAP No.	Area (ha)	Cons. Rating	Current Status
Majura Valley (E): Field Firing Range Airport	28 28	142.2 47.1	1 1	National Land National Land
York Park, Barton	34	0.4	2	National Land/ Urban Open Space
CSIRO: Limestone Avenue	25	2.8	4	National Land
Yarramundi Reach	24	1.0	4	National Land

Other Areas Supporting *S. plana*
There are several areas of varying sizes with modified grassland habitat supporting *S. plana*. These are not proposed to be protected either as nature reserves under the Territory Plan or through an MOU with the Commonwealth. However, parts of these areas may be appropriately managed to retain their conservation values for the species. Such arrangements include planning and management agreements with non-government landholders and protection of sites within the urban fabric.

- Sites will be included where feasible in appropriate Public Land categories under the Territory Plan.
- To ensure that the conservation values of these areas are protected, management agreements that incorporate conservation objectives will be developed for implementation by the relevant agency.

(i) Public Land (Urban Open Space)
Most land included in Hills, Ridges and Buffer Areas is identified as Public Land and can therefore be assigned a category under the Territory Plan. This would include (other than Nature Reserves), Urban Open Space and Special Purpose Reserves. Activities permitted in these land use categories can be compatible with conservation values, provided that appropriate conservation management is in place. In these cases, maintenance of the conservation values of the site is the responsibility of the relevant ACT Government agency. Other similar land uses include road reserves and powerline easements. Areas of Public Land supporting *S. plana* are listed in Table 4.

Table 4. Public Land - Urban Open Space

Location and site	GAP No.	Area (ha)	Cons. Rating	Current Status
Black St., Yarralumla	32	4.1	3	Urban Open Space
Dudley St., Yarralumla	30	0.9	3	Urban Open Space
Lady Denman Drive, Yarralumla	29	2.5	4	Urban Open Space
Lake Ginninderra	19	0.1	4	Urban Open Space

(ii) Other Land Categories
Where Territory Land includes other sites with populations of *S. plana,* these may be retained and appropriately managed within the development context, by consideration at the appropriate stages of the concept planning and development approval process. Such measures provide a means of enabling the primary land use to continue while accommodating the conservation needs of *S. plana* habitat on the site, but without the additional protection mechanism of being Public Land.

Where small sites occur within urban leases, advice can be provided to assist landholders to maintain conservation values. Advice may be given as site management guidelines and plans. This enables protection and management of areas occurring as road reserves, easements and urban parks, since they can be maintained as landscape features, research resources or buffers. Similar guidelines are relevant for sites which are currently under rural agistment pending development, such as the two areas adjacent to the Mulligans Flat Reserve. When incorporating these sites into the urban fabric, the entire site may not be retained. In these instances, boundaries of the areas to be incorporated require clarification.

These planning and site management measures do not preclude future land use changes, but are intended to retain the conservation values of the sites until future land use decisions are made. Urban leases supporting *S. plana*, for which negotiation of site management guidelines are appropriate, are listed in Table 5.

- Planning and site management mechanisms will be applied as required to urban sites so that, where possible, the natural grassland values of the *S. plana* habitat are conserved in the context of the primary land use.

Table 5. Sites within the Urban Fabric

Location and site	GAP No.	Area (ha)	Cons. Rating	Current Status
Mulligans Flat North	N/A		2	Rural Lease

(paddock)				
Mulligans Flat South (paddock)	N/A		2	Rural Lease
Constitution Avenue, Campbell	26	3.0	4	Designated Land.

MFR = Mulligans Flat Reserve.

Grassland Areas Requiring Further Investigation

There are several further sites containing the *Danthonia* grassland association, which provide potential habitat for the species. These are yet to be assessed to determine their conservation significance and value. Assessment of the conservation significance of these sites will be conducted as soon as practicable. Protection measures for each are already outlined in the Natural Temperate Grassland Action Plan.

OTHER ACTIONS FOR PROTECTION

The Draft Canberra Nature Park Management Plan and the Action Plan for Natural Temperate Grassland will provide further support for the conservation management of *S. plana* and its habitat.

Environment ACT will work with Planning and Land Management and the National Capital Authority to ensure that land uses in areas adjacent to sites supporting *S. plana* are compatible with conservation objectives and to minimise any adverse impacts.

The Royal Australian Naval Transmitting Station site (Belconnen Naval Station) has been listed on the Register of the National Estate, on the basis of its conservation value for *S. plana*.

Socio-economic Issues

The main social benefits of conserving representative communities of natural temperate grassland in which *S. plana* occurs are:

- meeting community concerns that further loss or extinction of significant ecological communities, together with their component native species, be prevented;
- the amenity and recreational values associated with the grassland reserves, in which the species occurs; and
- the tourism potential of a successful program to protect a threatened species along with its endangered habitat.

The potential for economic utilisation of native grassland habitat sites is relevant for those sites where current management or land uses are deemed to be compatible with the retention of conservation values. There are four main aspects of planning in Canberra that will be affected by the implementation of this Action Plan: These are:

1. Future Urban Areas

Proposals for future urban areas, as identified in either the National Capital Plan or the Territory Plan, and provided for in the Residential Land Release Program may for some areas have their viability affected by the size and location of possible future *S. plana* reserves.

2. Transport Facilities

The provision and/or upgrading of the following transport facilities may be affected:

- Majura Parkway - southern section and connections
- William Slim Drive - possible extension (Belconnen Naval Station)
- Very High Speed Train corridor (Majura and Jerrabomberra valleys)
- John Dedman Parkway- Kaleen East paddocks (potential *S. plana* habitat).

3. Industrial Areas
The planning for future industrial areas, in particular, a possible extension to the Hume industrial area and a possible industrial complex associated with the Airport in the Majura Valley. Some potential habitat adjacent to the Mitchell Industrial Area may also be affected.

4. Rural Leasing Aspects
One of the four sites of high conservation value, Jerrabomberra West (Site A) on "Woden" property, is within a rural lease. Preliminary investigations indicate that this lease currently contains withdrawal clauses allowing for the use of land for public purposes. The Rural Policy Taskforce has recently reviewed all aspects of rural leases including the recommendation of appropriate lease terms. Two recommendations of the Taskforce that will affect the Action Plans are that:

- the lease term for the Jerrabomberra Valley will be to the year 2020; and
- there will be no withdrawal clauses over any part of a rural lease unless it has been clearly defined for an imminent public work, such as a road, stormwater or other infrastructure.

This will mean that the Territory would have to withdraw any area of land having conservation significance at the time of an application for a new lease, or acquire it subsequently under the provisions of the *Land Acquisition Act 1994*.

It is expected that it will be sometime later in 1998 before rural lessees are able to take up a new lease as proposed by the Taskforce. In the meantime, Environment ACT will need to identify areas requiring special conservation measures before applications for extended lease terms are received. In the event that large areas of a lease will be withdrawn for conservation purposes, consideration will be given to the viability of the remainder of the lease.

In addition to the issues outlined above, there are some site specific issues which need to be addressed in order to implement the protection measures specified in this Action Plan. These are:

- Belconnen Naval Station, Lawson (GAP 20): This area potentially has high value as residential land. A decision on conservation will be complex given that the land is currently owned by the Commonwealth and may be transferred to the Territory in the near future.
- Mulligans Flat (north) agistment paddocks, Forde: This area has yet to have detailed planning conducted. Grassland conservation will be considered in the urban structure review of Forde and Horse Park, and lease boundaries and land use policies will be determined at that stage. This will be undertaken during the urban structure review process.

Legislative Provisions

The following legislation is relevant to conservation of flora and fauna in the ACT:

Nature Conservation Act 1980
The Nature Conservation Act provides a mechanism to encourage the protection of native plants and animals (including fish and invertebrates), the identification of threatened species and communities, and management of Public Land reserved for nature conservation purposes. Specified activities are managed via a licensing system.

Native plants and animals may be declared in recognition of a particular conservation concern and increased controls and penalties apply. Species declared as endangered must also be declared as having special protection status, the highest level of statutory protection that can be conferred.

As an endangered species, *S. plana* must be declared a special protection status (SPS) species and any activity affecting an SPS species is subject to special scrutiny. Conservation requirements are of paramount consideration and only activities related to conservation of the species or serving a special purpose are permissible. The Conservator of Flora and Fauna may only grant a licence for activities affecting a species with SPS where satisfied that the act specified in the licence meets a range of stringent conditions. Further information can be obtained from the Licensing Officer, Compliance and Quarantine Services, Environment ACT, telephone 6207 6376.

Natural Temperate Grassland, of which the *Danthonia* component provides habitat for *S. plana*, has been declared as an endangered ecological community (currently Determination No. 7 of 1998). The Conservator of Flora and Fauna has prepared an Action Plan for its conservation.

Land (Planning and Environment) Act 1991
The Land (Planning and Environment) Act is the primary authority for land planning and administration. It establishes the Territory Plan, which identifies nature reserves, national parks and wilderness areas within the Public Land estate. The Act also establishes the Heritage Places Register. Places of natural heritage significance be identified and conservation requirements specified.

Environmental Assessments and Inquiries may be initiated in relation to land use and development proposals.

***Australian Heritage Commission Act 1975* (C'th)**
The Australian Heritage Commission Act establishes the Register of the National Estate (RNE) and imposes a special duty of care on Commonwealth agencies in relation to actions that have an adverse effect on any part of a place entered in the Register. The Belconnen Naval Station and precinct have been entered in the RNE in recognition of its habitat value for *S. plana.*

Consultation and Community Participation
For the best management of National Land and rural leases, liaison and agreements between Environment ACT and Commonwealth agencies and rural lessees will be necessary.

Community participation with activities assisting the conservation of native grasslands and *S. plana* will be encouraged through groups such as the Friends of Grasslands and Park Care Groups operating near grassland areas supporting the species. Information on the conservation of the species will be incorporated into community education programs conducted by Environment ACT.

The conservation of *S. plana* and its associated *Danthonia* habitat will be promoted through suitable information signs, community liaison and public education. The National Capital Authority has an information sign in preparation for York Park to explain the purpose of that site.

- Public access to sites will be encouraged provided it is consistent with the requirements of landholders or lessees and is not likely to cause damage to the grassland. Encouragement will be given to the constructive involvement of community organisations.
- Environment ACT will cooperate with NSW NPWS in surveying for *S. plana* and in identifying likely habitat in southern NSW.

Implementation and Review

RESPONSIBILITY FOR IMPLEMENTATION
Environment ACT (WR&M) will be responsible for coordinating implementation of this Action Plan, subject to the availability of Government resources. Primary responsibility for conservation and management of grassland communities supporting *S. plana* on Territory Land will rest with the ACT Parks and Conservation Service whilst relevant Commonwealth agencies will have responsibility for National Land, although provisions in the *Nature Conservation Act 1980* (ACT) are still applicable.

- The ACT Government will seek the cooperation of the Commonwealth Government in setting in place coordinated and complementary action to protect the species' native grassland habitat in the ACT.

EVALUATION
Implementation of this Action Plan will be a collaborative exercise between government agencies, landholders and the community generally. Commonwealth and NSW participation will be critical in some cases. The Action Plan will be reviewed after three years. The review will comprise an assessment of progress using the following performance indicators:

- completion of commitments that can reasonably be expected to be finalised within the review timeframe (e.g. introduction of a statutory protection measure for a species; development of a management plan);
- completion of a stage in a process with a time line that exceeds the review period (e.g. design or commencement of a research program);
- commencement of a particular commitment that is of a continuing nature (e.g. design or commencement of a monitoring program for population abundance); and
- expert assessment of achievement of conservation objectives of the Action Plan.

The review will be reported to the ACT Flora and Fauna Committee. This will provide an opportunity for Environment ACT and the Flora and Fauna Committee to assess progress, take account of developments in nature conservation knowledge, policy and administration, and review directions and priorities for future conservation action.

The following conservation actions will be given priority attention:

- completion of surveys in all known native grassland sites where the species occurs (including those that contain potential habitat) to determine the extent of the population;
- establishment of a monitoring program to provide information on how populations respond to management practices and environmental pressures;
- putting in place protection measures; and
- establishing liaison mechanisms with NSW authorities and determining the regional distribution and conservation status of the species.

Acknowledgments
Material for this draft Action Plan was prepared for Environment ACT by Mr E.D.Edwards, CSIRO Entomology.

The illustration of the species (Figure 1) was prepared for Environment ACT by Sarah Reglar.

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List of Action Plans - June 1998

In accordance with Section 23 of the *Nature Conservation Act 1980,* the following Action Plans have been prepared by the Conservator of Flora and Fauna:

No. 1: Natural Temperate Grassland - an endangered ecological community.

No. 2: Striped Legless Lizard (*Delma impar*) - a vulnerable species.

No. 3: Eastern Lined Earless Dragon (Tympanocryptis lineata pinguicolla) - an endangered species.

No. 4: A leek orchid (*Prasophyllum petilum*) - an endangered species.

No. 5: A subalpine herb (*Gentiana baeuerlenii*) - an endangered species.

No. 6: Corroboree Frog (*Pseudophryne corroboree*) - a vulnerable species.

No. 7: Golden Sun Moth (*Synemon plana*) - an endangered species.

No. 8: Button Wrinklewort (*Rutidosis leptorrhynchoides*)
- an endangered species.

No. 9: Small Purple Pea (*Swainsona recta*) - an endangered species.

FURTHER INFORMATION

Further information on this Action Plan or other threatened species and ecological communities can be obtained from:

Environment ACT
(Wildlife Research and Monitoring)
Phone: (06) 207 2126
Fax: (06) 207 2122
or on the Environment ACT Homepage
http://www.act.gov.au/ environ

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ARCHIVAL RECORD

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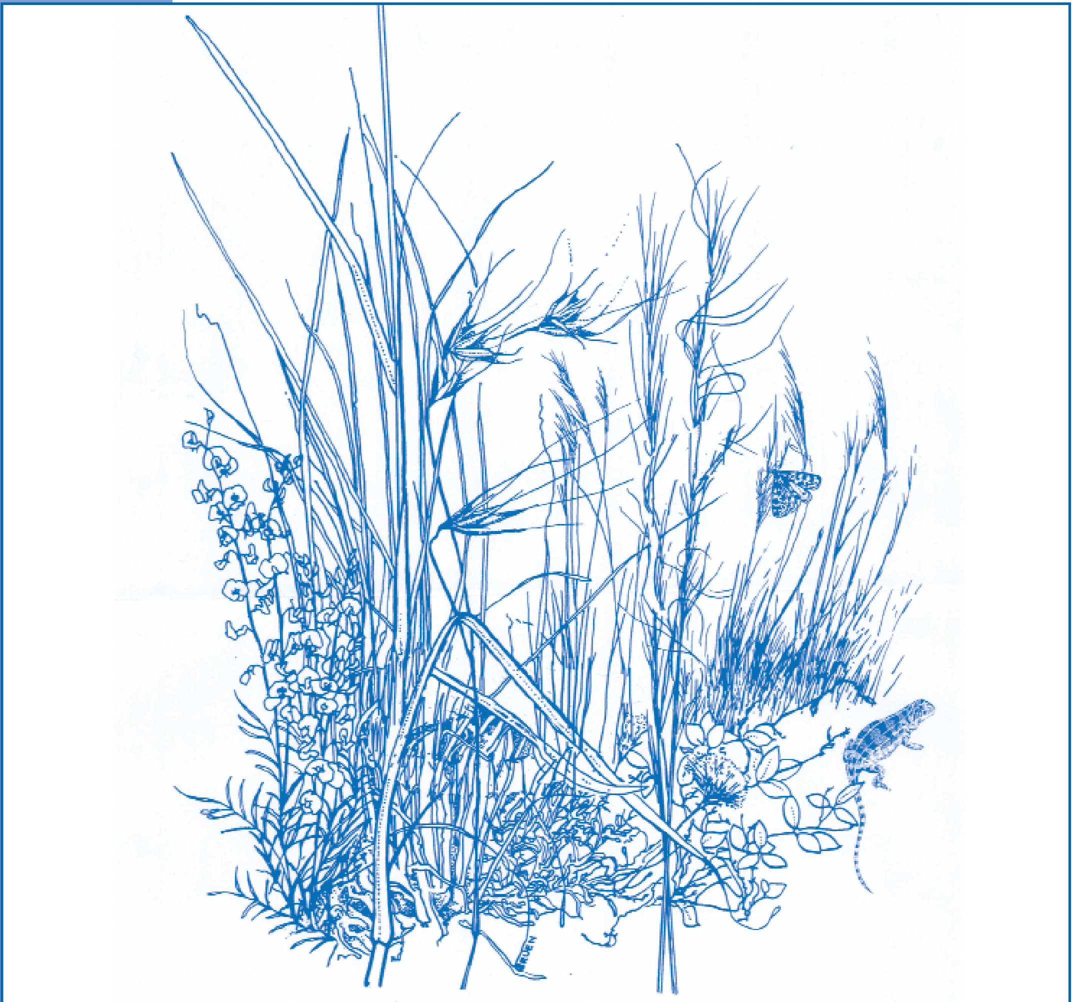
Environment ACT, Canberra

Action Plan No. 28

A

Vision Splendid of the Grassy Plains Extended

ACT Lowland Native Grassland Conservation Strategy



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Action Plan No. 28

A Vision Splendid of the Grassy Plains Extended

ACT Lowland Native Grassland
Conservation Strategy

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Note on the title:

A Vision Splendid of the Grassy Plains Extended

With an apology to Banjo Patterson and the line from his poem 'Clancy of the Overflow':
'And he sees the vision splendid of the sunlit plains extended'.

(*The Bulletin* 21 December 1889)

Vision

The Australian Capital Territory makes an outstanding contribution, regionally and nationally, to conservation of lowland native grassland and grassland flora and fauna.

Before European settlement, the temperate grasslands of the ACT and region, and their associated flora and fauna, were part of an extensive band of grasslands in south-eastern Australia. Occurring across broad plains and in low elevation areas subject to cold air drainage, they formed a mosaic with lowland woodland and riparian and wetland communities. These grasslands and associated grassy woodlands were the natural resource base for the development of the Australian pastoral industry from the early 1800s. Their accessibility and productivity resulted in their almost complete transformation by the new pastoral economy. In the ACT, the development of Canberra in the valleys and on the plains during the 20th century destroyed most of the grassland that remained.

Natural temperate grassland is one of Australia's most threatened ecosystems. In south-eastern Australia, 99.5% of the estimated pre-European natural temperate grassland has been destroyed or grossly altered. Some form of degrading disturbance threatens all grassland remnants, even those in permanent reserves. Loss of grassland habitat and the fragmentation and degradation of the remaining areas has had a severe impact on plants and animals that are dependent on grasslands. Characteristic species of grasslands such as the Grassland Earless Dragon and the Striped Legless Lizard now survive only in small and disconnected populations. The once extensive 'wildflower' displays provided by species of inter-tussock forbs are restricted to remnants of relatively undisturbed grassland.

The *ACT Lowland Native Grassland Conservation Strategy* builds on more than ten years of survey, monitoring, research, conservation planning and management in relation to lowland native grasslands in the ACT and region. From a slim knowledge base in 1990, a good understanding has been developed of the remaining grasslands in the ACT and some of their component species. Some grasslands have been placed in reserves and there are good prospects for conserving other areas. The *Strategy* provides the strategic context for the ongoing protection, management and restoration of this unique Australian ecosystem.

Acknowledgements

The *Strategy* was prepared for the Conservator of Flora and Fauna by the Wildlife Research and Monitoring Unit of Environment ACT. The team comprised: Mark Dunford (data management and mapping), Murray Evans, Marjo Rauhala, Sarah Sharp and David Shorthouse. David Wong assisted Sarah Sharp in the 2003–04 surveys.

Assistance by contract staff, consultants and researchers in undertaking flora and fauna surveys and analyses over the past 10 years has contributed greatly to the preparation of the *Strategy*.

Kevin Frawley prepared drafts of the report and managed its compilation.

Progress in preparing the *Strategy* was reported to the ACT Flora and Fauna Committee, and individual members provided expert comment and advice.

Cover illustration modified from illustrations by Bev Bruen and Liz Faul.

Figure 2.1 provided by NSW Department of Environment and Conservation.

THIS DOCUMENT SHOULD BE CITED AS:

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FURTHER INFORMATION

Further information on this Action Plan or on threatened species and ecological communities can be obtained from:

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(Wildlife Research and Monitoring)
Phone: (02) 6207 2126
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Contents

Contents

Contents

LIST OF FIGURES

LIST OF TABLES

Contents

1 Introduction

1.1

A New Focus for Nature Conservation in the ACT

In 2002 the ACT Government introduced a *New Focus for Nature Conservation in the ACT*, which includes a program to establish strategies for priority species/ecological communities. This is to ensure that resources are directed to achieving maximum effect in conservation activities. To implement this program, Environment ACT initiated a three-year review of existing Action Plans for threatened species and ecological communities.

The first review in 2002–03 resulted in *Woodlands for Wildlife: ACT Lowland Woodland Conservation Strategy* covering endangered Yellow Box–Red Gum Grassy Woodland, other lowland woodlands and the species dependent upon these woodlands (ACT Government 2004a). This *ACT Lowland Native Grassland Conservation Strategy* is the product of the second review covering natural temperate grassland (an endangered ecological community), other native grasslands, and plant and animal species dependent upon these. In 2004–05, Action Plans for aquatic species (and the riparian zone) were reviewed and a new integrated strategy prepared. These three strategies are complementary and recognise that ecological communities are dynamic—evolving and intergrading with each other, and sharing the more mobile of their constituent fauna.

Coincident with this ACT Government program, a *Planning Framework for Natural Ecosystems of the ACT and NSW Southern Tablelands* has been completed (Fallding 2002). The document was prepared through close cooperation between ACT agencies, NSW local and state government agencies and the ACT Housing Industry Association. The framework provides the basis for a more coordinated approach to threatened species conservation in the region. The *Planning Framework* does not cover all the Southern Tablelands. It includes the ACT and areas to the north-west, north-east and east of the ACT, and south to the southern border of the ACT.

The *Planning Framework* compares the pre-1750 and current distributions of the broad native vegetation types found within the ACT and NSW Southern Tablelands region. About 45% of the region supported grassy ecosystems (native grassland, grassland–woodland mosaic, box–gum woodland) pre-1750, compared to about 13% in 2000. Native grassland has been reduced from 11% of the region pre-1750 to about 1% in 2000. Only a very small proportion of the remaining grasslands are in good condition (i.e. floristically and structurally intact and having a low weed cover). Of the pre-1750 natural temperate grassland in the Southern Tablelands as a whole (i.e. extending south to the Victorian border), there is less than three percent remaining that retains a level of ecological integrity justifying recognition as having high conservation value and warranting protection.

The *Planning Framework* concludes that remnants of many vegetation types in good structural and floristic condition are relatively rare. The grassy ecosystems, including lowland native grassland ‘can be regarded as the most important from a conservation planning point of view because of their extremely restricted extent following development and agricultural land use’ (p. 15). Grassland sites of high biodiversity value are rare, isolated and fragmented, and with the exception of reserves established in the ACT, are poorly represented in the regional reserve network (p. 17).

1.2

Scope of the *Lowland Native Grassland Conservation Strategy*

Reflecting Government policy, the *Lowland Native Grassland Conservation Strategy* takes an integrated, territory-wide approach within a regional context, to the protection of the remaining lowland native grasslands.

The *Strategy* seeks to maintain and improve the natural integrity of the remaining lowland native grassland ecosystems. Within the grassland remnants, this means maintaining and improving the viability of the grassy ecosystem. Externally, it means maintaining and improving connectivity to other native vegetation, avoiding further fragmentation, and minimising harmful effects from adjacent land uses.

The *Strategy* recognises that in addition to natural temperate grassland, which has been declared an endangered ecological community, there are also areas of native pasture (see Chapter 2) and secondary grassland (included in the *ACT Lowland Woodland Conservation Strategy* as it is derived from cleared woodland). Lowland native grassland also exists as part of the grassland–woodland mosaic that covers about 3% of the region (Fallding 2002, p. 20). The *Strategy* encompasses the conservation of grassland flora and fauna, including those species declared as 'vulnerable' or 'endangered' under the *Nature Conservation Act 1980* (ACT).

The *Lowland Native Grassland Conservation Strategy* supersedes seven separate Action Plans previously published for the natural temperate grassland ecological community, four threatened animal species associated with lowland grassland, and two plant species—all declared threatened under the *Nature Conservation Act 1980* (ACT) (Table 1.1). The statutory requirement for the ACT Conservator of Flora and Fauna to prepare Action Plans for declared threatened species and ecological communities remains and this *Strategy* incorporates this requirement in an integrated way. While the legal authority of the *Strategy* is confined to the Australian Capital Territory, management considerations are addressed in a regional context. Should any other species associated with lowland native grassland be declared threatened in the future, the *Strategy* will require amendment to incorporate the details and requirements for that species.

The focus of the *Strategy* is lowland native grassland, including the endangered natural temperate grassland ecological community, across the ACT, regardless of tenure and land use. In this way, it differs from a management plan applied to a particular area or areas. A central purpose of the *Strategy* is to inform decision-making with regard to land use planning, and the development and management of land in the ACT.

Specifically, the *Strategy*:

- identifies the remaining areas of natural temperate grassland and other important areas of lowland native grassland in the ACT;
- identifies the floristic associations found in lowland native grassland areas in the ACT;
- outlines the values of the remaining lowland native grassland areas focusing on the conservation values of the ecological communities and component flora and fauna (recognising that areas may also have social and cultural values e.g. recreational, aesthetic, Aboriginal and European heritage);

Table 1.1: Ecological Community/Species Included in the *Lowland Native Grassland Conservation Strategy* and Existing Action Plans

Species/Ecological Community	Status	Action Plan No. Date	Declaration Date (in accordance with section 21 of the *Nature Conservation Act 1980 (ACT)*)
Natural Temperate Grassland	Endangered	No. 1, 1997 (ACT Government 1997a)	15 April 1996
Striped Legless Lizard (*Delma impar*)	Vulnerable	No. 2, 1997 (ACT Government 1997b)	15 April 1996
Grassland Earless Dragon (*Tympanocryptis pinguicolla*)	Endangered	No. 3, 1997 (ACT Government 1997c)	15 April 1996
Golden Sun Moth (*Synemon plana*)	Endangered	No. 7, 1998 (ACT Government 1998a)	15 April 1996
Perunga Grasshopper (*Perunga ochracea*)	Vulnerable	No. 21, 1999 (ACT Government 1999)	19 May 1997
Button Wrinklewort (*Rutidosis leptorrhynchoides*)	Endangered	No. 8, 1998 (ACT Government 1998b)	15 April 1996
Ginninderra Peppercress (*Lepidium ginninderrense*)	Endangered	No. 25, 2003 (ACT Government 2003b)	4 September 2003

- outlines conservation goals, objectives and actions for lowland native grassland and grassland dependent species, including those declared as threatened under the *Nature Conservation Act 1980* (ACT);
- outlines principles on which to base conservation actions;
- incorporates the Action Plans for listed species and communities which are required by the *Nature Conservation Act 1980* (ACT);
- provides a basis for planning and land management decisions with regard to areas containing lowland native grassland;
- encourages community participation in the conservation of lowland native grassland and component species;
- satisfies the requirement under section 23(2) of the *Nature Conservation Act 1980*, that an Action Plan includes proposals for the identification, protection and survival of a threatened species or ecological community, or, in the case of a threatening process, proposals to minimise its effect.

1.3

Definition of Natural Temperate Grassland

Natural temperate grassland is a native ecological community that is dominated by native species of perennial grasses. There is also a diversity of other native herbaceous plants (forbs) present. An important characteristic of the community is that it is naturally treeless, or has less than 10% projective foliage cover (see Glossary) of trees, shrubs and sedges in its tallest stratum (Moore 1964; Kirkpatrick 1993). In the ACT, natural temperate grassland occurs up to an altitude of 625 m.

The ecological community is described in greater detail in Chapter 2.

1.4

Role of the ACT Flora and Fauna Committee

The ACT Flora and Fauna Committee is established under amendments to the *Nature Conservation Act 1980* that were enacted in 1994. It is comprised of seven members with expertise in biodiversity or ecology. It advises the ACT Minister for the Environment in relation to nature conservation.

Since its establishment in 1995 the Flora and Fauna Committee has received and assessed nominations of species or ecological communities that may be threatened with extinction. The Committee is required to make assessments on nature conservation grounds only and is guided by specific criteria set out in its publication *Threatened Species and Communities in the ACT: Criteria for Assessment* (July 1995) (ACT Flora and Fauna Committee 1995). In making its assessment of natural temperate grassland and the listed plant and animal species included in this Strategy, the Committee concluded that each nomination satisfied these criteria.

As a group of experts in biodiversity, the Committee is asked to draw on its knowledge and experience of the region's flora and fauna during preparation by Environment ACT of draft and final Action Plans and to advise the Conservator of Flora and Fauna on progress in implementing them. These reviews are published in the Committee's Annual Reports. The Committee is also asked for its views on topical nature conservation issues as they apply to the ACT and it regularly provides such advice to Environment ACT. Thus the Committee is a valuable source of technical expertise, independent of Environment ACT and the Conservator of Flora and Fauna.

ACTION PLAN REVIEWS

The Flora and Fauna Committee conducts annual reviews of progress in implementing Action Plans for threatened species and communities. In 2003 the review comprised assessment of Action Plans for Natural Temperate Grassland, Striped Legless Lizard, Grassland Earless Dragon, Golden Sun Moth, Button Wrinklewort and Perunga Grasshopper, A Leek Orchid, Small Purple Pea and A Subalpine Herb.

The Committee's assessment used the following performance indicators:

- completion of commitments that can reasonably be expected to be finalised within the review timeframe (e.g. introduction of a statutory protection measure for a species; development of a management plan);
- completion of a stage in a process with a time line that exceeds the review period (e.g. design or commencement of a research program);
- commencement of a particular commitment that is of a continuing nature (e.g. design or commencement of a monitoring program for population abundance); and
- expert assessment of achievement of conservation objectives of the Action Plan.

The Flora and Fauna Committee reported in October 2003 to the Conservator of Flora and Fauna recommending that the species included in the review (with the exception of A Subalpine Herb *Gentiana baeuerlenii*) be incorporated into this *Lowland Native Grassland Conservation Strategy*. A Leek Orchid (*Prasophyllum petilum*) and the Small Purple Pea (*Swainsona recta*) are found in grassy woodland and have been included in the *ACT Lowland Woodland Conservation Strategy*. The Committee noted that the protection and management of lowland native grassland areas (and associated threatened species) would become increasingly important because of development pressures in areas such as the Majura and Jerrabomberra valleys. The Committee recommended that greater priority be given to education of the Canberra community about grassland conservation, and expressed concern that no Memorandum of Understanding had been negotiated with Canberra Airport in relation to the protection of native grasslands.

1.5

Relevant Legislation

1.5.1 ACT Planning and Land Management

The *Australian Capital Territory (Planning and Land Management) Act 1988* provides for two categories of land in the ACT:

- National Land—used by or on behalf of the Commonwealth, and managed by the Commonwealth; and
- Territory Land—all the remaining land of the ACT. The ACT Government manages this land on behalf of the Commonwealth.

Important areas of natural temperate grassland on National Land occur in the Majura Valley, Jerrabomberra Valley (HMAS Harman) and at the Belconnen Naval Station.

The *National Capital Plan* (NCA 2003) sets out general land use policies for the Territory as a whole and may specify areas of land that have the special characteristics of the National Capital as Designated Areas. The Plan may set out detailed conditions of planning, design and development in Designated Areas. The National Capital Authority has planning responsibility for these areas, which may be either National Land or Territory Land. This *Lowland Native Grassland Conservation Strategy* accords with relevant objectives of the *National Capital Plan* (p. 5), and principles and policies in the *Plan* for the National Capital Open Space System (Ch. 8), Rural Areas (Ch. 9) and Environment (Ch. 11).

Planning for areas that are not Designated Area is the responsibility of the ACT Planning and Land Authority and planning policies are set out in the *Territory Plan* (ACTPLA 2003).

1.5.2 Legislation Applying to the Conservation of Flora and Fauna in the ACT and Region

The following legislation applies to the conservation of flora and fauna in the ACT and region:

NATURE CONSERVATION ACT 1980 **(ACT)**

The *Nature Conservation Act 1980* provides authority for the Conservator of Flora and Fauna to manage Public Land reserved for conservation of the natural environment. Activities that are inconsistent with management objectives for nature conservation are controlled. Special measures for conservation of a species or community of concern can be introduced in a reserved area, including restriction of access to important habitat. Provisions of the *Nature Conservation Act 1980* are applicable to National Land (which is land used by, or intended to be used by the Commonwealth).

Part 1 of the Act establishes the ACT Flora and Fauna Committee with responsibilities for assessing the conservation status of ACT flora and fauna and the ecological significance of potentially threatening processes. Where the Committee believes that a species or ecological community is threatened with extinction or a process is an ecological threat, it is required to advise the responsible minister, and recommend that a declaration be made accordingly.

Parts 4 and 5 of the Act provide for protection of native plants and animals. Section 21 of the Act authorises the declaration of (a) a vulnerable or endangered species, (b) an endangered ecological community, and (c) a threatening process, based upon the advice and recommendation to the responsible Minister by the ACT Flora and Fauna Committee.

Native plants and animals may also be declared as ‘protected’ (s. 17) or as having ‘special protection status’(s. 16) in recognition of a particular conservation concern that warrants additional protection. Increased controls apply to declared species and licensing constraints are specified. Species declared as endangered under the Act, or threatened with extinction, must also be declared as having special protection status. This is the highest level of statutory protection that can be conferred on a species in the ACT. Further information on these matters can be obtained from Environment ACT by phoning the Arts, Heritage and Environment Helpline on 6207 9777.

Under s. 47 of the Act, the Conservator of Flora and Fauna may give the occupier of land, directions for protection or conservation of native plants and animals. This provision is relevant to the management of threats to a species or ecological community of concern that occurs on leased land. Conservator's directions were issued in January 2004 to lessees in the Jerrabomberra Valley to ensure that natural temperate grassland and a population of the Grassland Earless Dragon are protected while consideration is given to the pattern of future land use in the valley.

Part 9 of the Act allows the Conservator to enter into a Management Agreement with an agency where its activities have potential to conflict with nature conservation objectives. This provision is relevant to management of conservation threats on unleased land and applies to utilities (e.g. gas, electricity), navigation and communication facilities, and land development.

LAND (PLANNING AND ENVIRONMENT) ACT 1991 (ACT)

The *Land (Planning and Environment) Act 1991* is the primary authority in the ACT for land planning and administration and establishes the *Territory Plan*. One of the goals of the *Plan* is 'to promote ecologically sustainable development, protect biodiversity, and provide for high standards of environmental amenity, urban design and landscape' (ACTPLA 2003). The *Plan* identifies nature reserves, national parks, wilderness areas and special purpose reserves within the Public Land estate. The Act requires that management plans be prepared for areas identified as Public Land under the *Territory Plan*.

The Act provides for the *Territory Plan* to incorporate a Heritage Places Register. Places of natural heritage significance may be included in the Register and conservation requirements specified. The Act also provides for environmental assessments and inquiries to be initiated in relation to land use and development proposals. This is included in the *Territory Plan* environmental planning policies.

It should be noted that Part IV (Environmental Assessments and Inquiries) and Part V (Land Administration) of the *Land (Planning and Environment) Act 1991* apply to all Territory Land. This includes Territory Land within Designated Areas under the *National Capital Plan* (see s. 1.5.1) that is subject to regulations under the Act. In circumstances where the regulations do not apply, collaborative solutions are sought between the Territory and the Commonwealth.

The Canberra Spatial Plan (ACT Government 2004b) was released in March 2004 and provides a clear strategic direction for the development of Canberra over the next 30 years and beyond, but with the flexibility required to respond to change. It sets the framework for spatially based decision making in the future and outlines the actions needed to achieve the strategic direction for Canberra over the next 30 years. The *Spatial Plan* does not replace the *Territory Plan*, but will inform changes to both the *Territory Plan* and the *National Capital Plan*.

The *Spatial Plan* contains key principles to guide the future growth of Canberra. Protection of the natural environment is one of these key principles. The *Plan* states that the location of future residential development will ensure that areas identified as having significant biodiversity values, such as threatened species and ecological communities and habitat for threatened species, are protected from development. In particular, the *Spatial Plan* notes that development in the new employment corridor in Majura, Symonston and Jerrabomberra, including around the airport, will take into account the areas of native grassland and habitat for threatened species that are of significant nature conservation value.

ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 (COMMONWEALTH)

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the primary Commonwealth legislation for environment protection. Under the EPBC Act, an action will require approval from the (Commonwealth) Environment Minister if the action has, will have, or is likely to have a significant impact on a matter of national environmental significance and it is not subject to certain specified exceptions. Exceptions include actions taken in accordance with Commonwealth accredited management plans. The Act also promotes ecologically sustainable development through the conservation and ecologically sustainable use of natural resources, the conservation of biodiversity, and a cooperative approach to the protection and management of the environment involving governments, the community, landholders and indigenous peoples.

Matters of national environmental significance trigger the Commonwealth's environmental assessment and approval responsibilities. The matters are: World Heritage and National Heritage properties, Ramsar wetlands of international importance, nationally listed threatened species and ecological communities, migratory species protected under international agreements, Commonwealth marine environment and nuclear actions.

'Natural Temperate Grassland of the Southern Tablelands of New South Wales and the Australian

Capital Territory' and several of the plant and animal species included in this *Strategy* are listed as threatened under the EPBC Act. There is also potential application of the EPBC Act in the ACT to nationally listed threatened species (see Table 2.4, 2.5), National Land, and in relation to Commonwealth actions (see http://www.deh.gov.au/epbc/index.html).

The Commonwealth prepares Recovery Plans for species and ecological communities listed under the EPBC Act (e.g. *National Recovery Plan for Natural Temperate Grassland of the Southern Tablelands (NSW and ACT): an endangered ecological community* (Environment ACT 2005)). In situations where such Recovery Plans coincide with ACT Action Plans or ACT management responsibilities, every effort is made to ensure coordination, consistency and cooperation between the Commonwealth and ACT governments and their agencies.

Pursuant to s. 23 of the *Nature Conservation Act 1980*, the *Draft ACT Lowland Native Grassland Conservation Strategy* was released for public comment on 12 October 2004 for the period to 21 December 2004. Twelve submissions were received and a detailed analysis of these was presented to the Flora and Fauna Committee on 14 March 2005. The *Strategy* has been finalised, taking into account both the submissions and the advice of the Committee.

THREATENED SPECIES CONSERVATION ACT 1995 (NSW)

The *Threatened Species Conservation Act 1995* (TSC Act) provides for the protection of all threatened plants and animals native to New South Wales (with the exception of fish and marine plants which are covered by other laws). Under the Act, threatened species are classified as endangered or vulnerable. A recovery plan must be prepared for endangered species (other than those presumed extinct), endangered populations, endangered ecological communities and vulnerable species. For each key threatening process that is listed, the NSW Department of Environment and Conservation (Parks and Wildlife Division) is required to prepare a threat abatement plan.

One of the important features of the TSC Act is the integration of the conservation of threatened species into development control processes under the NSW *Environmental Planning and Assessment Act 1979*. The effect of a development or activity on threatened species must be considered by a consent and/or determining authority. Where there is likely to be a significant effect on threatened species, the preparation of a species impact statement is required.

The requirements of this legislation, including the preparation of recovery plans by the NSW Department of Environment and Conservation (Parks and Wildlife Division), apply to four species included in this *Lowland Native Grassland Conservation Strategy*. These are the Striped Legless Lizard (Vulnerable, TSC Act), Grassland Earless Dragon (South-eastern Lined Earless Dragon), Golden Sun Moth, and Button Wrinklewort (Endangered, TSC Act). Natural temperate grassland is not listed under the TSC Act, however the ecological community receives some protection under the Act because it provides habitat for threatened species.

FLORA AND FAUNA GUARANTEE ACT 1988 (VIC.)

The *Flora and Fauna Guarantee Act 1988* is the primary legislation for the protection of Victoria's biodiversity, native plants and animals and ecological communities on land and in water. Species and ecological communities can be listed as threatened under the Act, based on assessments by an independent Scientific Advisory Committee. Threatening processes may also be listed. The Victorian Department of Sustainability and Environment maintains lists of rare or threatened species in Victoria. Conservation status categories used in these lists (presumed extinct, endangered, vulnerable, rare, poorly known) are also applied to species or communities listed as threatened under the Act.

1.6

Consultation and Community Participation

A community forum was held in March 2004, to enable community groups and interested individuals to provide comment on pre-circulated draft sections of the *Lowland Native Grassland Conservation Strategy*. A range of groups and individuals with an interest in grassland conservation was represented at the forum. Matters raised by forum participants included clarification of the concept of a comprehensive, adequate and representative protected area system; the importance of ecological connectivity and prevention of fragmentation; the need for grassland rehabilitation; increasing the knowledge of native grassland and promotion of its conservation; involvement of the community; and the response to development threats.

The *Draft ACT Lowland Native Grassland Conservation Strategy* was released for public comment from 12 October 2004 to 21 December 2004. Twelve submissions were received and a detailed analysis of these was presented to the Flora and Fauna

Committee on 14 March 2005. The strategy has been finalised, taking into account both the submissions and the advice of the Committee.

There is active community interest in the ACT in the conservation of native grassland. Community groups, including the Conservation Council of the South East Region & Canberra, Friends of Grasslands, Australian Native Plants Society, Friends of Aranda Bushland and ACT Park Care and Landcare groups have been involved in advocacy, research, publication and on-ground work in support of the conservation of native grasslands. An objective of the *Strategy* (Table 4.1) is that 'landholders, community groups and others are actively involved in natural temperate grassland conservation'. As a means to further build community involvement, the *Strategy* proposes the formation of a Conservation Management Network as pioneered in other jurisdictions.

1.7

Implementation

The *Lowland Native Grassland Conservation Strategy* is not a management plan prepared under the *Land (Planning and Environment) Act 1991*, nor does it propose that management plans be prepared for each grassland area independent from existing management plans and management arrangements. The *Strategy* is a *thematic* document i.e. it deals with lowland native grassland conservation across all land tenures in the ACT. The goals of the *Strategy* will be achieved through a variety of means, relevant to the different tenures. The *Strategy* provides the strategic, ACT-wide and regional context for the consideration of lowland native grassland conservation in planning studies for specific areas of the ACT. It is in such planning studies that issues such as a buffer between native grassland and urban development will be determined.

Environment ACT has responsibility for coordinating implementation of this *Lowland Native Grassland Conservation Strategy* in partnership with relevant public and private land managers and the wider community. Building upon the existing community interest in native grassland conservation, will be an important part of achieving the goals of this *Strategy*. The remaining lowland native grassland in the ACT is mainly on Public Land (Territory Land) reserved under the *Territory Plan* and National Land, with other areas on leased and unleased Territory Land. Achievement of the objectives of the *Strategy* will require the participation of the managers of these lands, in particular in undertaking the actions set out in Chapter 4.

Primary responsibility for conservation of lowland native grassland and component species on reserved Public Land will rest with the ACT Parks and Conservation Service, with the directions of the *Strategy* expressed through management plans. For example, the *Canberra Nature Park Management Plan* (ACT Parks and Conservation Service 1999, p. 18) includes an action 'to provide assistance in the development and implementation of conservation strategies for threatened native plant species and communities and provide for long term monitoring'. Memoranda of Understanding (especially with Commonwealth landholders), Land Management Agreements (with rural lessees), and directions by the Conservator of Flora and Fauna under s. 47 of the *Nature Conservation Act 1980* in relation to activities on unreserved Public Land in the urban area are also means by which the *Strategy* may be implemented. Cooperation with NSW agencies, especially the Department of Environment and Conservation (Parks and Wildlife Division) is an important element in implementing the *Strategy*, as part of a growing regional effort to conserve the biodiversity of the ACT and Southern Tablelands.

The role of the *Strategy* in land use planning and land management in relation to ACT legislation is shown in Figure 1.1 on page 8.

1.8

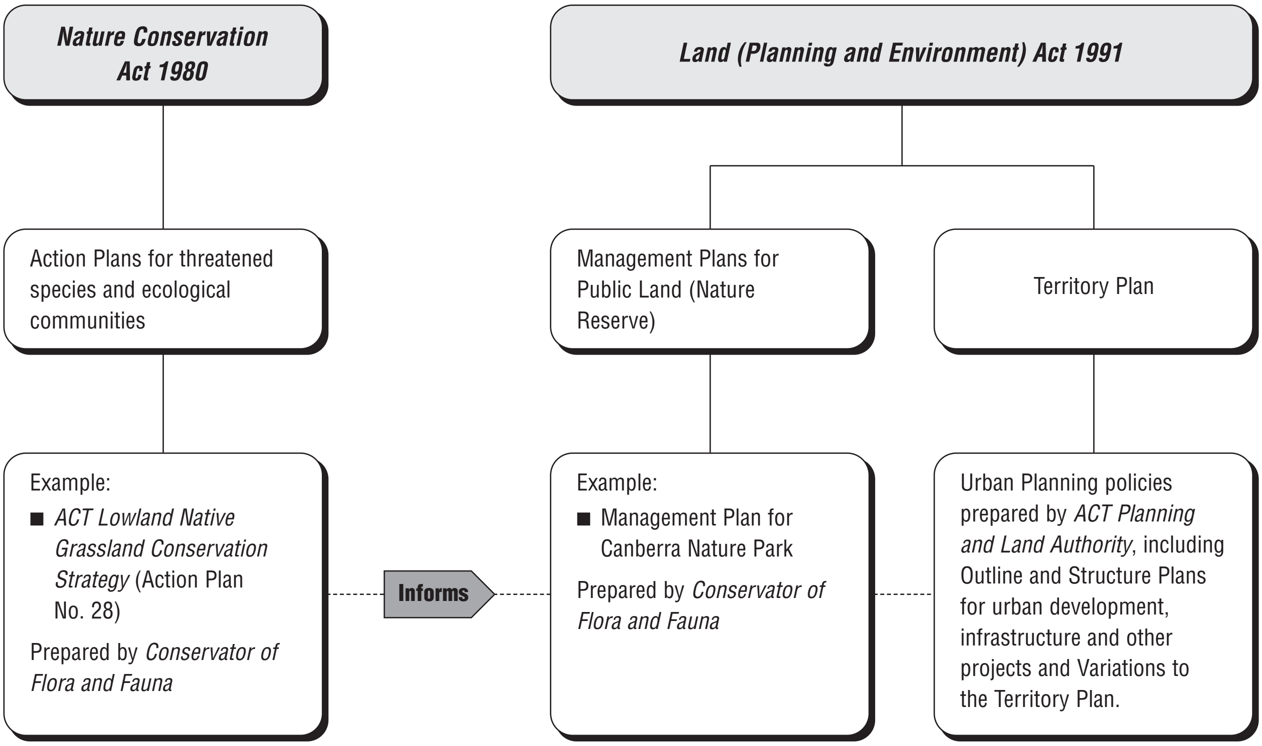
Structure of the ACT Lowland Native Grassland Conservation Strategy

The *Strategy* is structured as follows:

Chapter 1: The **Introduction** outlines the scope of the *Strategy*, the basis for declaring species threatened in the ACT and the role of the ACT Flora and Fauna Committee. It also includes a brief summary of the structure of ACT planning and land management, an outline of legislation applying to the conservation of flora and fauna in the ACT and region, and sections on community consultation and implementation of the *Strategy*.

Chapter 2: Lowland Native Grassland contains sub-sections on lowland native grassland (including the natural temperate grassland ecological community), grassland flora and grassland fauna. The first sub-section provides a description of natural temperate grassland and places the NSW Southern Tablelands distribution in its south-eastern Australian context. The sub-section outlines the surveys undertaken to compile the vegetation data for the *Strategy*. It describes other

Figure 1.1: The Role of the Lowland Native Grassland Conservation Strategy in Land Use Planning and Land Management in the ACT.



(A brief outline of the broader ACT planning framework including the role of the National Capital Plan is contained in s. 1.5.1.)

lowland native grassland communities, grassland not included in the *Strategy*, and categories of lowland native grassland in the ACT. Changes to natural temperate grassland since European settlement and ongoing threats are outlined.

The second sub-section (Grassland Flora) briefly describes the lowland native grassland flora of the ACT region. It outlines how disturbance tolerant and disturbance sensitive species have been used as indicators of levels of grassland modification. The sub-section sets out specific conservation actions for ACT threatened grassland flora species, and uncommon species found in the ACT, some of which are listed as threatened in other jurisdictions.

The third sub-section (Grassland Fauna) discusses the interdependence of fauna and grassland ecosystems, outlines threats to fauna and briefly describes grassland fauna of the ACT region. The sub-section discusses the conservation of grassland fauna in the ACT, critical habitat features for threatened species, and threats to those species. It concludes with specific actions for the conservation of grassland fauna.

The chapter includes maps showing the location in five geographic areas of the remaining ACT lowland native grassland and known occurrences of threatened species.

Chapter 3: Lowland Native Grassland: Planning and Management for Conservation considers principles underlying conservation planning for native grassland and criteria for identifying areas of highest conservation significance. Planning and management issues for each part of the ACT are outlined. The chapter also reviews aspects of the management of native grassland.

Chapter 4: The Lowland Native Grassland Conservation Strategy brings the elements of the *Strategy* together, placing the Strategy into the ACT planning and land management context and considering policy guidelines for grassland conservation. The chapter evaluates the state of protection for lowland native grassland in the ACT, outlines actions taken to improve lowland grassland conservation, future actions necessary, and determines priorities. In particular, in support of the *Strategy's* goals, the chapter (s. 4.2) sets out objectives, the actions necessary to achieve those objectives, and relevant performance criteria.

2 Lowland Native Grassland

2.1

Natural Temperate Grassland

2.1.1 Natural Temperate Grassland in South-Eastern Australia

Natural grasslands are one of the major vegetation formations in Australia. Moore and Perry (1970) recognised four basic types: arid tussock grassland (e.g. Mitchell Grass *Astrebla* spp.), arid hummock grasslands (e.g. spinifex *Triodia* spp.); coastal grasslands; and sub-humid grasslands (tropical, temperate and sub-alpine). Prior to European settlement, temperate grasslands had an irregular distribution from north of Adelaide through south-eastern Australia to northern New South Wales, and including the Tasmanian midlands (Groves and Williams 1981). The grasslands occurred throughout the fertile inland and sub-coastal plains and lower slopes of the Great Dividing Range at low elevations (100–350 m asl). In the rolling hills of the South Australian mid-north and the Southern Tablelands of New South Wales, they occurred as high as about 1000 m asl (Lunt *et al.* 1998). The changes wrought by European pastoralism and agriculture, often the complete removal of the native grasslands and woodland trees that marked the grassland–woodland interface, mean that it is no longer possible to delineate the original grassland distribution with any accuracy. It was probably a dynamic boundary, reflecting variability in temperature and rainfall, and perhaps fire regimes (Sharp, pers. comm.).

The temperate grasslands and woodlands were the home of Aboriginal people, and their activities over millennia helped to shape the plant and animal communities found by the first Europeans. When Aborigines came to Australia, the grasslands were rich in animal life, including the giant marsupials ('megafauna'), and the plains provided many edible tubers and bulbs. The tubers of Murnong or Yam Daisy (*Microseris lanceolata*), for example, were stored as a winter food (Kirkpatrick *et al.* 1995). There is no doubt that Aborigines burnt the grasslands and associated grassy woodlands. It is often assumed that the burning-off recorded in explorers' accounts was only to provide good feed ('green pick') for grazing animals, however, it also had horticultural benefit, encouraging yams and tubers (Lunt *et al.* 1998).

Prior to European colonisation, fire regimes in temperate grasslands and woodlands were probably a combination of deliberate Aboriginal burning (possibly mosaic cool spring or autumn fires that favoured the maintenance of a diverse herbaceous cover) and summer 'wildfires' that occasionally swept across the landscape (Benson 1994; Benson and Wyse Jackson 1994; Lunt *et al.* 1998). The nature of pre-European burning regimes remains largely unknown and the precise ecological effects of Aboriginal burning are unclear, but the available evidence does not support the hypothesis that it caused the evolutionary diversification of the Australian flora (Bowman 1998). Aboriginal burning followed millions of years of evolutionary adaptation in which lightning-generated fire probably played a significant part. With regard to grassland–woodland boundaries, it seems most likely that absence of trees was controlled by a combination of soil and regional climatic features, with pre-European fire regimes playing a minor role in controlling tree regeneration (Lunt and Morgan 2002).

The natural temperate grasslands and temperate eucalypt woodlands were the natural resource base for the development of the Australian pastoral industry from the early 1800s. In the 1830s, Mitchell traversed some of these lands describing them as 'Austral Felix' (Mitchell 1838). By the mid-nineteenth century, 30 million sheep, 1.7 million cattle and 32 000 horses were grazing on the grassy plains and lower open slopes of the Great Dividing Range of New South Wales and Victoria (Lunt *et al.* 1998). The productivity of the plains resulted in their early and thorough alienation and almost complete transformation by the new pastoral economy (Stuwe 1986). With few physical or institutional barriers to this expansion, it is not surprising that the temperate grasslands are now one of Australia's most endangered terrestrial ecological communities (Kirkpatrick *et al.* 1995).

2.1.2 Lowland Native Grassland: ACT and Southern Tablelands Region—Past Distribution

Lowland native grassland in the ACT region occurs within the South Eastern Highlands Region as defined in the Interim Biogeographic Regionalisation for Australia (Thackway and Cresswell 1995; Environment Australia 2000). This bioregion includes about 80% of the ACT, the tablelands and western slopes of south-eastern NSW and extends from near Bathurst in the north, into Victoria in the south.

Forming part of this South Eastern Highlands Region, the Southern Tablelands extend southwards from the Abercrombie River to the Victorian border, from Booroowa and Jindabyne to the west and Goulburn to Braidwood and Bombala in the east. Natural temperate grassland was widespread in the Southern Tablelands at the time of European settlement as part of the woodland–grassland mosaic (Costin 1954; Benson 1994; Fallding 2002). An accurate estimate of the extent of natural temperate grassland prior to European settlement is not possible, due to lack of knowledge of the characteristics of this mosaic. For the Monaro region (extending from Canberra and Queanbeyan in the north to the Victorian border in the south, and from the Kybean Range in the east to the Snowy Mountains and Fiery Range in the west), Benson and Wyse Jackson (1993) estimated a total of 250 000 ha of the ecological community. However, this estimate appears to include two montane grassland types that are not part of the listed ecological community. For the Southern Tablelands as a whole, estimates range from approximately 386 000 ha or less (Thomas *et al.* 2000) to approximately 480 000 ha or more (Rehwinkel 1997).

Natural grassland was particularly common in areas of lower elevation, often extending across large parts of the plains and the river valleys at elevations from 560 m to about 1000 m. The Monaro Plains, Bungendore Plains, Goulburn Plains, Yass Plains and Limestone Plains (ACT) supported large areas of natural temperate grassland (Figure 2.1). Smaller areas located between Braidwood and Crookwell and from Murrumbateman to Tumut also supported natural temperate grassland on various substrates and topography (Rehwinkel 1997).

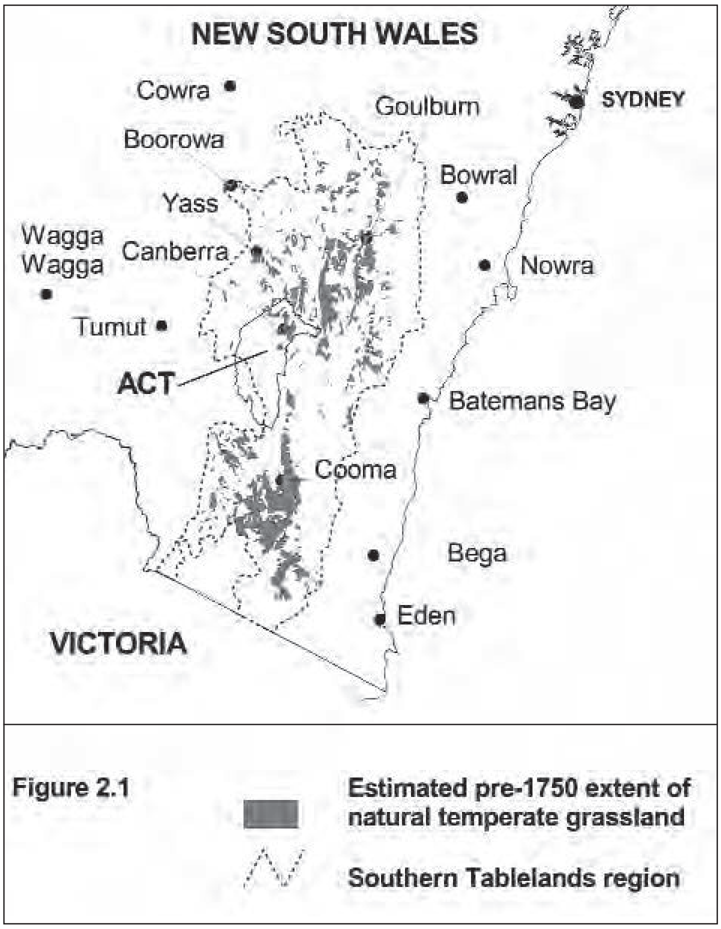


Figure 2.1:
Estimated Pre-1750 Extent of Natural Temperate Grassland in the Southern Tablelands Region.

Geological formations that supported the ecological community included Cainozoic sediments, Silurian and Ordovician volcanics, mudstones, shales and limestones. Typical soils were derived from volcanic and sedimentary substrates and included red, grey and brown clay podsols and laterites (Benson 1994).

In the ACT, natural temperate grassland was the dominant ecological community in lower elevation areas in the Molonglo River Valley, which forms the central part of the Canberra region and the adjacent Jerrabomberra and Majura valleys. Natural temperate grasslands also dominated large areas of the lowland plains at Tuggeranong in the south, and the plains at Belconnen and Gungahlin to the north (Pryor 1938, Benson and Wyse Jackson 1994; Wildlife Research Unit 1994). Benson (1994) estimated that in the ACT there were 20 000 ha of natural temperate grassland present prior to European settlement.

The pre-European distribution of natural grasslands in the region is believed to have been influenced by a combination of environmental factors, including low temperatures due to cold air drainage in winter, periods of low soil moisture availability in summer associated with the heavy clay soils, and low rainfall in some areas (Chan 1980; Groves and Williams 1981; Benson and Wyse Jackson 1994; Benson 1994). Story (1969) considered the effects of seasonal burning by Aborigines to have been an important factor determining distribution of the ecological community, a view not supported by Lunt and Morgan (2002) for temperate grasslands as a whole. In environments where edaphic and climatic factors did not preclude tree growth, natural temperate grassland graded into open grassy woodlands and other vegetation formations.

In the Southern Tablelands of New South Wales and the ACT, the earliest known site of Aboriginal occupation is from Birrigai, ACT, dated at 21 000 years BP (Flood *et al.* 1987). Archaeological evidence points to the more sheltered river valleys as being the main occupation sites, with some montane valley camps and high summer camps that were probably associated with exploitation of the Bogong Moth and associated social and ceremonial activities. The lowland grasslands, woodlands, and river valleys provided mammals, reptiles, ducks and other birds and vegetable foods (e.g. Yam Daisy, ferns, fruits and seeds) as well as a seasonal abundance of fish (Flood 1980, pp. 61–82, 97–100). There is little evidence for year-round occupation of the treeless tablelands, an inhospitable location in winter. While grass seeds are known to have been part of the diet on the western plains of New South Wales, seed grinding of the now less common Kangaroo Grass (*Themeda australis*) and Hairy Panic Grass (*Panicum effusum*) does not appear to have been part of the economy on the Monaro (Flood, 1980, pp. 97–8).

It is not possible to establish with any certainty the nature of Aboriginal and lightning induced fire regimes in the grasslands of the Southern Tablelands and the ACT. While early European explorers such as Throsby, Kearns, Cunningham, Hume and Hovell recorded Aboriginal fires, these may have been signal and campfires as well as burning-off (Lunt *et al.* 1998). The botanist Alan Cunningham provided an account of burning at Tuggeranong, ACT, in April 1824 (quoted in Flood, 1980, p. 20):

> *These interesting Downs had been burnt in patches about two months since, and as the tender blade had sprung up, these portions, having assumed a most lively appearance, formed a striking contrast with the deadened appearance of the general surface, still clothed with the vegetation of the last year. It was common practice of the aborigines, to fire the country in dry seasons where it was wooded and brushy; to oblige game of the kangaroo kind to quit their covery and subject themselves to be speared.*

By the mid-1820s after Capt. Mark Currie had ridden south of the Limestone Plains and discovered the high plains of the Monaro (Hancock 1972), the grasslands of the Southern Tablelands were known to Europeans and the pastoral advance followed. Squatting runs and land grants superimposed a new map over the Aboriginal tribal boundaries and transformation of the country began. By 1840, only fifteen years after Europeans had settled on the Monaro, P.E. de Strzelecki, in a report to Governor Gipps expressed concern about the effects that drought, cropping and over-grazing were having on soil erosion (Hancock 1972).

2.1.3 Lowland Native Grassland: ACT and Southern Tablelands Region—Present Distribution

European land uses, particularly grazing, pasture improvement, cropping, the introduction of exotic species (including pasture species) and changes to the pattern of burning, have greatly reduced the extent and integrity of natural temperate grassland in the region. Tree planting on natural temperate grassland also threatens its integrity. Urban development has contributed significantly to the further loss of this ecological community in the region, particularly in parts of the ACT associated with the establishment and expansion of Canberra.

Disconnected areas of native grassland of varying conservation significance are all that remain of the pre-European distribution of the natural temperate grassland community in the ACT and region (Environment ACT 2005). It is found along roadsides and railway easements, and in urban areas, churchyards, cemeteries, special purpose sites (e.g. radio transmission tower areas), travelling stock reserves and privately owned or leased rural land. Many remaining sites are small (less than 10 ha). Some of the largest sites are on private land and on Commonwealth occupied land in the ACT, including areas managed by the Department of Defence.

REGIONAL GRASSLAND SURVEYS

The Southern Tablelands have not been uniformly surveyed for the presence of native grassland. Ecological surveys were initially focused on the ACT (which has been comprehensively surveyed) and the Monaro sub-region. More recently, the north-western and eastern sub-regions (in NSW) have been the subject of survey effort. Private land in NSW is inadequately surveyed across all sub-regions and information regarding the location and boundaries of sites across all land tenures is incomplete. In the NSW portion of the Southern Tablelands, over 400 sites on both public and private land (covering more than 7 000 ha) have been identified as containing natural temperate grassland in moderate to good condition. A similar amount, as yet unsurveyed, is likely to exist on private land (Environment ACT 2005).

SURVEYS IN LOWLAND NATIVE GRASSLAND IN THE ACT

In 1938 Pryor modelled the natural distribution of natural temperate grassland in the ACT based on the valley landform occurring in the altitude range of up to 600 m (Pryor 1938). This mapping has formed the basis of all subsequent work. However, prior to 1990, knowledge of natural grassland remnants in the ACT was limited to a small number of incomplete botanical surveys (e.g. Chan 1980, who identified and mapped the location of native grassland sites and their dominant grasses). The need to survey and document the remaining grasslands was identified in a proposal for a *Recovery Plan for Lowland Native Grasslands in the Australian Capital Territory* prepared by the Wildlife Research Unit of the ACT Parks and Conservation Service in 1991. In 1992 the Plan was approved for funding under the Commonwealth's Endangered Species Program (see s. 3.1).

In the period 1991 to 1996, comprehensive surveys were undertaken, resulting in a major increase in knowledge of the distribution and ecology of natural temperate grassland and component plant and animal species in the Territory. The surveys identified all the remaining grassland sites and formed the basis for the assessment of their conservation value. This information provided the foundation for the 1997 Action Plan for natural temperate grassland prepared pursuant to the *Nature Conservation Act 1980* (ACT Government 1997a).

Evaluation of the conservation significance of native grassland must be done in a regional context. Complementary to the ACT grassland survey work in the 1990s, was the Monaro and Southern Tablelands Native Grasslands Conservation Project (Rehwinkel 1996c) which followed up on the survey work on the Monaro by Benson (1994), Jones (1995) and Rowell (1994). The project included grassland floristics, fauna habitat and grassland conservation ratings, but noted that 'the faunal values of native grasslands on the Monaro are poorly known (Rehwinkel 1996c, p. 9). The project focussed on ways to ensure that the best grassland sites would continue to be managed in ways that preserved and enhanced their conservation values, but also included the recording and survey of new grassland sites. A summary of the grassland floristic survey work for the South-Eastern Highlands region (including the ACT) is contained in Rehwinkel (1997, pp. 33–35).

In 2003–4 the vegetation in all known grassland sites was again surveyed as part of the preparation of this *Strategy*. The same methods that were developed to survey woodland sites in the ACT were applied (ACT Government 2004a). The ACT Rapid Assessment Technique has been developed to provide information about the species present, habitat features, condition, ecological communities and floristic associations. The survey specifically aimed to provide accurate mapping and assessment of the spatial extent of areas of grassland of natural temperate grassland and native grassland of varying condition and containing the different floristic associations. Each grassland area was mapped as polygons of vegetation that reflected homogeneity of vegetation composition and structure. Contiguous polygons of natural temperate grassland, native pasture and small areas of connecting exotic grassland or vegetation could then be combined to identify discrete native grassland sites.

The surveys of polygons do not provide a complete species inventory. These surveys aim to provide an overall description of the species present and types of species likely to be present as a result of the level of disturbance that is evident at the sites. As is described in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a) studies undertaken by Prober and Thiele (1995), and Dorrough (1995) have described which species occur more frequently in grazed and ungrazed areas. In addition, an analysis of the frequency of all species surveyed in over 700 sites across the Southern Tablelands region has been used to identify species that appear to have declined as a result of site disturbance. Appendix 1 lists examples of species categorised by their sensitivity to disturbance.

Comparisons of grassland distribution, species diversity and condition at all ACT sites when first surveyed (between 1991 and 1996) and subsequently (in 2003/4) were undertaken (s. 3.3.1, Appendix 2). The Strategy is open to the addition of new areas of native grassland in the ACT, should further areas be located.

PRESENT ACT DISTRIBUTION OF LOWLAND NATIVE GRASSLAND

The distribution of lowland native grassland in 2004, including natural temperate grassland, in the ACT, together with the estimated distribution of entirely treeless grassland prior to European settlement, is shown in Figure 2.2. Grassland sites outside the treeless area identified by Pryor (1938) occur where records, visual estimation and presence of cold air drainage areas indicate that projective foliage cover of trees was probably less than 10% prior to European settlement. On this basis it has been estimated that natural temperate grassland occurs in the ACT at elevations less than 625 m (Sharp 1997).

In the ACT lowland region, remnant lowland native grassland has been recorded at 47 sites (2172 ha) (Figure 2.2, Table 3.2). Sites are defined as areas that have separate land uses or ownership, or are separated by a major road or development, or by a significant area of other vegetation (native or exotic). Some sites are adjacent to each other, forming larger grassland units.

Native grassland sites that contain a substantial proportion of natural temperate grassland are regarded in this *Strategy* as the endangered ecological community. They may also contain areas or patches of native pasture, degraded native pasture or exotic vegetation. However, as they are managed in their entirety, the whole site is considered to be the community. Many sites identified as containing natural temperate grassland contain several or more floristic associations. These sites also may contain threatened flora and/or fauna species.

There are also other native grassland sites that contain no natural temperate grassland (or very small patches, less than 0.25 ha), being dominated by native pasture, degraded native pasture or exotic vegetation. These sites are included in the *Strategy* if they support threatened grassland species.

2.1.4 Description of the Ecological Community: Natural Temperate Grassland

Native grassland communities in those parts of the south-east of the continent and Tasmania with a mean annual rainfall of 500 to 1000 mm are referred to as **natural temperate grassland**, or lowland native grassland. The ecological community is defined by the vegetation structure thought to have been present at the time of European settlement. While the definition of natural temperate grassland is expressed in terms of the vegetation, the ecological community comprises both the flora and the fauna, the interactions of which are intrinsic to the functioning of grassy ecosystems.

Sites that meet the defining characteristics of natural temperate grassland encompass those that clearly demonstrate the natural ecological function of grasslands and those that may be deficient in some respects, but are considered recoverable. However, the distinction between what constitutes the ecological community and what are degraded remnants that are beyond recovery may not always be readily apparent. Ecological survey and assessment of individual sites is necessary to clarify which sites warrant protection or recovery action.

DEFINITION OF NATURAL TEMPERATE GRASSLAND

Natural temperate grassland is a native ecological community that is dominated by native species of perennial tussock grasses. The dominant grasses are *Themeda triandra*, *Austrodanthonia* species, *Austrostipa* species, *Bothriochloa macra* and *Poa* species. The upper canopy stratum generally varies in height from mid high (0.25–0.5 m) to tall (0.5–1.0 m). 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 has less than 10% projective foliage cover of trees, shrubs and sedges in its tallest stratum. In the ACT it occurs where tree growth is limited by cold air drainage, generally below 625 m asl.

COMPOSITION

Plants

In addition to a wide variety of grasses, native grasslands in their natural state contain a high diversity of forbs including sedges, rushes, orchids, lilies and broad-leaved herbs such as daisies. About 700 species of native herbs have been identified in grasslands of south-eastern Australia, the majority of which are not grasses (Eddy 2002). ‘Bare ground’ in grasslands may be covered by a layer of lichens and mosses (the ‘cryptogamic crust’). An important characteristic of the community is that it is naturally treeless, or has less than 10% projective foliage cover (2–20% crown cover density) (see Glossary) of trees, shrubs and sedges in its tallest stratum (Moore 1964; Kirkpatrick 1993). To simplify assessment, Lunt *et al.* (1998) estimated that this cover is equivalent to a tree cover of less than one mature tree per hectare. The degree of tree cover remains a contentious attribute in defining the range of native grasslands (Carter *et al.* 2003).

Natural temperate grassland intergrades on slopes at slightly higher elevations with grassy woodland (defined as having a tree cover greater than 10% projective foliage cover). Yellow Box–Red Gum grassy woodland is declared an endangered ecological community in the ACT under the *Nature Conservation Act 1980* (see ACT Government 2004a). Natural temperate grassland may contain poorly drained areas, and at lower elevations, wetlands or drainage lines with a characteristic flora (including wetland species such as sedges and rushes) (Moore 1964). These wetlands and the fauna associated with the moister conditions are a component of the grassland community. River Tussock (*Poa labillardieri*) frequently dominates grassland along drainage lines.

Animals

An integral part of this community is the grassland fauna ranging from large herbivores such as kangaroos to a multitude of invertebrates (see s. 2.3). Many small mammals (e.g. bandicoots, bettongs, rat kangaroos, rats) are known to have occupied the grasslands and may have been important agents of disturbance (Whalley 2003). The rapid transformation of the grasslands by pastoral activity from the early 1800s resulted in the decline or extinction of many species (Lunt *et al*. 1998).

The fauna found in natural temperate grasslands of the Southern Tablelands typically includes a rich diversity of invertebrates, reptiles, amphibians and birds (including several specialist grassland species). The more common grassland species include the Delicate Skink (*Lampropholis delicata*), Spotted Marsh Frog (*Limnodynastes tasmaniensis*), Spotted Burrowing Frog (*Neobatrachus sudelli*), Richard's Pipit (*Anthus novaeseelandiae*), Brown Quail (*Coturnix ypsiliphora*) and Stubble Quail (*C. pectoralis*). Latham's Snipe (*Gallinago hardwickii*), a species protected under migratory bird agreements with Japan (JAMBA) and China (CAMBA), utilises wetlands in native grassland sites (ACT Government 1997a). Generalist species such as the Australian Magpie (*Gymnorhina tibicen*) and the Eastern Grey Kangaroo (*Macropus gigantea*) use the grassland community for foraging. Some characteristic grassland fauna species are no longer found within native grasslands including the Emu (*Dromaius novaehollandiae*), Australian Bustard (*Ardeotis australis*) and Little Button-quail (*Turnix velox*) (Frith 1984).

Little is known about the past and present distribution and ecology of many of the grassland fauna, particularly invertebrates, though some species have been the subject of detailed studies in recent years (especially the Grassland Earless Dragon (*Tympanocryptis pinguicolla*), Striped Legless Lizard (*Delma impar*), and Golden Sun Moth (*Synemon plana*)). Further studies are required to investigate abundance, distribution and habitat use of a range of grassland faunal species. Appropriate management strategies also need to be developed to ensure the species are adequately conserved as part of the grassland community.

Given the lack of information on distribution and abundance of the wide range of grassland fauna, the diversity of plants and structure of the community is taken to be an indicator that the typical native grassland fauna may still be present.

STRUCTURE

Perennial tussock grasses impart a characteristic structure to natural temperate grassland. The tussocks are often closely spaced, forming an upper stratum of loosely interlacing leaf canopies (Costin 1954; Sharp 1997). This upper canopy stratum generally varies in height from mid high (0.25–0.5 m) to tall (0.5–1.0 m), and in cover from open to dense (greater than 70% ground cover) (Walker and Hopkins 1984).

A second, lower stratum may be discernible, typically comprising shorter perennial and annual grasses, and forbs, growing between the tussocks. At ground level, there may also be a third discontinuous stratum of dwarf forbs and grasses, with occasional mosses and lichens also present on 'bare ground' forming a 'cryptogamic crust' (Costin 1954; Lunt *et al*. 1998). The community sometimes includes areas of embedded rocks, which provide habitat for animals.

FLORISTICS

The characteristic dominant genera of natural temperate grassland in Australia include *Themeda, Poa* and *Austrostipa* (Groves and Williams 1981). In the Southern Tablelands (including the ACT), dominants include Kangaroo Grass (*Themeda triandra*) wallaby grasses (*Austrodanthonia* spp.), spear grasses (*Austrostipa* spp.), Red Grass (*Bothriochloa macra*) and tussock grasses (*Poa* spp.) (Benson and Wyse Jackson 1994; Benson 1994; Sharp 1997).

Most natural temperate grassland has been subject to grazing by domestic stock or by rabbits, which has modified its species composition and structure. Exotic plant species are common in natural temperate grassland, which may vary from a semi-natural state with few exotic species, to a highly modified state in which exotic species form a dominant component of the community (Groves and Williams 1981; McIntyre 1994; Sharp 1997). Surveys show that exotic species comprise over 35% of the flora at most native grassland sites in the Monaro region (Benson 1994; Sharp 1997). The majority of these exotic species are annuals (Sharp 1997). Exotic species have either invaded through natural processes, often assisted by human activity, or have been sown as pasture species e.g. clovers and Phalaris (*Phalaris aquatica*).

Five floristic associations have been defined for natural temperate grassland in the ACT (Sharp and Shorthouse 1996; Sharp 1997). This is a sub-set of eight floristic associations described for natural temperate grassland in the broader Monaro region (Benson 1994). The ACT floristic associations comprise both wet tussock grasslands including 'Wet *Themeda*' Grassland and '*Poa labillardieri*' Grassland, and dry tussock grasslands including '*Austrodanthonia*' Grassland, 'Dry *Themeda'* Grassland and '*Austrostipa*' Grassland (Sharp 1997).

Surveys of threatened fauna indicate a strong correlation between these floristic associations and habitat for certain species. The presence of these associations is related to both intrinsic site factors and land use practices since European settlement. In particular, drainage patterns related to slope and landform, soil characteristics, and intensity of land use appear to influence these floristic associations (Sharp 1997). These factors also affect the plant species present in sites, their characteristic life and growth form, and the degree of invasion by exotic species (Sharp 1997).

The following descriptions of the ACT floristic associations are based on detailed studies by Benson (1994) and Sharp (1997). Appendix 3 contains a list of common names for the species mentioned.

- **Wet *Themeda* Grassland**

  Wet *Themeda* grassland is a tall, dense, closed tussock grassland. It is often degraded, with a low native species diversity and high weed content. It occurs in moist to poorly drained sites.

  Dominant native grasses: *Themeda triandra, Poa labillardieri, Poa* spp. and *Austrodanthonia* spp.

  Other characteristic native species: *Carex inversa, Juncus* spp., *Asperula conferta, Bulbine bulbosa, Wurmbea dioica*.

  Common exotic species: *Trifolium glomeratum, Trifolium campestre, Vulpia myuros, Tragopogon dubius, Hypochaeris radicata, Cerastium glomeratum, Bromus hordeaceus, Holcus lanatus, Phalaris aquatica*.

- ***Poa labillardieri* Grassland**

  Poa labillardieri grassland is a tall, dense, closed tussock grassland. It occurs in the ACT as small, often degraded remnants that are part of larger grassland sites. It is found in poorly drained areas and along seepage lines, drainage lines and creeks.

  Dominant native grasses: *Poa labillardieri, Themeda triandra.*

  Other characteristic native species: *Carex appressa, Carex inversa, Juncus* spp., *Haloragis heterophylla, Hydrocotyle laxiflora.*

  Common exotic species: *Poa pratensis, Rumex crispus, Trifolium repens, Trifolium dubium, Cirsium vulgare, Holcus lanatus, Phalaris aquatica.*

- ***Austrodanthonia* Grassland**

  Austrodanthonia grassland is a mid-high, open tussock grassland found in well drained areas with shallow or skeletal soils. Despite moderate to high levels of disturbance, it exhibits high native species diversity, and often includes low growing species not found in other floristic associations.

  Dominant native grasses: *Austrodanthonia carphoides, A. caespitosa, A. laevis, Austrostipa bigeniculata, A. scabra* spp. *falcata, Bothriochloa macra.*

  Other characteristic native species: *Chloris truncata, Elymus scaber, Triptilodiscus pygmaeus, Panicum effusum, Oxalis perennans, Goodenia pinnatifida, Vittadinia muelleri, Chrysocephalum apiculatum, Plantago varia, Wahlenbergia* spp., *Solenogyne dominii.*

  Common exotic species: *Hypochaeris radicata, Trifolium* spp., *Aira elegantissima, Vulpia* spp., *Tolpis umbellata*.

- **Dry *Themeda* Grassland**

  Dry *Themeda* grassland is a tall, dense, closed tussock grassland generally found on well drained, loamy soils. In the ACT, this association is now only found on sites where there have been low levels of past disturbance. Dry *Themeda* grassland sometimes includes species no longer found in other grasslands due to their higher levels of disturbance.

  Dominant native grasses: *Themeda triandra, Austrostipa* spp., *Poa sieberiana, Austrodanthonia* spp.

  Other characteristic native species: *Leptorhynchos squamatus, Plantago varia, Stackhousia monogyna.*

Common exotic species: *Avena* spp., *Centaurium erythraea, Tragopogon porrifolius, Trifolium* spp., *Bromus hordaceous*.

- ***Austrostipa* Grassland**

  Austrostipa grassland is a tall, open tussock grassland. Most sites are likely to have been previously dominated by *Themeda triandra*. Sites are usually degraded, with a low diversity of native species. The association often includes shorter grasses interspersed between the tussocks.

  Dominant native grasses: *Austrostipa bigeniculata, A. scabra* ssp. *falcata, Elymus scaber, Austrodanthonia caespitosa, Enneapogon nigricans.*

  Other characteristic native species: *Austrodanthonia* spp., *Bothriochloa macra, Themeda triandra, Wahlenbergia* spp., *Chrysocephalum apiculatum.*

  Common exotic species: *Trifolium arvense, Vulpia myuros, Hypochaeris glabra, Hypochaeris radicata, Carthamnus lanatus, Paronychia brasiliana, Aira caryophyllea, Dactylis glomerata, Arctotheca calendula.*

Since European settlement, these floristic associations have all been modified to varying degrees (see Table 2.1 and s.2.1.8).

2.1.5 Other Lowland Native Grassland Vegetation Included in the Strategy

Other lowland native grassland vegetation bears some resemblance to the structure and species composition of natural temperate grassland but is not considered to be part of the endangered ecological community, based on the loss of species diversity and high levels of disturbance. These areas are unlikely to have the soil seed-store that would allow them to rehabilitate naturally. However, the distinction between what constitutes the ecological community and what are degraded remnants that are beyond recovery may not be readily apparent. Further ecological survey and assessment may be necessary to clarify those sites that warrant protection or recovery action. If such sites indicate a more diverse flora as a result of recovery they should be re-classified as containing the endangered ecological community.

Whatever the classification, the more degraded sites may still have a role in landscape function (e.g. erosion and groundwater management, salinity control and resistance to weed invasion), provide habitat for some threatened species, buffers to more diverse grassland stands, and connectivity in the landscape.

NATIVE PASTURE

About five percent of the pre-European extent of natural temperate grassland in the Southern Tablelands now exists as native pastures with a high cover of native grasses, but very low to no forb diversity. They contain a low cover of exotic species (Table 2.1). Previously, these grasslands may have been intensively grazed, but are unlikely to have undergone extensive pasture ‘improvement’ (sowing of introduced species including crops, legumes or perennial pasture species, continuous application of fertiliser). Native pastures may have economic, social and biodiversity values. These sites may provide important habitat for threatened animal species and with appropriate management may have some capacity for ecological restoration, particularly as habitat for threatened species tolerant of such modified vegetation. Native pasture may also provide buffers to remnants of higher value native grassland or connect remnants of native vegetation.

DEGRADED NATIVE PASTURE

Large areas of the Southern Tablelands contain degraded native pasture (Environment ACT 2005). Degraded native pastures are at the other end of the continuum from high quality natural temperate grassland that retains its ecological integrity (Table 2.1). These grasslands contain one or more native grass species (which may not have been the original dominants), but have very few or no native forbs. Such pastures have a high content of introduced perennial species (both weeds and pasture species), in particular, persistent or invasive species such as Phalaris (*Phalaris aquatica*), African Lovegrass (*Eragrostis curvula*), Serrated Tussock (*Nassella trichotoma*) and Chilean Needlegrass (*Nassella neesiana*).

Typically, these grasslands have been subject to pasture improvement (species introduction and/or fertiliser addition) in the past or to intense grazing pressure over a long period.

2.1.6 Native Grassland Communities Not Included in the Strategy

SECONDARY (DERIVED OR DISCLIMAX) GRASSLAND

Secondary grasslands are derived from lowland grassy woodlands or forests that have been extensively cleared of trees since European settlement, through intentional removal, dieback or prevention of natural regeneration (Benson 1996). They are found on hillslopes beyond the normal extent of natural temperate grassland to which they have a superficial resemblance. Species composition in secondary grassland is often very similar to natural grasslands, but they may also contain shrubs and herbaceous species more characteristic of the former woodland community. Native species diversity ranges from very high to low, similar to that of natural grasslands. Secondary grasslands have important ecological values (which may include habitat for threatened species) and may warrant consideration for protection, management and rehabilitation.

Reflecting their origins, secondary grasslands in the ACT are considered to be part of the Yellow Box–Red Gum Grassy Woodland endangered ecological community and are included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a).

Sub-Alpine and Alpine Grassland

Sub-alpine grassland or sod tussock grassland occurs at higher elevations in level or gently undulating terrain on alpine humus soils (Costin 1981). It is common in ‘frost hollow’ valleys in upland areas such as the mountainous western portion of the ACT. The main dominants are Snow Grass (*Poa* spp.), Alpine Wallaby Grass (*Austrodanthonia nudiflora*), Spreading Rope-rush (*Empodisma minus*), with some local occurrences of Kangaroo Grass (*Themeda triandra*). *Poa* spp. may be dominant also in some higher elevation alpine herbfield areas e.g. the Brindabella Range.

Grassy ‘Glades’

Above about 625 m, patches of grassland occur in grassy woodland often at locally lower elevations and near creek lines that are subject to cold air drainage (‘frost hollows’). These areas are too small to map separately as natural temperate grassland. Their presence indicates how natural temperate grassland and grassy woodland intergrade to form a vegetation mosaic, though there are now few intact examples of this.

2.1.7 Changes to Natural Temperate Grassland Since European Settlement and Ongoing Threats

Some form of degrading disturbance threatens all grassland remnants, even those in permanent reserves. As noted previously, natural temperate grassland has been reduced to small and disconnected fragments across its former range throughout south-eastern Australia. An estimated 99.5% has been destroyed or grossly altered since European settlement (Kirkpatrick *et al.* 1995). In most areas the grassland has been replaced completely by plant introductions associated with the European pastoral and agricultural economy or by urban and infrastructure development. In other areas, it has been partly transformed both intentionally and inadvertently (e.g. through weed invasion) and survives with varying levels of degradation. There are small remnants that give an indication of the presumed character of natural temperate grassland prior to European settlement, commonly in cemeteries, churchyards, on roadsides or in travelling stock reserves. A shared feature of these places is that they have been fenced off from continual grazing and have not been subject to intensive pasture improvement or cropping (Benson 1994). Characteristically, they have rich forb diversity and grasses intolerant of continuous grazing pressure are present.

A key issue for natural temperate grassland conservation is the maintenance of grassland fauna as a part of the ecological community. Invertebrates are the dominant faunal element in lowland grasslands and are involved in most ecological processes. However, they have a history of being largely unrecognized or thought of mainly in terms of control of pest species (Yen 1995).

Following European settlement, a number of factors have been responsible for the loss of natural temperate grassland and degradation of the remnants in the ACT and region. These factors generally remain as ongoing threats. The changes and threats may be categorised as follows:

- **Pastoral and agricultural development:** Natural temperate grasslands in the Southern Tablelands were carved up into grazing runs from 1830. Small-scale pasture improvement began in the 1860s and clovers were first sown in the 1920s. Intensive pasture improvement involving the use of subterranean clover and application of superphosphate was undertaken after the Second World War (Benson and Wyse Jackson 1994). This accelerated the loss of native grassland. However, some of the ACT rural lands held on short-term leases were not subject to intensive pasture improvement and retained significant components of their native vegetation cover.

  Where native grassland has not been completely replaced by sown crops or ‘improved pastures’, the ecological effects of grazing depend upon its intensity and timing, and length of time that the area has been grazed. Most of the impacts of stock grazing have been inferred by comparing the vegetation at sites protected from grazing (or known to have been only lightly grazed), with more intensively grazed sites. Grazing can affect grassland species and the ecological community through the removal of biomass, trampling, nutrification, increased weediness (through creation of bare ground, dispersal of seeds, introduction of weeds through fodder), destruction and modification of faunal habitat, soil erosion, and loss of soil moisture (Sharp 1994). Plant species sensitive to grazing become less common as the ecological community is simplified.

Changes in species composition and loss of floral diversity are two of the significant changes that occur in heavily grazed grasslands. An early observation in 1862 by grazier James Litchfield on the Monaro was the problem with infestations of 'corkscrew grass' (speargrasses *Austrostipa* spp.) (Hancock 1972). This probably replaced more palatable species such as Kangaroo Grass as they were grazed out. Speargrasses now dominate many native pastures, especially on the Monaro (Eddy *et al*. 1998). Perennial grasses such as Red Grass or Red-leg Grass (*Bothriochloa macra*), wallaby grasses (*Austrodanthonia* spp.) and speargrasses (*Austrostipa* spp.) become more prominent as grazing intensity increases (Story 1969; Frawley 1991; Benson 1994). Decades of pasture improvement have contributed to changes in the floristic composition of natural temperate grassland.

Much of the biodiversity of native grasslands is made up of species other than grasses (see s. 2.1.4). As well as being trampled, lilies, orchids and forbs are less likely to survive under heavy grazing due to their palatability and failure to set seed (especially upright forbs from which grazing removes the flower stalks). Palatable forbs can be lost, even at low grazing intensities, with little obvious effect on the dominant grasses (Lunt 1991).

It should be noted that there has been a significant improvement in knowledge of and recognition of native grasslands in the last 15 years, and interest on the part of landholders in conserving remnant native grassland on their properties (Lunt 2005). This is reflected, for example, in the establishment of Conservation Management Networks, four of which are currently established in grassy ecosystems of south-eastern Australia (Thiele *et al.* 2003).

- **Urban and Infrastructure Development:** This is particularly relevant to the ACT where the most extensive areas of natural temperate grassland (Figure 2.2) have been destroyed during the development of urban Canberra. Some fragments of the former grasslands remain, with the larger remnants located in areas set aside for special purposes such as radio beacons, the airport and military uses. Other smaller areas remain on land originally set aside for future government uses and on current and former rural leases. Some of these grasslands remain on Public Land within the urban fabric while others have been reserved as part of Canberra Nature Park. The setting aside of areas for public institutions and government offices resulted in small grassland areas remaining in the Central National Area of Canberra (Frawley 1995). Examples include the Australian Centre for Christianity and Culture (ACCC) Barton (1.9 ha) containing very high quality *Themeda* grassland, and York Park, Barton (0.4 ha), an *Austrodanthonia* grassland containing a population of the endangered Golden Sun Moth *Synemon plana*.

  In recent years, the conservation values of the remaining native grassland areas in the ACT have been recognized in land-use planning, resulting in significant planning changes. Grassland reserves have been established in Gungahlin (1995) and Dunlop (1997), announced for the Jerrabomberra Valley (July 2004), and proposed for Lawson (Belconnen Naval Station).

  Threats to remaining grassland areas from urban and infrastructure development are of two types: direct loss of grassland, and deleterious impacts on the natural integrity of grassland from adjacent urban areas. Urban edge threats can be lessened at the planning stage (e.g. by allowing adequate buffers and not permitting housing on the outer edge of perimeter roads) and by effective management of reserves involving the local community.

- **Weed Invasion:** Grassland vegetation appears particularly prone to weed invasion, probably due to its location on fertile soils (Kirkpatrick *et al.* 1995). In the ACT, even the remaining grassland considered to be in moderate to good condition may have more than 20% cover of exotic plants. Many weeds are indicative of levels of past disturbance and now function as part of the grassland vegetation without apparently threatening the integrity of the surviving native plants e.g. hairgrasses (*Aira* spp.) and Quaking Grass (*Briza minor*) (Kirkpatrick *et al.* 1995; Eddy *et al.* 1998). However, they may be replacing or out-competing annual or spring flowering native species and could be critical in terms of native species richness and diversity (Sharp 1995). Weeds are favoured by soil disturbance, changes to drainage and nutrient levels (sites that become wetter are often subject to increases in nutrients from upslope fertiliser application) and in some instances, fire. For example, Chilean Needlegrass (*Nassella neesiana*) a Weed of National Significance has spread dramatically in abundance and distribution in the last decade and is promoted by fire, which creates bare ground and reduces competition from other species (Muyt 2001).

Categories of plants that have become established as weeds in natural temperate grassland include: annual grasses (e.g. Rat's Tail Fescue and Squirrel Tail Fescue *Vulpia* spp., barley grasses *Hordeum* spp.); annual and biennial forbs (e.g. Viper's Bugloss *Echium vulgare*, Great Mullein or Aaron's Rod *Verbascum thapsus*); perennial grasses (Sweet Vernal Grass *Anthoxanthum odoratum*, Yorkshire Fog *Holcus lanatus*, Chilean Needlegrass *Nassella neesiana*, Serrated Tussock *N. trichotoma*, Phalaris or Canary Grass *Phalaris aquatica*, Bulbous Bluegrass *Poa bulbosa*); perennial forbs (e.g. St John's Wort *Hypericum perforatum*); and shrubs or woody weeds (e.g. Hawthorn *Crataegus monogyna*, African Boxthorn *Lycium ferocissimum*, Sweetbriar *Rosa rubiginosa*) (Rowell 1994; Sharp 1995; Rehwinkel 1996a,b,c; Eddy *et al.* 1998; Sharp and Rehwinkel 1998; Eddy 2002).

Weeds are a major threat to all grassland remnants. Weed invasion is encouraged by disturbance to grassland sites and the small size of remnants; which makes them vulnerable to the spread of weeds from adjacent land. The following perennial and highly invasive weed species are of particular concern and are all the subject of weed control activities by land management agencies in the ACT, coordinated through the ACT Weeds Working Group:

(a) African Lovegrass (*Eragrostis curvula*). This is an aggressive, tenacious, drought and frost tolerant species capable of dominating the ground flora on lighter low-nutrient soils (Muyt 2001). The ACT African Lovegrass Management Plan (2002) focuses on control of new and scattered infestations while undertaking management of existing heavy infestations.

(b) Serrated Tussock (*Nassella trichotoma*). A Weed of National Significance, Serrated Tussock is a major weed of the Southern Tablelands. In this region it is widespread, but may have occupied only 20% of its potential range. It has broad site tolerance and is highly invasive. Mature plants develop a drooping, smothering form eventually excluding other ground flora and are capable of producing 100 000 seeds annually with some remaining viable for 10–15 years (Parsons and Cuthbertson 1992; Muyt 2001).

(c) Chilean Needlegrass (*Nassella neesiana*). A Weed of National Significance, Chilean Needlegrass is one of the most threatening invasive plants of grassy ecosystems in south-eastern Australia and has spread rapidly since 1990. Its adaptability to a wide range of conditions, large persistent seed bank, ease of seed dispersal, and tolerance of various treatments make control extremely difficult. Plants tolerate periodic inundation, extended dry periods, fire and heavy grazing and are adapted to low or high fertility soils, moderate shade or sunny locations (Muyt 2001). The species was surveyed in the ACT in 2000 and 2002 and found to be present in or adjacent to 85% of natural temperate grassland sites.

(d) St Johns Wort (*Hypericum perforatum*). This species is a major weed of grasslands, grassy woodlands and forests in south-eastern Australia. It forms extensive infestations excluding most other ground flora and impeding overstorey regeneration. Perennial crowns develop from shallow rhizomes and produce new aerial growth each year. It also reproduces from seed (Muyt 2001). It is widespread in lower elevation areas of the ACT.

- **Changed and Inappropriate Fire Regimes:** While it is known that fire regimes have changed, it is not exactly clear what they changed from and what the results have been. It is generally accepted that natural temperate grassland was adapted to a fire regime derived from Aboriginal burning (probably consisting of a mosaic of patchy, low intensity fires in spring and autumn) and occasional high intensity fires in summer (most probably caused by lightning strike). With European settlement, the dominant disturbance agent changed from burning under low grazing pressure by native species to grazing by stock with little burning. At local scales, however, areas such as roadsides and railway easements were burnt frequently. Increasingly, this burning has been phased out in favour of other means of defoliation (Lunt and Morgan 2002).

  The timing of fire in relation to the life cycles of plants, the intensity and frequency of fires, all have a strong influence on the long-term results of a fire regime. The primary threats posed to native grasslands by fire are that the grassland is burnt too frequently, too hot or at the wrong time in the life cycles of the plants, and that the whole of a grassland remnant is burnt leaving no escape for native animals. In the absence of other defoliation, fire can also be too infrequent allowing native grassland to become overgrown with consequent loss in biodiversity. This is due, in particular, to the decline of inter-tussock perennial forbs that appear to need open conditions for seed production and germination (Eddy 2002; Lunt and Morgan 2002).

The effects of grassland fire regimes on fauna have been poorly studied, however, frequent burning is widely perceived as having negative impacts on many animals, particularly small species that are relatively immobile and live in small grassland fragments. The challenge for managers of small grassland remnants that contain a diverse flora and threatened fauna is to maintain an open vegetation structure to maintain plant diversity while also maintaining viable animal populations (Lunt and Morgan 2002). In these circumstances, defoliation by mowing or intermittent, light grazing may be more appropriate.

In their review of fire regimes in temperate lowland grasslands, Lunt and Morgan (2002) highlight the complexity of the subject and note that burning regimes should be tailored to individual grassland remnants. They suggest that experience with *Themeda* grasslands points to the need to regularly burn productive grassland remnants to prevent further declines in biodiversity. While few fire studies have been conducted in grasslands dominated by *Austrodanthonia* and *Austrostipa*, these have less biomass and shorter lifespans than *Themeda triandra* or *Poa* spp., so litter accumulation and competitive exclusion do not present the same threat to plant diversity. A significant issue is that fire opens the ground surface to opportunistic post-fire colonisation by exotic annual weed species that have a large soil seed bank and to exotic perennial grasses e.g. Chilean Needlegrass. Incorporating fire into the management of native grasslands remnants is difficult where off-site spread is a danger. These areas are also vulnerable to unplanned fires (e.g. bushfires, arson) from surrounding areas. There are a number of reasons, therefore, why other forms of defoliation are now used instead of burning in grassland remnants.

■ **Other Forms of Disturbance**

Grazing by feral animals: Loss or degradation of natural temperate grassland has also resulted from grazing by feral animals (particularly rabbits), soil disturbance, soil fertility change, altered drainage, traffic and trampling, and stockpiling and dumping of materials (Eddy 2002). Grazing by rabbits puts pressure on more succulent species that are less tolerant of regular or heavy grazing. The rabbit plague that engulfed south-eastern Australia in the second half of the 19th century reached the Monaro in the early 20th century, having devastating effect on both the vegetation and the pastoral economy (Hancock 1972). Eddy (2002) suggests that a significant proportion of the change in native grasslands has been the result of grazing by rabbits, rather than grazing by domestic stock.

Physical disturbance: Physical disturbance of the soil has occurred through activities such as cultivation, ripping rabbit burrows, laying pipes and cables. These activities remove or kill the existing vegetation, often releasing soil nutrients and creating a favourable environment for weed invasion. Soil moisture is a major determinant of plant community structure and composition. Alteration of drainage patterns by the construction of dams, roads and other earthworks, for example, has resulted in increased water flows on to grassland sites often bringing extra nutrients and allowing exotic species to out-compete the original vegetation. Traffic and trampling result in bare, compacted ground that is vulnerable to weed invasion, increased run-off and erosion, and cause the loss of cryptogams from naturally occurring bare patches. Vehicle traffic assists in weed seed dispersal. Grassland has been lost from road verges and public land areas following dumping, stockpiling and spreading of soil and gravel which smothers the vegetation and creates bare areas vulnerable to weed invasion.

Use of fertilisers and other soil ameliorants: Changes in soil fertility (e.g. by application or drift of superphosphate, gypsum or lime) can alter the competitive relationships between plants to the point where species composition in the community changes.

Mowing and slashing: Mowing and slashing can be a threat to native grassland if it prevents flowering and seed production by being undertaken too frequently or at the wrong time. Mowing and slashing equipment can also transfer weed seeds and this is thought to be one of the means by which African Lovegrass and Chilean Needlegrass have been spread (Eddy 2002). A major concern with mowing is that cut material left on site acts as mulch and inhibits inter-tussock forb growth. Mowing and slashing may also affect animal habitat.

Tree planting: Natural grasslands are treeless or contain only scattered trees and this characteristic is important to their ecology. Tree planting in or near grasslands can have detrimental effects through shading, effects on soils, attracting birds that are vectors of weed seeds, and giving rise to the spread into the grassland of wildings (e.g. Radiata Pine *Pinus radiata*). For example, forward tree planting in what is now the Crace Nature Reserve has affected the grassland and habitat for the Striped Legless Lizard and will need to be managed to ensure habitat is not lost permanently.

Herbicide use: While herbicides are essential for the control of weed species, such application or spray drift has the potential to affect grassland native species (Eddy 2002).

Collection of grass seed: There is increased interest in collection and propagation of native seed for use in revegetation work. Harvesting seed without considering recruitment requirements of the source community is a potential threat. Concern has also been raised about the genetic effects of the introduction of plants or seeds of the same species from another area (Eddy 2002). This is the subject of ongoing research.

Salinisation of soils: There is a medium-term likelihood of salinisation of soils becoming a threat to natural temperate grassland in parts of the Southern Tablelands. When remediation works are undertaken, it is important that the characteristics of the grassland are not compromised, especially by extensive tree planting (Environment ACT 2005).

2.1.8 Condition of Lowland Native Grassland in the ACT

The remaining areas of lowland native grassland can be considered on a continuum from those that appear largely intact (similar to their estimated pre-1750 state though there are likely to be changes in component species) to those in a substantially modified state with only a few elements representing their origins. For the purposes of the *Strategy*, the remaining lowland native grassland in the ACT has been classified in relation to its assessed degree of modification since European settlement, the corollary of which is the degree to which it retains its natural integrity. This categorisation of grassland is adapted from a similar conceptual framework developed for lowland woodland in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a), which itself is based on a means of conceptualising human modification of woodland landscapes presented by McIntyre and Hobbs (1999) and McIvor and McIntyre (2002).

Because annual exotic species fluctuate in their cover and diversity between seasons and years, they are not used in the evaluation of the degree of disturbance, although generally there is a greater cover of annual exotic species in the more disturbed sites. However, grasslands almost invariably now contain annual and perennial plant species.

Categories of remaining lowland native grassland reflecting varying degrees of modification are shown in Table 2.1, and discussed on page 22.

Table 2.1: Condition of Lowland Native Grassland in the ACT

Degree of Modification	Vegetation Cover (predominant cover, may also contain small patches of more or less disturbed vegetation)	Grassland Category	↓↑
Unmodified (pre-1750 composition	Native cover only, reflecting biological diversity prior to European settlement. Community dominated by perennial tussock grasses with wide variety of other herbs. Treeless or less than 10% projective foliage cover.	Natural Temperate Grassland	↓
Partially Modified	High diversity and cover of native species, including disturbance sensitive species and/or moderately sensitive species. Includes high diversity of forbs (BSR 1–2).	Natural Temperate Grassland (endangered ecological community)	↓
Moderately Modified	Moderate diversity and cover of native species, including disturbance tolerant species (but excluding disturbance sensitive or moderately sensitive species) (BSR 3).	Natural Temperate Grassland (endangered ecological community)	↓↑
Highly Modified	Low diversity of native species (mostly disturbance tolerant native grasses), very low native forb diversity, low cover of introduced perennial species (BSR 4).	Natural Temperate Grassland (endangered ecological community)	↓↑
Substantially Modified	One or more disturbance tolerant native grass species, few or no native forbs, low cover of introduced perennial species (BSR 5).	Native Pasture	↓
Severely Modified	Dominated by exotic annual and/or perennial species, but may contain some native species (E).	Degraded native pasture or exotic pasture	↓
Destroyed	Exotic pasture, crops, urban or other development.	Not applicable	

[grey shading] Natural Temperate Grassland (endangered ecological community) declared under the *Nature Conservation Act 1980* (ACT).

↓↑ Areas of grassland may change levels depending upon land use, management and disturbance factors.

BSR: Botanical Significance Rating: see s. 3.2 and Appendix 1.

- **Unmodified (pre-1750 composition and structure): Natural Temperate Grassland**

  Although grassland in this category no longer exists, estimation of the features of the pre-1750 natural temperate grassland provides a basis against which to consider the type and extent of subsequent modification. The characteristics of this grassland are outlined in s. 2.1.4. The key features are considered to have been dominance by native species of perennial grasses, a high diversity of other herbs especially forbs, and the absence of trees or only scattered trees. Though floristic composition varied geographically, Kangaroo Grass (*Themeda triandra*) is thought to have been dominant over extensive grassland areas on the Southern Tablelands with River Tussock (*Poa labillardieri*) dominant in wetter areas. Higher areas of the Monaro underlain by basalt were almost certainly dominated by Poa Tussock (*Poa sieberiana*) (Benson and Wyse Jackson 1994) and still are today (Eddy *et al.* 1998). On drier sites, speargrasses (Corkscrew *Austrostipa scabra* and Tall Speargrass *A. bigeniculata*) and wallaby grasses (*Austrodanthonia* spp.) were probably dominant. Speargrasses and wallaby grasses have subsequently expanded their range, replacing Kangaroo Grass under grazing pressure. The grasslands were maintained by a disturbance regime involving regular burning, grazing by native herbivores and some physical disturbance to the soil by Aboriginal digging for edible roots where these were present and digging by an abundance of small mammals (Whalley 2003). As well as the mammalian fauna, the grasslands supported a rich diversity of invertebrates, reptiles, amphibians and birds (including several specialist grassland species).

- **Partially Modified: Natural Temperate Grassland (endangered ecological community)**

  These are lowland grassland areas that are considered to have had the least amount of change from the pre-1750 ecological community. In particular they have a high diversity and cover of native species (including perennial grasses thought to have been the original community dominants), a high diversity of forbs, and species sensitive or moderately sensitive to disturbance. In the ACT, these are sites containing natural temperate grassland with a botanical significance rating (BSR) of 1–2 (for explanation see s. 3.2), where particular land uses have resulted in lower levels of disturbance. These sites may contain threatened plant and/or animal species.

- **Moderately Modified: Natural Temperate Grassland (endangered ecological community)**

  Moderately modified lowland grassland differs from partially modified grassland in regard to the loss of species diversity and likely changes in the dominant perennial grasses. These changes have often resulted from grazing practices and there is evidence that some changes occurred early in the European pastoral period (Benson and Wyse Jackson 1994). There is still a moderate diversity and coverage of native species, including disturbance tolerant species, but few or no disturbance sensitive species. In the ACT, these are sites with a botanical significance rating of 3 (see s. 3.2). The majority of areas of natural temperate grassland in the ACT are of this rating. These sites may contain threatened plant and/or animal species.

- **Highly Modified: Natural Temperate Grassland (endangered ecological community)**

  Areas of highly modified natural temperate grassland contain the characteristic features of natural temperate grassland, but have lost much of the diversity present in less modified sites. The reduction in diversity is largely a result of the loss of many forbs and some of the more disturbance sensitive grasses (for example Kangaroo Grass). These sites still contain, however, a high cover of native species. It is unclear on the basis of existing evidence whether these sites are likely to gain a higher level of diversity as a result of changes to management practices, but are defined as a component of the ecological community on the basis that there may be adequate species remaining to provide the basis for natural regeneration and enhancement of diversity. These sites have a BSR of 4 and may contain threatened plant and/or animal species.

- **Substantially Modified: Native Pasture**

  These sites are characterised by a high cover of native grasses, especially Spear grasses (*Austrostipa* spp.), and lack the more disturbance sensitive grasses such as Kangaroo Grass. At most they contain only several native forbs that are the most disturbance tolerant species (particularly Sheeps Burr *Acaena ovina*, Swamp Dock *Rumex brownii*, some Bluebell species *Wahlenbergia* spp. and Wattle Mat-rush *Lomandra filiformis*). The sites contain a low cover of exotic perennial species. Evidence from surveys and monitoring indicate that these sites are so modified that they are unlikely to increase in diversity as a result of natural regeneration. These sites have a BSR of 5 and may contain threatened plant and/or animal species.

- **Severely Modified: Degraded Native Pasture**

  Degraded native pasture contains a small cover of native species, but is characterised by a high cover of exotic species that may have been deliberately introduced or have invaded as a result of significant levels of modification of the site (e.g. cropping followed by uncontrolled regrowth of weeds, some deliberately introduced species and some native species, particularly speargrasses). These sites are indicated in the *Strategy* by the notation 'E'. Threatened plant and/or animal species have been found in some of these sites.

- **Destroyed**

  Exotic pasture, other exotic vegetation or infrastructure has now replaced most of the natural temperate grassland existing at the time of European settlement. The grasslands were affected initially by grazing or cropping prior to the establishment of the National Capital and during the course of its development. The total destruction of natural temperate grassland over much of the ACT (see s. 2.1.3) has been mainly due to the development of the city of Canberra in the valleys where natural temperate grassland was naturally distributed.

2.2

Grassland Flora

2.2.1 Natural Temperate Grassland Flora

Natural temperate grasslands and other native grasslands are characterised structurally by grass species, particularly Kangaroo Grass, spear grasses, wallaby grasses, Red Grass and *Poa* grasses, and grasses usually dominate in terms of cover. However, the term 'natural temperate grassland' can disguise the fact that a characteristic of this grassland in a relatively undisturbed condition is the presence of large number of non-grass species (forbs), which are not obvious in all seasons and all years. One of the most attractive features of natural temperate grassland is the extensive 'wildflower' display, in particular by representatives of the lily and daisy families. These displays are a window to the floral diversity of the spaces between the grass tussocks where may be found also a variety of orchids, peas and gentians and, in moister areas, rushes and sedges (Eddy *et al*. 1998), amongst many more plant families. Many of these plants disappear from grasslands as disturbance increases (Table 2.1).

For much of the year many of these species are not readily noticeable, because they emerge from rootstock, flower, set seed and then die back to rootstock in autumn or earlier. The winter monotones of brown and grey are replaced in early spring by greens, whites, yellows and blues, as the plants respond to the onset of warmer weather. Spaces in the grasslands provide opportunities for many of the smaller, more delicate species such as orchids and lilies to grow and reproduce. The white Early Nancy, a small lily, is one of the first species flowering, a promise that spring is coming. Orchids are rarely visible for more than several weeks, and over spring there is a constant change over of species. Especially prevalent in early spring are various species of *Caladenia*, white and purple Wax-lipped orchids and Yellow-flowered *Diuris* species. Even where the ground appears bare, there may be 'soil crust' lichens and bryophytes forming an extensive ground-surface covering. This is often less easy to see in dry periods when many species desiccate as a protective response.

In surveys undertaken in ACT lowland native grasslands since 1991, 50 species of grasses, over 200 species of native forbs (including sedges and rushes, lilies and orchids), and about 150 introduced species have been identified. Dominant grasses, other characteristic species and common exotic species of ACT lowland native grasslands are listed in s. 2.1.4. Many of these and/or related species are illustrated in Eddy *et al*. (1998).

Partially modified sites (Table 2.1) contain species that are uncommon, rare or non-existent in more disturbed sites. These species include orchids, some lilies and other more palatable forbs. However, many moderately disturbed sites still retain a high diversity of species, although they tend to be those that are common throughout many sites. Even the least disturbed sites contain a significant proportion of introduced species.

2.2.2 Threatened and Uncommon Grassland Flora Species in the ACT: Threats, Conservation Objectives and Actions

Eleven plant species found in natural temperate grasslands in the Southern Tablelands region are listed as threatened under Commonwealth, New South Wales or ACT legislation (Environment ACT 2005). Seven of these species are known to occur in the ACT (Table 2.2). Many other grassland plant species are rare or uncommon, or have suffered dramatic declines in their frequency and abundance, occurring either in low density within sites, or in very few sites in the region. The abundance and distribution of many of these is poorly known. Unpublished data from recent studies are revealing more species with very low population densities in natural temperate grassland in the region (R. Rehwinkel pers. comm.; S. Sharp pers. comm.). These data will need to be kept under review to assess whether targeted conservation actions are required for these species.

Three plant species of grassland/grassy woodland listed as threatened under ACT and/or Commonwealth legislation are included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a). These species are the Hoary Sunray (*Leucochrysum albicans* var. *tricolor*), Tarengo Leek Orchid (*Prasophyllum petilum*) and Austral Toadflax (*Thesium australe*) (Table 2.3).

Button Wrinklewort (*Rutidosis leptorrhynchoides*) and Ginninderra Peppercress (*Lepidium ginninderrense*) are included in this *Lowland Native Grassland Conservation Strategy*. While *Rutidosis leptorrhynchoides* is generally considered to be a herb of natural temperate grassland, in the ACT it occurs on the margins of Yellow Box–Red Gum Grassy Woodland. The largest population at Stirling Park occupies open areas within the woodland, especially previously disturbed areas and patches with skeletal soils. Action Plans pursuant to the *Nature Conservation Act 1980* were adopted for these species in 1998 and 2003 (ACT Government 1998b, 2003) and are subsumed into this Action Plan. Declarations by other jurisdictions of these species are summarised in Table 2.2.

Threatened Species: Button Wrinklewort (*Rutidosis leptorrhynchoides*)

Button Wrinklewort was declared an endangered species in 1996 under the *Nature Conservation Act*

Table 2.2: Plant Species listed under Commonwealth, State and Territory Legislation that occur in Natural Temperate Grassland of the Southern Tablelands

Species	Common Name	C'wlth	ACT	NSW	Vic
Calotis glandulosa [3]	Mauve Burr-daisy	V		V	
Dillwynia glaucula [3]	Michelago Parrot-pea			E	
Diuris pedunculata	Golden Moths	E		E	
Dodonaea procumbens [3]	Creeping Hopbush	V		V	
Lepidium ginninderrense [1]	Ginninderra Peppercress	V	E (SPS)		
Leucochrysum albicans var. *tricolor* [2]	Hoary Sunray (white form)	E			
Prasophyllum petilum [2]	Tarengo Leek Orchid	E	E	E	
Rutidosis leiolepis [2]	Monaro Golden Daisy	V		V	
Rutidosis leptorrhynchoides [1]	Button Wrinklewort	E	E (SPS)	E	T
Swainsona sericea	Silky Swainson-pea			V	
Thesium australe [2]	Austral Toadflax	V		V	

E: endangered; **V**: vulnerable; **T**: threatened (as defined under Victorian legislation); **(Nom.)**: nominated; **SPS**: Special Protection Species.

Notes:

1. ACT declared threatened species included in this Strategy
2. Species included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a)
3. Species not known to occur in the ACT

Legislation:

Commonwealth: *Environment Protection and Biodiversity Conservation Act 1999*

ACT: *Nature Conservation Act 1980*

NSW: *Threatened Species Conservation Act 1995*

Vic: *Flora and Fauna Guarantee Act 1988* (Note that under this Act, species are listed as 'threatened' rather than being assigned to categories)

1980 (ACT) and is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). It is a slender perennial forb, 25–35 cm tall, with bright yellow button flowers (2 cm wide) from December to April. Formerly widespread in south-eastern Australia, the species has a disjunct distribution with 18 known populations in the ACT region and nine in Victoria. The species' habitat is both native grassland and native woodland in the ACT and the region. Populations at Red Hill, Stirling Park and State Circle are found within grassy woodland, and at West Block in a very small grassy woodland remnant (less than 0.25 ha). These sites are considered in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a). Another small population occurs at the Baptist Church in Currie St, Parkes, in degraded native grassland over-planted with eucalypts and exotic trees including pines. This population has been indicated in Figure 2.7 as habitat only. Further details of the species including ACT listing, distribution and abundance, habitat and biology are contained in Appendix 4.1.

Under existing circumstances, the species is considered to be reasonably secure in the ACT region. With the exception of the ACCC (Barton) site and West Block (Parkes) all populations are increasing in size. The location of each known occurrence of this species is shown in Figures 2.3–2.7 (at end of Chapter 2).

THREATS

Threats to the populations of *Rutidosis leptorrhynchoides* in the ACT and region are primarily:

- **Habitat loss or degradation:** While habitat loss is an ever-present threat, it should be noted that the majority of ACT sites are in reserves or adequately protected by other means. The largest populations in the ACT are on National Land at Stirling Ridge and Majura Training Area. These areas are not in reserves, but MOUs between Environment ACT and the respective Commonwealth land managers generally provide an adequate level of conservation management. The small area occupied by the Majura population increases its vulnerability to damage (Crawford and Rowell 1996).

- **Competition with other vegetation, including weeds:** *Rutidosis leptorrhynchoides* prefers an open habitat and is a poor competitor amongst tall, dense sward-forming grasses. Sites may need specific defoliation measures to reduce this competition. Grazing is not recommended as a routine management method, as it can have an adverse effect on *R. leptorrhynchoides* and its habitat. Occasional slashing in late summer may be used on sites where other factors (e.g. fire risk to property) make burning undesirable. Patch burning may be appropriate on other sites, but its effects should be monitored. Burning should not be used as a broad-scale management tool on *R. leptorrhynchoides* sites in the ACT until it has been established by experimentation that the benefits (seedling establishment) are likely to outweigh the costs (mortality of adult plants).

  Woody weed invasion and native tree and shrub regeneration may also affect *R. leptorrhynchoides* especially in grassy 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 (no spot spraying of herbicide should be used within 2 metres of any *R. leptorrhynchoides* plant).

  Native trees and shrubs not indigenous to the ACT (e.g. Cootamundra Wattle *Acacia baileyana*, Knife-leaved Wattle *A. cultriformis*) should be treated as woody weeds in grasslands. In the absence of fire, slashing or grazing, regeneration of eucalypts and some native shrubs such as *Cassinia quinquefaria*, Bitter Pea (*Daviesia mimosoides*), Silver Wattle (*Acacia dealbata*) and Green Wattle (*A. mearnsii*) may shade out *R. leptorrhynchoides*. Where necessary, a selection of these should be removed (cut and dabbed) annually, to maintain open mixed-age/species woodland.

- **Heavy grazing:** (See s. 2.1.7 and s. 3.7.4) Under heavy grazing *R. leptorrhynchoides* disappears because it is a tall herb palatable to stock. However, intermittent grazing in late summer may not be detrimental.

- **Erosion of genetic diversity and increased inbreeding:** This 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. The species has been the subject of considerable genetic research aimed at understanding the factors that limit population viability (Young *et al.* 2000). Research has indicated that populations of fewer than 200 plants are experiencing low seed set as a result of loss of genetic variation (CSIRO Plant Industry 2001).

CONSERVATION OBJECTIVE

1. Conserve in perpetuity, viable, wild populations of *Rutidosis leptorrhynchoides* in the ACT.
2. Support local, regional and national efforts towards conservation of the species.

Key elements in achieving this objective are protecting and managing major sites where significant populations occur, and developing an understanding of the requirements for the genetic conservation of the species as a basis for management.

CONSERVATION ACTIONS

Conservation actions for this species (mostly undertaken by Environment ACT) identified for this *Strategy* (Table 2.3) are mainly adapted from those included in Action Plan 8, Button Wrinklewort *Rutidosis leptorrhynchoides* (ACT Government 1998b). However, there are also some new actions that better reflect activities being undertaken or proposed with regard to this species. Table 2.3 contains notes on progress with actions undertaken in the period 1998–2003.

Table 2.3: Conservation Actions for Button Wrinklewort (*Rutidosis leptorrhynchoides*)

Actions (adapted from Action Plan 8 and new actions)	Notes on Progress with Actions 1998–2003
INFORMATION (SURVEY, MONITORING, RESEARCH)	
Maintain alertness to the possible presence of the species while conducting surveys in appropriate habitat.	1. Increase in number of known populations in the ACT. 2. New sites found in ACT since the preparation of Action Plan 8 are: ■ Crace Grassland Reserve (150 plants in 1998; 4000 plants in 2000); ■ Baptist Church, Manuka (50–100 plants in 2000); ■ Tennant St, Fyshwick (100 plants in 2000); ■ Harman (203 plants and 782 plants in two locations in 2003 (HLA-Envirosciences 2004)). 3. Additional populations were found at Stirling Ridge in 2000 and 2003 and at Campbell Park in 2002.
Review research by the CSIRO directed towards understanding how genetic variations influence the viability of small populations, for its potential to be applied to the conservation management of the species in the ACT.	1. A report commissioned by Environment ACT on issues and options for genetic conservation of small populations of threatened plants in the ACT outlines factors to be considered in, and directions for, genetic conservation of the species (CSIRO Plant Industry 2001). 2. Seed has been collected from several populations and is being stored at the Australian National Botanical Gardens. 3. Options are being considered for translocating plants from large populations to populations of less than 200 plants.
Maintain a monitoring program for the species with particular attention to seedling establishment and inspection for site damage. Coordinate this program with National Recovery Team efforts.	1. Populations are included in annual monitoring programs and site inspections are undertaken as required. Seedling establishment is generally healthy. 2. Ongoing contact has been maintained with researchers from the CSIRO and the Australian National University. There is close liaison with NSW Department of Environment and Conservation (DEC) (Queanbeyan) with regard to the regional conservation of *R. leptorrhynchoides*.
PROTECTION	
Protect *R. leptorrhynchoides* in native grassland habitat through the provisions of the *Land (Planning and Environment) Act 1991*, the Territory Plan and Memoranda of Understanding with the Commonwealth and the Anglican Church.	1. Most populations are under conservation management. 2. All *R. leptorrhynchoides* sites (except Australian Centre for Christianity and Culture (ACCC), Barton and Baptist Church, Manuka) are under the control of either the ACT or Commonwealth Governments. 3. MOUs have been signed for the Stirling Park–Attunga Point site (National Capital Authority) and Majura Training Area (Department of Defence). An MOU for the ACCC site remains under negotiation. *(Continued)* ▶

Table 2.3: *(Continued)*

Actions (adapted from Action Plan 8 and new actions)	Notes on Progress with Actions 1998–2003
PROTECTION *(Continued)*	
Through the National Recovery Team, promote complementary protection through reservation in NSW.	A consistent regional approach is established. This is the subject of on-going liaison with NSW Dept of Environment and Conservation.
Manage as a component of the grassy community, any conservation area established primarily for *R. leptorrhynchoides*.	1. Habitat for the species is being maintained. 2. Conservation management arrangements provide for the maintenance of the populations in their natural habitat.
Work with the ACT Planning and Land Authority and the National Capital Authority to ensure that land uses adjacent to sites supporting *R. leptorrhynchoides* are compatible with conservation objectives to minimise any adverse impacts.	1. Standard guidelines for the protection of the populations is provided to all land agencies as required. 2. Site by site advice has been provided as required. 3. Threats from adjacent land uses have been identified and minimised.
MANAGEMENT	
Develop an appropriate management regime for each site, in the form of a Management Plan or agreed management under the terms of a Memorandum of Understanding.	Draft management plans have been prepared for the majority of the ACT sites. Ongoing liaison is required to ensure that management is adequate.
Take an adaptive management approach, liaising with the National Recovery Team, CSIRO Centre for Plant Biodiversity Research and other regional researchers, and incorporating the results of research into management prescriptions for ACT *R. leptorrhynchoides* sites.	Adaptive management is implemented on sites. Management approaches have taken into account the results of monitoring and research work on the species.
Explore possibilities for horticultural effort being applied as a conservation measure for *R. leptorrhynchoides*.	1. Issue raised with National Recovery Team for consideration in consultation with relevant organisations. 2. This action is not considered to warrant a high priority.
COMMUNITY/LANDHOLDER INVOLVEMENT	
In consultation with the National Recovery Team, compile and distribute management guidelines and maintain contact with land managers responsible for areas on which populations of *Rutidosis leptorrhynchoides* occur.	1. Guidelines for management have been prepared in conjunction with the National Recovery Team. 2. Close liaison occurs with land managers and management advice has been provided to them. 3. Land managers are now aware of *R. leptorrhynchoides* populations on their land and management requirements.
Encourage community groups including the Friends of Grasslands and appropriate Park Care Groups to assist in the conservation of native grasslands and their component species including *R. leptorrhynchoides*.	1. Information on the species is provided to community groups and other stakeholders. 2. The community was involved in the (unsuccessful) translocation of plants at the Australian Centre for Christianity and Culture, Barton. There is strong community involvement in the management of the species in Red Hill Nature Reserve.
Promote the conservation of *R. leptorrhynchoides* through suitable information signs, community liaison and public education.	Actions to date include: information signs at ACCC, Barton; factsheet on the ACT Government website; inclusion in grassland field guide (Eddy *et al.* 1998); displays and talks at public events.

Threatened Species: Ginninderra Peppercress (*Lepidium ginninderrense*)

Ginninderra Peppercress was declared an endangered species in 2001 under the *Nature Conservation Act 1980* (ACT) and listed in 2005 as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). It is a perennial herb to a height of about 20 cm, with one to six branched stems arising from a rootstock. The inflorescence is an elongating raceme with small flowers appearing in late spring. The only known population of *Lepidium ginninderrense* occurs at the Belconnen Naval Transmission Station in the suburb of Lawson, ACT. Further details of the species including ACT listing, distribution and abundance, habitat and biology are contained in Appendix 4.2. The location of the known occurrence of this species is shown in Figure 2.6 (at end of Chapter 2).

THREATS

It is unlikely that the species exists anywhere else in the ACT. The issues for protecting the species, therefore, are related specifically to the need to preserve the single extant population.

The main threat to the survival of *L. ginninderrense* is likely to be urban infill, and deliberate or unintended actions associated with visitor and/or land management activities in the local area.

Observations by Avis (2000) suggest that the species grows well in locations where competing grass tussocks and other plant growth are short and open, and consequently there is little competition for space and light. Thus, inappropriate management leading to loss of such habitat may be also a threat to the species. It is important to determine management practices that are most conducive to the maintenance of the population at the only known site in Lawson.

CONSERVATION OBJECTIVES

1. Preserve the existing ACT population of *Lepidium ginninderrense* as it is the only known population of the species.
2. Conserve and manage the habitat of *Lepidium ginninderrense* so that natural ecological processes continue to operate.

CONSERVATION ACTIONS

Conservation actions (mostly undertaken by Environment ACT) are adapted from actions identified in Action Plan 26, Ginninderra Peppercress *L. ginninderrense* (ACT Government 2003) (Table 2.4). Table 2.4 contains notes on progress with actions identified in Action Plan 26.

Table 2.4: Conservation Actions for Ginninderra Peppercress (*Lepidium ginninderrense*)

Actions (adapted from Action Plan 26)	Notes on Progress with Actions
INFORMATION (SURVEY, MONITORING, RESEARCH)	
Monitor the population of *L. ginninderrense* annually and encourage research into the species.	Monitoring occurs annually.
Advise field workers, interested naturalists and conservation groups of the presence of the species to increase the potential that any other existing populations are identified.	1. Field workers in ACT grasslands are aware of the species, its habitat and identifying characteristics. 2. No other populations have been identified.
Liaise with NSW Dept of Environment and Conservation to encourage surveys of potential habitat outside the ACT.	
PROTECTION	
Support reservation under the *Land (Planning and Environment) Act 1991* (ACT) of the Lawson grassland including the area containing *L. ginninderrense* as part of the planning for the new suburb of Lawson.	1. The area in which the population of Ginninderra Peppercress occurs is within the Belconnen Naval Transmission Station, which is shown as National Land in the *National Capital Plan* (NCA 2003) and the *Territory Plan* (ACTPLA 2003). 2. The closure of the Belconnen Naval Transmission Station in the near future and development of the suburb of Lawson will require the protection of the Ginninderra Peppercress in a reserve. 3. Preliminary planning for Lawson has recognised the significance of this species and the need to protect it *in situ*. *(Continued)* ▶

Table 2.4: *(Continued)*

Actions (adapted from Action Plan 26)	Notes on Progress with Actions
MANAGEMENT	
Facilities such as walking tracks will not be developed near the site, with the aim of discouraging visitor access to the area.	Tracks near the population are currently in low use; the species grows to the edge and in places, across the tracks.
Consider actions relevant to protection of the population from adjacent activities.	1. This is not an issue until closure of the Belconnen Naval Station brings a potential for increased utilisation of the area. 2. A 'low profile' will be maintained for the site where the species is located.
Statements of conservation objectives and intended management actions for the species will be placed in relevant management plans and strategies.	To be undertaken when the Belconnen Naval station is closed.
Expert advice on best practices for management of the species will be sought, particularly (a) maintenance of an open habitat, and (b) actions considered desirable based on the results of monitoring (as part of an 'adaptive management' approach).	1. Current management is to maintain the open vegetation structure and otherwise provide minimal impact to the site. 2. Advice is incorporated into management guidelines for the species.
GENETICS AND *EX-SITU* CONSERVATION	
The following actions will be undertaken on the advice of CSIRO Plant Industry (2001): (a) Collect open-pollinated seed from a wide range of individuals. (b) Use some of the seed to establish new populations at other apparently suitable locations. (c) Store remaining seed under appropriate conditions (e.g. at the Australian National Botanical Gardens) to act as a core for *ex-situ* genetic conservation.	1. Existing plants of *L. ginninderrense* support high seed set, allowing opportunities for translocation and *ex-situ* conservation (CSIRO Plant Industry 2001). 2. Seed collection is already underway and seed is stored at the Australian National Botanical Gardens.
COMMUNITY/LANDHOLDER INVOLVEMENT	
Explore opportunities to involve the local community in Park Care activities as part of the management of the proposed reserve.	Under the current land use (Belconnen Naval Transmission Station) there is no public access to the *L. ginninderrense* site. However, with the development of the new suburb of Lawson recreational use of open spaces in the area will increase.

Uncommon Grassland Flora Species in the ACT

Species not listed under legislation as vulnerable or endangered may be also of conservation concern and it is important that their status be monitored over time and threats minimised, especially those species listed as threatened under other State or Commonwealth legislation (see Table 2.2). Some plant species in native grassland are naturally rare or have become uncommon due to clearance or disturbance. Some species may also be considered to be 'declining', if there is a suspected or recorded decrease in numbers (population decline). Decline also alludes to a potential or actual loss of vigour within the population (Crawford and Rowell 1996). For reasons such as the inconspicuous habit of some species, seasonal variation, and lack of historical knowledge of abundance and distribution, considerable uncertainty may surround these assessments. The conservation status of species needs to be considered in a regional context. The ACT has been comprehensively surveyed, but coverage of the Southern Tablelands region as a whole is variable with private land, in particular, being inadequately surveyed (Environment ACT 2005).

From surveys at the ten most diverse grassland sites in ACT Crawford and Rowell (1996) identified 28 species that they assessed as uncommon or declining. Of these, one has been described as a new species and declared endangered (Ginninderra Peppercress), and another is the threatened Button Wrinklewort, dealt with in the previous section. Several others of these species were probably under-surveyed in the past, as the more recent surveys have found populations to be more common than previously thought (e.g. Blue Devil (*Eryngium ovinum*) and Wiry Dock (*Rumex dumosus*)).

Of the more uncommon species, the status of several is of particular concern:

- *Amphibromus nervosus* is a small forb occurring in swampy ground at low elevations and in valleys (Burbidge and Gray 1970). It has been found in two grassland locations in the ACT (Dunlop Nature Reserve and 'Woden Station' in the Jerrabomberra Valley) (Crawford and Rowell 1996). More recently, it has been found at two woodland sites, including Mulligans Flat Nature Reserve. Collections of the species from the ACT are lodged with the National Herbarium.
- *Burchardia umbellata* (Milkmaids) was found at one grassland location (Dunlop Nature Reserve) (Crawford and Rowell 1996) and has been found subsequently at two woodland sites, including Mulligans Flat Nature Reserve. It is also known from Hall Cemetery, in habitat of the Tarengo Leek Orchid. The species is widespread in other parts of temperate Australia, but is uncommon on all but the north-western parts of the Southern Tablelands region (Eddy *et al.* 1998).
- *Microseris lanceolata* (Yam Daisy) is known to have declined since European settlement. The species is described as being common in the ACT and widespread in temperate Australia (Burbidge and Gray 1970), however, it is seldom recorded in surveys. It occurs in one grassland site (Australian Centre for Christianity and Culture, Barton), and has been recently recorded in Mulligans Flat and Farrer Ridge nature reserves.
- *Ophioglossum lusitanicum* (Adder's Tongue) is probably frequently overlooked as it is a tiny one or two leaved fern (up to 25 mm tall) with an inconspicuous green fertile spike. Crawford and Rowell (1996) found it at six grassland sites (Canberra International Airport, Gungahlin Grassland Reserves, Majura Training Area, Dunlop Reserve and 'Woden Station').
- *Stuartina muelleri* (Spoon Cudweed) is one of the few annual herbaceous species found in ACT grasslands. It occurs in grassland, woodland and sclerophyll forest, and is relatively widespread (Crawford and Rowell 1996). This is a very small plant, which is easily missed in surveys, particularly as it has inconspicuous tiny flowers and is only present in spring (Eddy *et al.* 1998). The species was found by Crawford and Rowell (1996) at the Belconnen Naval Station and Gungahlin Grassland Reserve. More recently it has been recorded at Yarramundi Reach and Mulligans Flat Nature Reserve.
- *Swainsona sericea* (Silky Swainson-pea) is a grassland and grassy woodland species listed as vulnerable in NSW. The species flowers from October to December, but quickly dies back to rootstock after flowering. It was recorded on the Monaro at four locations (Benson 1994), at three ACT grassland sites in 1996 (Gungahlin Grassland Reserve, Majura Training Area and 'Woden Station') and at four ACT woodland sites (Crawford and Rowell 1996).
- *Zornia dyctiocarpa* var. *dyctiocarpa* (Zornia) is recorded as being widespread in grassland and open forest in a number of biogeographic regions (Crawford and Rowell 1996). In the ACT, however, it is less commonly found, but is known to occur in grassland at Dunlop Grassland Reserve (Crawford and Rowell 1996) and at 'Woden Station' and in woodland on Tuggeranong Hill and Wattle Park, Lyneham (S. Sharp, pers. comm.).

THREATS

Threats to uncommon species are those previously discussed for the ecological community generally (see s. 2.1.7). An additional threat is the lack of botanical and ecological knowledge of these species, as they do not have the same 'profile' as listed threatened species.

CONSERVATION OBJECTIVES

1. Conserve populations of known uncommon plant species in ACT natural temperate grassland as viable populations in perpetuity.
2. Conserve the full range of habitat diversity to maintain a range of species in suitable habitat.

CONSERVATION ACTIONS

Conservation actions (Table 2.5) for uncommon grassland flora species (mostly undertaken by Environment ACT) are framed within the actions for the Strategy as a whole in Table 4.1. Table 2.5 contains notes on activities currently being undertaken in relation to these actions.

Table 2.5: Conservation Actions for Uncommon Grassland Flora Species

Actions	Activites Completed or Currently being Undertaken in Relation to these Actions
INFORMATION (SURVEY, MONITORING, RESEARCH)	
Maintain alertness to the possible presence of uncommon grassland plant species when undertaking surveys in appropriate habitat.	1. Field workers in ACT and regional grasslands are aware of the need to record occurrences of a range of species of concern. 2. A survey for 53 species considered uncommon or declining in ACT grasslands and grassy woodlands has been undertaken (Crawford and Rowell 1996). Surveys of all ACT grasslands include records of these species.
Maintain a database of known occurrences and abundance of uncommon grassland plant species to enable analysis of changes in distribution and abundance.	The ACT vegetation database contains records of all species identified in all grassland plant surveys undertaken in ACT since 1991.
Maintain a watching brief on ACT populations of uncommon grassland plant species and evaluate their conservation status in a regional context.	Field workers are aware of the need to look out for occurrences of a range of species that may be declining.
Facilitate and encourage research that will provide information on the status of uncommon grassland plant species and management requirements.	
PROTECTION	
Ensure known populations of uncommon grassland plant species are protected from inadvertent damaging actions (e.g. by advising landholders of their presence).	The presence of populations is taken into account in the management of grassland sites.
MANAGEMENT	
Prepare management guidelines for uncommon grassland plant species where necessary.	
Manage sites, and provide advice to other landowners and managers, to maintain optimum habitat (where known) for uncommon grassland flora species.	
Consider nomination for ACT listing if uncommon grassland flora species show evidence of local decline in extent and abundance.	
REGIONAL AND NATIONAL COOPERATION	
Liaise with interstate agencies involved in protection and management of uncommon grassland flora species with the aim of increasing knowledge of their biology, and habitat and conservation requirements.	Liaison with NSW Dept of Environment and Conservation threatened species officers includes information exchange about the status of particular species of concern.

2.3

Grassland Fauna

2.3.1 Fauna as part of the Grassland Ecosystem

Animals are intrinsic to the overall functioning of ecosystems, including grassy ecosystems. Animals are essential for pollination and dispersal of many grassland plants and are involved in nutrient recycling and maintenance of soil condition. Grasslands provide habitat for animals and are a source of food for both herbivores and predators. Invertebrates are particularly important though it is not known what constitutes a natural invertebrate community for grasslands (Driscoll 1994). However, they are the dominant faunal element in grasslands and are involved in most ecological processes (Sharp and Dunford 1994; Yen 1995).

Australian grasslands have evolved under grazing from a range of animals, including kangaroos, wallabies, wombats and other herbivores such as termites. The population sizes (or densities) of grazing animals are determined largely by seasonal abundance of the grassland plants upon which they feed. In turn, plant species composition and abundance of grassland vegetation are affected by the population size of grazers (grazing intensity) and seasonal conditions (rainfall and temperature). Thus grazers and grasslands are linked in a complex feedback loop driven by fluctuating seasonal conditions.

Loss of native animal species or introduction of exotic animal species can alter ecosystem processes and may lead to a change in the composition of grassland vegetation (such as a shift in the dominant plant species following removal of grazers or after sustained heavy grazing). There may be adverse affects also on the health of the ecosystem (such as the loss of native plants following loss of their insect pollinator or increased erosion due to loss of vegetation cover through heavy grazing). The well-known phenomenon of rural tree dieback that affects woodlands and isolated paddock trees in grasslands is a notable example of an altered ecosystem process that has resulted in widespread impact at the landscape level. One of the possible explanations for the increasing occurrence and severity of insect-mediated dieback is a reduction in the abundance and efficacy of natural controls of damaging insects, in particular the decline in insectivorous birds and insect parasitizers of pasture scarabs (Reid and Landsberg 2000; Martin and Green 2002).

2.3.2 Threats to Grassland Fauna

The main threat to fauna in native grasslands in Australia, and the primary reason for the decline of many grassland animal species, is the widespread removal, modification and fragmentation of grassland habitat since European settlement. Other threats include increased predation by introduced predators, competition from introduced herbivores and human disturbance. These threats to grassland fauna are described in more detail in the following sections.

CONTINUED REMOVAL AND FRAGMENTATION OF HABITAT

The decline of grassland fauna is related to the history of land clearing and conversion of grasslands to agriculture, including cropping of introduced plants and grazing by introduced animals largely on introduced pastures. Clearance of native vegetation, including native grassland, still remains the most significant threat to terrestrial biodiversity despite apparently tight legislative controls (Australian State of the Environment Committee 2001) and is listed as a key threatening process in NSW and nationally. Expanding urban development increases pressure on remnants of native vegetation, whereas construction of roads and other urban infrastructure leads to increased fragmentation of habitat. There is an extensive literature on the effects of fragmentation on animals, especially birds and mammals (Andren 1994). Whilst much of this literature relates to removal of shrub and tree layers, the effects can also be extrapolated to fragmentation of habitat for grassland fauna.

The size and isolation of a remnant is critical for the long-term persistence of many animal species within the remnant. Minimum patch size to support a viable population of larger animals such as Eastern Grey Kangaroos is likely to be greater than for some smaller mammals or reptiles, and all species are likely to require larger patch sizes in poor quality or degraded habitat than in good quality habitat. Animal populations too small to be viable in the long term may persist for some time in remnants following habitat fragmentation, resulting in a time lag (in some cases years or decades) between habitat disturbance and species decline (Recher and Lim 1990; Saunders *et al.* 1991; Traill 2000). Such time lags can occur if individuals are long-lived (but may not be breeding) or if the habitat is sufficient to satisfy the requirements of the species during good conditions, but not during or following major environmental disturbances such as drought or fire.

Habitat fragmentation is of particular significance for many invertebrates whose populations can fluctuate dramatically, often related to the prevailing weather. Species whose populations fluctuate in size will frequently exist only in small populations and their persistence may derive from repeated recolonisation following local extinction, involving immigration from other populations (Driscoll 1994). Some invertebrates have limited mobility. Populations of the threatened Golden Sun Moth (*Synemon plana*) separated by more than 200 m are effectively isolated but the lack of genetic differentiation between closely located populations may indicate that these were all historically connected and have only recently undergone fragmentation (see Appendix 5.3). Management of grassland fragments for invertebrate conservation is particularly difficult given the lack of knowledge and the isolation of fragments. Timing and type of biomass reduction, for example, is critical to the life cycle of many species.

The degree of isolation or connectivity of a remnant determines its potential for recolonisation and is a critical issue for fauna conservation. Connectivity has been defined as ‘the degree to which the landscape facilitates or impedes movements among patches’ (Bennett 1999). Movement between patches can be impeded by unsuitable habitat between patches (e.g. cultivation or urban development) or by barriers such as major roads and traffic. Although there are possible disadvantages to linking habitats (e.g. corridors might serve as conduits for disease or fire), connectivity is generally regarded as desirable in conservation planning (Saunders and Hobbs 1991). Lack of connectivity in highly fragmented ecosystems is clearly a threat to the long-term viability of some animal populations (Smith and Hellmann 2002), though the best means of rebuilding connectivity is subject to debate and depends upon the species in question. For example, it is not known whether species such as the Grassland Earless Dragon or Striped Legless Lizard are able to cross a major road and what structures would assist such crossing.

The value of corridors has been debated on the basis of adequate width, high cost and edge effects. An alternative is closely spaced patches forming ‘stepping stones’ (Beier and Noss 1998; Martin and Green 2002; Freudenberger 2001). Stepping stones are likely to benefit species that are sufficiently mobile to cross areas of unsuitable habitat (such as some birds and kangaroos) but may not benefit less mobile species such as many reptiles. Even amongst highly mobile species, fragmentation can result in the necessity to move greater distances between resources, such as between feeding and shelter (e.g. kangaroos moving between shelter trees and open feeding areas). Movement between fragments can also increase exposure to risks such as predation or road collision (e.g. kangaroos in the Canberra urban area and migrating Eastern Long-necked Turtles (*Chelodina longicollis*)).

DEGRADATION OF EXISTING HABITAT

The major threat to animals in existing habitat, even where the habitat may have sufficient area and connectivity, is the modification or degradation of habitat. Habitat modification can be through a change in plant species composition (e.g. exotic species replacing native species), habitat structure (e.g. short grass as opposed to tall grass, or tussocks replaced by non-tussock species, trampling of grass, removal of rocks), plant species diversity (e.g. loss of diversity in a monoculture) or quality (e.g. loss of organic matter, loss or addition of nutrients, change in soil characteristics). Such changes can be brought about through grazing by stock at an intensity that reduces plant diversity of the ground layer, planting of crops or exotic pastures, invasion by weeds, addition of fertilizer, use of chemicals, removal of rocks, dumping of soil, gravel or rubbish, and altered fire regimes. Each of these modifications may reduce the suitability of habitat for certain animal species. Removal of bush rock, invasion by exotic perennial grasses, and high-frequency fire regimes are listed in NSW as key threatening processes. Grazing by stock and use of exotic pasture plants and fertilizer (i.e. ‘pasture improvement’) have caused the most extensive modifications to existing grasslands. Improved pastures are of little conservation value.

INTRODUCED PREDATORS

Foxes, cats and dogs are known to prey on grassland fauna, which can form a substantial proportion of the diet of these introduced predators. The native prey of foxes, and feral, stray and domestic cats includes mostly insects, small mammals, reptiles and birds commonly found on the ground or in lower understorey (Coman 1995; Newsome 1995; Dickman 1996). The impact of this predation on population sizes of grassland fauna has not been well quantified. It is evident, however, that some species have been highly vulnerable to predation by introduced predators. Mammals in the weight range between 35 g and 5.5 kg have shown disproportionate decline since European settlement, and this occurred prior to extensive agricultural clearing. Thirteen of the 27 species of native mammals that disappeared from western NSW were last collected in 1857 or earlier (Bauer and Goldney 2000). Dickman (1994) concluded that cats played an important role in the demise of these species. Feral cat and fox predation on native wildlife are listed as key threatening processes in NSW and nationally. The uncontrolled roaming of domestic cats, and in some cases dogs, in grassland nature reserves close to urban areas is likely to contribute to increased predation on wildlife. Conservation of susceptible fauna in these areas will depend on responsible pet ownership or stronger controls.

DIRECT HUMAN IMPACTS

Threats from direct human impacts include trapping, hunting, disturbance to grassland areas used for recreation, impacts of vehicle traffic and construction of urban infrastructure (e.g. drains, trenching for cables). Hunting is considered to have placed pressure on animal populations in the past and resulted in serious declines or extinction e.g. the Brush-tailed Rock Wallaby (*Petrogale penicillata*) in central western NSW (Bauer and Goldney 2000). Human disturbance to habitat is likely to be exacerbated in small grassland fragments close to population centers.

2.3.3 Grassland Fauna in the South Eastern Highlands Region

At the time of European settlement, lowland grasslands of south-eastern Australia supported a rich vertebrate fauna, including emus, kangaroos, bustards, rat kangaroos, predatory birds as well as less obvious animals including small marsupials, rodents, birds, bats, reptiles and frogs (Osborne *et al.* 1995). The grasslands also contained a diverse invertebrate fauna (Driscoll 1994) among which insects are a dominant and relatively conspicuous class involved in most ecosystem processes (Farrow 1999). With widespread clearance and modification of grasslands (s. 2.3.2), many grassland animal species have declined, including some of the larger vertebrates, though many of the smaller animals still remain common in grasslands that are in good condition. A few species, such as the Eastern Grey Kangaroo, Australian Magpie and Eastern Blue-tongue Lizard, show some tolerance to the modification of grasslands since European settlement and may even have benefited from some changes.

A variety of data sources were used to compile composite information on grassland fauna of the ACT region. These sources include scientific papers and books, reports and/or records of observations by Environment ACT staff, consultants, other government agencies including the NSW Department of Environment and Conservation, and community groups such as the Canberra Ornithologists Group (COG). The detail and accuracy of this data vary within the region, depending upon the locations and methods of surveys and the inclusion of opportunistic observations. Surveys for certain fauna groups (such as reptiles) and specific studies have been conducted in many grasslands and adjacent grassy woodlands. Opportunistic sightings of species provide valuable information for areas where detailed surveys have not been conducted.

INVERTEBRATES

Insects, other invertebrates and micro-organisms account for more than 90 per cent of the biodiversity in ecosystems such as grasslands and are vital for healthy ecosystem function. Invertebrates live in the soil, near the ground surface and in the grass and forb canopy. They are essential for pollination and reproduction of many plants, are involved in nutrient recycling through the breakdown of dead plant and animal material and are the main food of many grassland animals such as birds, reptiles and amphibians. Less information, however, exists on the composition, biodiversity and ecological requirements of invertebrates than for other fauna groups. Consequently, conservation of most invertebrate species falls under the umbrella of habitat protection for vertebrates and vegetation communities. It is evident, however, that more than just the dominant plant species are important habitat determinants for invertebrates. Vegetation and litter structure, soil types, soil and plant nutritional properties and topography are important factors, as are the type and timing of management interventions (Driscoll 1994; Farrow 1999; Greenslade 1994).

Management activities affecting grassland invertebrates include defoliation (grazing, mowing, burning), pasture improvement, and use of fertilizers and chemicals (Driscoll 1994). Grazing of livestock alters the species composition and abundance, and may reduce the diversity of invertebrates in grasslands. To best conserve invertebrates, mowing is considered to be preferable to grazing, in part because it is more flexible. The effects of fire on invertebrates are not well understood but are known to depend upon the season and intensity of fire, the size of the fire, the habitat upon which the life history stages of the invertebrates depend, and if relevant, the proximity of sources of recolonisation (Yen and Butcher 1997) (see s. 3.5.1). Sowing of grasslands with exotic pastures has major effects on grassland invertebrates. For example, abundance of Collembola (Springtails) has been shown to increase and introduced species become dominant (King 1991 in Driscoll 1994). A decline in ant diversity and replacement of native earthworms by exotic lumbricid worms has also been noted (Lee 1985 in

Driscoll 1994). Application of fertilizers and biocides (often associated with pasture improvement) has been shown to affect species composition and abundance as well as ecosystem function. For example, Titlyanova *et al.* (1990, in Driscoll 1994) noted changes in the biomass of a number of invertebrate Orders, and concluded that fertilizers decrease species diversity, simplify the trophic structure of animal populations, increase the rate of organic matter decomposition and decrease the regulatory functions of heterotrophs.

Two threatened insect species found in the ACT region, the Perunga Grasshopper (*Perunga ochracea*) and Golden Sun Moth (*Synemon plana*), are grassland specialists and are described more fully in Appendix 5.3 and 5.4 and in s. 2.3.5. Many other insect species and invertebrates in general may have undergone similar declines, but there is insufficient baseline data for such an assessment.

Insect species known to have declined include:

(a) The Canberra Raspy Cricket (*Cooraboorama canberrae*). This is a rare grassland insect found only in the ACT region with a raspy call made by rubbing the sides of the abdomen against the inside of the hind legs. Adults were formerly found in the gardens of new suburbs but the species has become more rare with urban expansion. It has been recorded at Gungahlin Grasslands, Majura Training Area, Jerrabomberra Valley and Belconnen Naval Base.

(b) Lewis's Laxabilla (*Laxabilla smaragdina*). This tiny wingless grasshopper has not been recorded for many years in the ACT (Farrow 1999). It was common on the lower slopes of Tuggeranong Hill before suburbs replaced the native grassland (Greenslade and Rentz c. 1998)

(c) Key's Matchstick Grasshopper (*Keyacris scurra*). This flightless grasshopper was formerly common in grasslands and grassy woodlands in south-eastern Australia but is now uncommon in the ACT region. There are records from near Hall, Mulligans Flat Nature Reserve, Crace Nature Reserve, near the Murrumbidgee River, Tidbinbilla Nature Reserve and the railway line easement near Royalla (NSW) (Rowell and Crawford 1995). Local abundance of the species is correlated with known and potential food plants (especially *Chrysocephalum apiculatum*) growing between tussocks of Kangaroo Grass (*Themeda triandra*) (Rowell and Crawford 1999). The species has an unusual life history for a grasshopper in that eggs hatch in autumn, juveniles grow over winter, and adults are found in spring. Even light grazing or mowing may destroy populations and, being flightless, the animals are very slow to recolonise areas from which they have been eliminated (Greenslade and Rentz c. 1998).

Australia has approximately 100 000 described invertebrate species and possibly twice that number undescribed (Yen and Butcher 1997). An unknown number of these are found in grasslands. An example of a new undescribed species from grassland is Whiskers Springtail (Tomoceridae new genus, undescribed species). Springtails are tiny, little known, soil and leaf litter insects usually about a millimetre or two long. Not obvious to the casual observer, they are common throughout Australia on grasses and other plants, as well as being especially abundant in soils and leaf litter. About one-tenth of Australian springtail species are restricted to very small areas of just a few hectares. The Whiskers Springtail comes from a single small grassland locality near Captains Flat (NSW). Springtails play an important role in maintaining the grassland ecosystem as they improve soil fertility by feeding on bacteria and fungi which decompose dead plant material, so increasing the availability of nutrients for plant growth (Greenslade and Rentz c. 1998).

BIRDS

Compared to more structurally diverse habitats such as woodlands and forests, grasslands are not particularly rich in bird species. However, about fifty bird species occur as residents or summer migrants in grassy woodlands and for many of these species nearby grasslands are an important component of their habitat. Five bird species are grassland specialists and are considered to be dependent on this habitat, namely Stubble Quail (*Coturnix pectoralis*), Brown Quail (*Coturnix australis*), Singing Bushlark (*Mirafra javanica*), Brown Songlark (*Cinclorhamphus cruralis*) and Richard's Pipit (*Anthus novaeseelandiae*). Stubble Quail are widely distributed in the ACT region though uncommon. Brown Quail are rare in the ACT region and within the ACT most records are from open paddocks on the western edge of the city and in the native grasslands of the Upper Cotter and Upper Naas catchments. Singing Bushlarks are rare in the ACT region and the few ACT records come from mainly the Lake Tuggeranong area and Point Hut silt trap. Brown Songlarks are widely distributed though rare in the ACT region, whereas Richard's Pipits are widely distributed and common in the ACT and region.

Latham's Snipe (*Gallinago hardwickii*), a species protected under migratory bird agreements with Japan (JAMBA) and China (CAMBA), utilises the wetter grasslands (R. Rehwinkel pers. comm.) and wetlands in native grassland (ACT Government 1997a). It has been recorded in wet grassland at HMAS Harman and

Gungaderra Nature Reserve. However, in the ACT most of the Snipe's habitat is now in exotic grassland. Two lowland woodland species, the Diamond Firetail (*Emblema guttata*) and Superb Parrot (*Polytelis swainsonii*) forage is grasslands. In the past ACT lowland grasslands supported good populations of Emu (*Dromaius novaehollandiae novaehollandiae*), Bush Stone-curlew (*Burhinus grallarius*) and Bustard (*Ardeotis australis*), now locally extinct.

Species often seen on or near the ground in open grassy habitats include Australian Magpie (*Gymnorhina tibicen*), Magpie Lark (*Grallina cyanoleuca*), Masked Lapwing (*Vanellus tricolor*), Rufous Songlark (*Cinclorhamphus mathewsi*) and to a lesser extent Golden-headed Cisticola (*Cisticola exilis*). Birds of prey such as Australian Kestrel (*Falco cenchroides*), Brown Falcon (*Falco berigora*) and Black-shouldered Kite (*Elanus notatus*) often hunt in grasslands, and insectivores such as Martins and Swifts are frequently seen flying and feeding above grasslands.

Introduced bird species commonly seen in grasslands include Starling (*Sturnus vulgaris*), Skylark (*Alauda arvensis*) and Goldfinch (*Carduelis carduelis*).

MAMMALS

Native mammals typically associated with native grasslands of the ACT region include the ubiquitous Eastern Grey Kangaroo (*Macropus giganteus*) and Common Wombat (*Vombatus ursinus*). Echidnas (*Tachyglossus aculeatus*) are also widespread in the ACT region and are occasionally seen in grasslands. Many species more typically associated with grassy woodlands often occur in nearby grasslands or where scattered trees or other suitable shelter exist in or close to grasslands, and include Swamp Wallaby (*Wallabia bicolor*), Common Brushtail Possum (*Trichosurus vulpecula*), Common Dunnart (*Sminthopsis murina*) and native Bush Rat (*Rattus fuscipes*). At least ten bat species occur in ACT open grassy woodlands and are likely to use adjacent grasslands and areas where isolated trees provide suitable roosting sites. These bats are the Lesser Long-eared Bat (*Nyctophilus geoffroyi*), Gould's Long-eared Bat (*N. gouldi*), White-striped Freetail-bat (*Nyctinomus australis*), Chocolate Wattled Bat (*Chalinolobus morio*), Gould's Wattled Bat (*C. gouldii*), Common Bentwing-bat (*Miniopterus schreibersii*), Little Forest Bat (*Vespadelus vulturnus*), Southern Forest Bat (*V. regulus*), Large Forest Bat (*V. darlingtoni*) and Southern Freetail-bat (*Mormopterus planiceps*).

All native mammal species found in ACT grasslands also occur in other habitats such as woodlands, forests, riparian zones and the ecotones between them. The Southern Freetail-bat is considered to be uncommon whereas the Common Bentwing-bat, although still reasonably abundant, is listed nationally under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) as being 'conservation dependent' because of the need to protect major roosting caves. The other mammal species occurring in ACT grasslands are considered to be common throughout most of their distributions (Strahan 1995) and are not listed as threatened in the ACT or NSW, although population sizes of many have declined since European settlement.

More recent additions to mammalian fauna found in grasslands include the Dingo, which was brought to Australia by humans around 3500–4000 years ago (Corbett 1995), and several domestic and feral species that were introduced either deliberately or inadvertently following European settlement. Domestic species include cattle, sheep and horses, whereas feral animals include pigs, rabbits, hares, cats, foxes, dogs and mice.

REPTILES AND AMPHIBIANS

Native grassland in the ACT region provides habitat for many lizard species and three snake species, and their abundances vary geographically. Two threatened reptile species found in the ACT region, the Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and Striped Legless Lizard (*Delma impar*), are grassland specialists and are described more fully in Appendix 5.1 and 5.2 and in s. 2.3.5. The Pink-tailed Worm Lizard (*Aprasia parapulchella*) is listed as threatened nationally. This species is very rare in New South Wales but locally common in parts of the ACT (Osborne *et al.* 1991). In the ACT the species is found in grasslands with outcrops of rocks of volcanic origin, particularly areas near the Murrumbidgee and Molonglo Rivers (s. 2.3.5).

Reptiles that are widespread and common in native grasslands of the ACT region are the Delicate Skink (*Lampropholis delicata*), Three-toed Skink (*Hemiergis decresiensis*), Garden Skink (*Lampropholis guichenoti*), Olive Legless Lizard (*Delma inornata*), Striped Skink (*Ctenotus robustus*), Copper-tailed Skink (*Ctenotus taeniolatus*) (particularly in rocky areas) and Eastern Blue-tongue Lizard (*Tiliqua scincoides*).

Less commonly seen lizards include the Shingleback (*Trachydosaurus rugosus*) and Bearded Dragon (*Pogona barbata*). The Shingleback is primarily an inhabitant of the drier inland and in the ACT occurs in grasslands and woodlands north of Canberra, which marks the easterly limit of its distribution. Specimens from the ACT and region are black or very dark brown in colour (Bennett 1997). Bearded Dragons are occasionally seen in grasslands of the ACT and region, though their numbers may have declined in recent years.

The Eastern Brown Snake (*Pseudonaja textilis*) and Red-bellied Black Snake (*Pseudechis porphyriacus*) are both widespread and common in grasslands of the region, with the latter species more frequently seen near dams and other waterbodies. The Blind Snake (*Ramphotyphlops nigrescens*) is also widespread in the region though less frequently seen, possibly due to its cryptic habits. This species tends to occur in relatively undisturbed environments, including native grasslands that have not been ploughed or heavily grazed for long periods (Bennett 1997).

The Eastern Snake-necked Turtle (*Chelodina longicollis*) is found throughout the ACT, including native grassland habitats, wherever there is a water source such as a creek, swamp or farm dam.

Frogs occur in wetter areas or at waterbodies within grassland and may use burrows and cracks in the soil, logs, rocks and thick grass for shelter. Species recorded in ACT native grassland include Spotted Grass Frog (*Limnodynastes tasmaniensis*), Whistling Tree Frog (*Litoria verreauxii*), Plains Froglet (*Crinia parinsignifera*), Common Eastern Froglet (*Crinia signifera*), Eastern Banjo Frog (*Limnodynastes dumerilii*), Brown-striped Frog (*Limnodynastes peronii*), Spotted Burrowing Frog (*Neobatrachus sudelli*) and Smooth Toadlet (*Uperoleia laevigata*). The Brown Toadlet (*Pseudophryne bibronii*) has declined in numbers in the ACT region and is no longer found within grasslands of the ACT. The Green and Golden Bell Frog (*Litorea aurea*) is listed as threatened in NSW and nationally and is now locally extinct in the ACT.

2.3.4 Conservation of Grassland Fauna in the ACT

Consistent with the requirements for threatened species in the *Nature Conservation Act 1980*, one of the two goals adopted for the *Lowland Native Grassland Conservation Strategy* is to:

> *Conserve in perpetuity, viable, wild populations of all lowland native grassland flora and fauna species in the ACT and support regional and national efforts towards conservation of these species.*

The major threat to native grassland fauna in the ACT region and the apparent reason for decline of some species is the loss and modification of grassland habitat (s. 2.3.2). The premise of this *Strategy* is that protection in nature reserves and off-reserve conservation management of grassland habitat provides the foundation for long-term conservation of grassland fauna, including threatened species. For this reason, objectives and actions in the *Strategy* for conservation of fauna relate largely to grassland habitat. In general, the *Strategy* takes an ecosystem approach to the conservation of grassland fauna rather than treating each species separately. Exceptions are threatened species, for which there is a legislative requirement to prepare Action Plans and some threatened species have specific recovery requirements.

From the general threats to grassland fauna previously discussed, it is evident that all grassland fauna will be advantaged by the conservation of large areas of grassland in sound ecological condition that are connected to other grasslands, grassy woodland, forest or wetland. This habitat is further enhanced where introduced predators can be controlled and deleterious human disturbance such as incompatible adjacent land uses can be managed.

Actions undertaken to conserve threatened, declining or uncommon animal species and their habitats (see s. 2.3.5) will also benefit the more abundant grassland animal species. For example, retention of adequate grass cover and structure for Grassland Earless Dragons and Striped Legless Lizards will also benefit the numerous other reptile species that inhabit grasslands. Actions that help conserve the Perunga Grasshopper and Golden Sun Moth will also benefit a diversity of grassland invertebrates. Any key conservation requirements for non-threatened species that do not fall under the umbrella of protection of natural temperate grassland or habitat protection for threatened species need to be explicitly identified. For example, water bodies (creeks, wetlands and dams) with good water quality and fringing and aquatic vegetation are habitat for amphibians, long-necked tortoises and some birds, and so should be conserved.

Objectives and actions for the *Strategy* related to grassland fauna, including threatened species, are shown in Table 4.1. The actions are not designed to prescribe every detailed task needing to be undertaken. Detailed actions will be developed by responsible agencies, often with community involvement and will be refined over time as more information is gained (as part of ‘adaptive management’). With regard to threatened species, objectives and actions in this *Strategy* must be integrated with state and national conservation efforts. Information in the next section provides a guide to more detailed or specific actions related to the conservation of threatened species.

Conservation of the Grassland Earless Dragon, Striped Legless Lizard, Golden Sun Moth and Perunga

Grasshopper in the ACT provides a major contribution to the conservation of these threatened species at regional and national levels. Importantly, two of the three extant populations of the Grassland Earless Dragon are located in the ACT. The Striped Legless Lizard is known to occur in only scattered locations in south-eastern Australia, of which the ACT is a stronghold. The Perunga Grasshopper has been recorded from scattered locations in south-eastern Australia, with most of the recent records from the ACT and surrounding areas. Distribution of the Golden Sun Moth has contracted to only scattered locations in south-eastern Australia, most of which are in the ACT region. Conservation of grassland habitat also substantially contributes to the regional conservation of several uncommon grassland animal species. The long-term viability of these threatened and uncommon species across their range at regional or national levels is dependant on appropriate conservation measures both within and outside the ACT.

2.3.5 Threatened and Uncommon Grassland Fauna Species in the ACT

Grasslands in the ACT provide critical habitat for four animal species (two reptiles and two insects) declared as threatened in the ACT under the *Nature Conservation Act 1980* (Table 2.6). These species are described further in Appendix 4 and 5. The Pink-tailed Worm Lizard (*Aprasia parapulchella*) (listed as threatened nationally) also occurs in grasslands of the ACT. This species does not occur in the low lying grasslands on valley floors, but is associated with river corridors and adjacent hill slopes at some sites.

The Pink-tailed Worm Lizard is included in the conservation strategy for aquatic species and the riparian zone (*Action Plan 29*) (in preparation).

Grassland species that are uncommon in the ACT region include Canberra Raspy Cricket, Lewis's Laxabilla, Key's Matchstick Grasshopper, Shingleback Lizard, Stubble Quail, Brown Quail, Singing Bushlark and Brown Songlark.

Threatened Species: Grassland Earless Dragon (*Tympanocryptis pinguicolla*)

The Grassland Earless Dragon (*Tympanocryptis pinguicolla*) is listed as threatened in the ACT, NSW, Victoria (where it no longer occurs) and nationally (Table 2.6). This small, cryptic lizard is a grassland specialist, with the three remaining populations occurring in the ACT region. Two of these populations occur in the ACT, with one population extending into nearby NSW. The third population is located near Cooma in NSW (Smith *et al.* 1999). Environment ACT has supported post-graduate research at the Australian National University (Nelson, 2004) into the biology and ecology of the Grassland Earless Dragon, including an analysis of the genetic differences between the ACT and Cooma populations. These were found to be consistent with species-level differences, suggesting these populations should be considered separate taxonomic units (Scott and Keogh 2000). A more detailed description of the species and its ecology is given in Appendix 5.2. The locations of the two ACT populations of this species are shown in Figures 2.3 and 2.4 (at end of Chapter 2).

Table 2.6: Conservation Status Nationally of ACT Threatened Animal Species of Native Grassland

Species	ACT	NSW	Other
Striped Legless Lizard	V	V	E (Cwlth), T (Vic)
Grassland Earless Dragon	E (SPS)	E	E (Cwlth), T (Vic), E (Qld)
Golden Sun Moth	E (SPS)	E	CE (Cwlth), T (Vic)
Perunga Grasshopper	V	—	—

CE: Critically Endangered; **E**: Endangered; **V**: Vulnerable; **T**: Threatened; **SPS**: Special Protection Species

Legislation:

Commonwealth: *Environment Protection and Biodiversity Conservation Act 1999*

ACT: *Nature Conservation Act 1980*

NSW: *Threatened Species Conservation Act 1995*

Vic: *Flora and Fauna Guarantee Act 1988* (Note that under this Act, species are listed as 'threatened' and specific conservation status (e.g. endangered) is applied in lists prepared by the Victorian Department of Sustainability and Environment.)

Qld: *Nature Conservation Act 1992*; *Nature Conservation (Wildlife) Regulation Act 1994*

THREATS

In common with other threatened grassland animal species, the main threats to the Grassland Earless Dragon are the continued loss and fragmentation of its grassland habitat due to agricultural, urban and industrial development and degradation of habitat through changed grazing intensity, pasture improvement, weed invasion, changed fire regimes and impacts of stock. Other threats include the impacts of predators and direct human disturbance.

The habitat of the Grassland Earless Dragon is extremely fragmented, such that the probability of unassisted movement between the three remaining populations (Majura Valley, Jerrabomberra Valley and Cooma) is now very unlikely. In NSW, populations are protected in reserves near Cooma and at Letchworth, near Queanbeyan. Species with small and isolated populations and extremely restricted distributions, such as the Grassland Earless Dragon, are more vulnerable to environmental disturbances such as wildfires and drought.

Areas of habitat for both populations of the Grassland Earless Dragon in the ACT are subject to development proposals. In the Majura Valley, proposals include airport taxiway extensions and new road and railway routes, all of which are located within Grassland Earless Dragon habitat. In the Jerrabomberra Valley planning studies have identified grassland habitat suitable for nature reserves and the ACT Government is establishing these as land becomes available.

Maintenance of suitable habitat is essential for the long-term conservation of the species. Key habitat for the Grassland Earless Dragon appears to be well-drained natural temperate grassland that is relatively undisturbed and minimally pasture-improved, preferably with a grass sward that is relatively short (around 10 cm high), open in structure or patchy. The species has also been recorded in adjacent *Austrostipa* dominated grassland with low floral diversity that has been modified by pasture improvement and weed invasion. Even within areas of apparently suitable habitat the occurrence of the species is patchy, suggesting a more subtle relationship between the species and its grassland habitat (Robertson and Cooper 2000).

Land management practices that appear to be compatible with maintaining the habitat of the species include grazing by stock at low intensity (such as occurs in the Jerrabomberra Valley), grazing by kangaroos (Majura Training Area) and regular mowing to a height of 10 cm (Canberra Airport). Where the species has persisted despite periods of more intense grazing, it is likely that the availability of shelter such as rocks and arthropod (spider) burrows has been critical. The species has been recorded using an area the year following a fire (Nelson *et al.* 1998) and during subsequent years (Evans and Ormay 2002). It is probable that infrequent patchy burns in grassland habitat are not a threat to the species, despite some mortality that may occur during the fire. However, widespread fires that affect all or most of the habitat or a fire regime that results in long-term changes in habitat structure are likely to pose a threat to the remaining fragmented populations.

Grassland Earless Dragons shelter within grass tussocks, beneath rocks and in burrows made by arthropods. In the ACT, Grassland Earless Dragons commonly use arthropod burrows, though it is not known whether the availability of these burrows is linked to abundance of the species.

Residential developments close to Grassland Earless Dragon habitat are likely to contribute to disturbance (vehicle traffic, weeds, increased visitation in reserves by people and dogs) and increase the risk of predation by uncontrolled roaming of domestic cats. Minimization of these impacts will depend on responsible pet ownership or stronger controls and, where possible, buffer areas between residential development and grassland habitat.

CONSERVATION OBJECTIVES

1. Protect in perpetuity several viable populations of the Grassland Earless Dragon in secure native grassland habitat across the range of the species in the ACT.
2. Maintain the potential of the species for evolutionary development in the wild.

CONSERVATION ACTIONS

See s. 2.3.6.

Threatened Species: Striped Legless Lizard (*Delma impar*)

The Striped Legless Lizard (*Delma impar*) is listed as threatened in the ACT, NSW, Victoria and nationally (Table 2.6). This small, snake-like lizard is known only from scattered locations in south-eastern Australia, mostly from the ACT region and Victoria (Melbourne region). It is a grassland specialist, occurring primarily in lowland native grasslands. A more detailed description of the species and its ecology is given in Appendix 5.1. The locations of the known occurrences of this species are shown in Figures 2.3–2.7 (at end of Chapter 2).

THREATS

In common with other threatened grassland animal species, the main threats to the Striped Legless Lizard are the continued loss and fragmentation of its grassland habitat due to agricultural, urban and industrial development and degradation of habitat through changed grazing intensity, pasture improvement, weed invasion, changed fire regimes and impacts of stock. Other threats include the impacts of predators (such as cats, foxes and birds of prey) and direct human disturbance.

Prior to European settlement the habitat for the Striped Legless Lizard appears to have been mostly contiguous. This habitat is now fragmented, such that the probability of movement between the four disjunct areas supporting the species (Gungahlin, Yarramundi Reach, Majura Valley and the Jerrabomberra Valley) is low. The population at Yarramundi Reach, the smallest of these habitat areas, may recently have become extinct. Only one population is protected (Gungahlin grassland reserves). Species with small and isolated populations, such as the Striped Legless Lizard, face increased vulnerability to environmental disturbances such as wildfires and drought.

Some areas of habitat for two populations of the Striped Legless Lizard in the ACT are subject to development proposals. In the Majura Valley proposals include new road and railway routes and in the Jerrabomberra Valley areas of habitat are part of a study to identify potential future land uses, including nature conservation.

Maintenance of suitable habitat is essential for the long-term conservation of the species. Key habitat for the Striped Legless Lizard appears to be native grasslands dominated by perennial, tussock-forming grasses such as Kangaroo Grass *Themeda triandra*, spear grasses *Austrostipa* spp. and wallaby grasses *Austrodanthonia* spp. The species is also found in some adjacent areas dominated by exotic grasses. An important habitat characteristic appears to be tussock structure, though little is known about the way in which its habitat is used. Grazing by stock at low intensity (such as occurs in the Jerrabomberra Valley) or kangaroos (Majura Training Area) appears to be compatible with maintaining the habitat of the species. Some areas where the species persists are thought to have had low to moderate levels of agricultural disturbance in the past. It has been suggested (Coulson 1990; Dorrough 1995) that more intensive land-uses, such as ploughing, may be incompatible with the survival of the species.

There is a paucity of information on the effect of fire and fire regimes on this species. It is probable that infrequent patchy burns in grassland habitat are not a threat if the tussock grass structure is retained after the fires. However, widespread fires that affect all or most of the habitat or a fire regime that results in long-term changes in habitat structure (such as loss of tussock structure) are likely to pose a threat to the remaining populations.

Residential developments close to Striped Legless Lizard 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. Minimization of these impacts will depend on responsible pet ownership or stronger controls and, where possible, buffer areas between residential development and grassland habitat.

CONSERVATION OBJECTIVES

1. Protect in perpetuity several viable populations of Striped Legless Lizard in secure native grassland habitat across the range of the species in the ACT.
2. Maintain the potential of the species for evolutionary development in the wild.

CONSERVATION ACTIONS

See s. 2.3.6.

Threatened Species: Golden Sun Moth (*Synemon plana*)

The Golden Sun Moth (*Synemon plana*) is listed as threatened in the ACT, NSW, Victoria and nationally (Table 2.6). This medium-sized moth is a grassland specialist, preferring a subset of native grasslands that have a higher proportion of short-growing wallaby grasses (*Austrodanthonia* spp.). The species derives its name from the bright orange hind-wings of the female and the flight of adults, which is restricted to sunny spring and summer days. Its distribution has contracted to only scattered locations in south-eastern Australia (Clarke and Dear 1998). Genetic differences between ACT, NSW and Victorian populations suggest historical isolation, whereas relatively less genetic difference amongst ACT populations suggests recent fragmentation (Clarke and O'Dwyer 1998). A more detailed description of the species and its ecology is given in Appendix 5.3. The locations of the known occurrences of this species are shown in Figures 2.3–2.7 (at end of Chapter 2).

THREATS

In common with other threatened grassland animal species, the main threats to the Golden Sun Moth are the continued loss and fragmentation of its grassland habitat due to agricultural, urban and industrial development and degradation of its habitat through changed grazing intensity, pasture improvement, weed invasion, changed fire regimes and impacts of stock.

Grasses suitable for the species dominate only a subset of the remaining natural temperate grassland. The habitat of Golden Sun Moth is extremely fragmented and though the species is able to fly, movement between habitat patches is likely to be severely impeded (particularly for the less mobile female) by unsuitable habitat and urban areas. In the ACT, approximately 25% of grassland patches where the species is known to occur are protected in reserves. Some areas of habitat for Golden Sun Moth in the ACT are subject to development proposals.

Maintenance of suitable habitat is essential for the long-term conservation of the species. Key habitat for the Golden Sun Moth appears to be natural temperate grassland dominated by low-growing wallaby grasses. However, many of its habitat requirements are still not known, e.g. the proportion of suitable wallaby grasses that make natural temperate grassland suitable habitat. Invasion by weeds is likely to be a major threat to habitat quality because of the requirement for vegetation of a certain species composition. Invasion by weeds and other species has already contributed to a decline in habitat quality in some areas and in some cases has resulted in loss of habitat. Exotic species such as Phalaris or Canary Grass (*Phalaris aquatica*), Paspalum (*Paspalum dilatatum*), Serrated Tussock (*Nassella trichotoma*), Chilean Needle Grass (*Nassella neesiana*), Brome Grasses (*Bromus* spp.), Wild Oats (*Avena* spp.), Clovers (*Trifolium* spp.), Flatweed (*Hypochoeris radicata*), Fescue (*Festuca elatior*) and Plantain (*Plantago lanceolata*) pose a continuing threat to surviving areas of native grasslands dominated by wallaby grasses.

The native grasslands currently dominated by wallaby grass and harbouring the Golden Sun Moth are subject to some low intensity management activities that apparently benefit low growing wallaby grasses and hence maintain habitat quality for the species. These activities include grazing by stock or native animals at low intensity, or regular mowing (Canberra International Airport). Indeed, light grazing may have increased areas of native grassland dominated by wallaby grasses. Cessation or modification of these management regimes may lead to a change in grassland composition or structure and possibly degradation of habitat for the Golden Sun Moth. More intensive agricultural practices involving ploughing, application of fertiliser, sowing of introduced pasture species or cultivation are destructive to native grasslands.

It is probable that infrequent patchy burns in grassland habitat are not a threat to the species, particularly at times when most of the population exists in its subterranean larval stages. However, there are observations suggesting that numbers may fall in years following fire before building up again. As larvae, Golden Sun Moth feed on the underground reserves of plants and as these reserves are mobilised to produce above ground growth following fire, their availability to the larvae are likely to be reduced. Widespread fires in the habitat when the adults have emerged in spring or summer could result in high levels of mortality. Frequent fires, or fire regimes that result in loss of wallaby grasses, are likely to pose a threat to the remaining populations of Golden Sun Moth. There is a paucity of information on what factors are responsible for determining the proportions of wallaby grasses in native grasslands.

Although several bird species are known to prey on the Golden Sun Moth, including introduced Starlings, there is no evidence that predators have contributed to the decline of the species.

CONSERVATION OBJECTIVES

1. Protect in perpetuity the existing viable populations of Golden Sun Moth in secure native grassland habitat across the range of the species in the ACT.
2. Maintain the potential of the species for evolutionary development in the wild.

CONSERVATION ACTIONS

See s. 2.3.6.

Threatened Species: Perunga Grasshopper (*Perunga ochracea*)

The Perunga Grasshopper (*Perunga ochracea*) is listed as threatened (vulnerable) in the ACT (Table 2.6). The cryptic species is a grassland specialist, preferring natural temperate grassland dominated by wallaby grasses (*Austrodanthonia* spp.), kangaroo grass (*Themeda triandra*) and *Stipa* spp. and has also been recorded in open grassy woodland. This stocky grasshopper has only rudimentary wings and is flightless. In the Canberra region, it is readily identified by a distinctive pale 'X' on its back. A more detailed description of the species and its ecology is given in the Appendix 5.4. The locations of the known occurrences of this species are shown in Figures 2.3–2.7 (at end of Chapter 2).

Threats

In common with other threatened grassland animal species, the main threats to the Perunga Grasshopper are continued loss and fragmentation of its grassland habitat due to agricultural, urban and industrial development and degradation of habitat through changed grazing intensity, pasture improvement, weed invasion, changed fire regimes and impacts of stock.

The Perunga Grasshopper had been recorded from only a few of the natural temperate grassland and open grassy woodland remnants in the ACT, suggesting that only a subset of native grassland appears to be suitable habitat for the species. The habitat of the Perunga Grasshopper is extremely fragmented and movement between habitat patches is likely to be severely impeded because the species is flightless. The ability of the species to recolonise isolated patches following localised extinction is therefore likely to be limited. In the ACT, approximately 30% of grassland patches where the species is known to occur are protected in reserves. Some areas of habitat for the Perunga Grasshopper in the ACT are subject to development proposals.

Maintenance of suitable habitat is essential for the long-term conservation of the species. Key habitat for the Perunga Grasshopper appears to be natural temperate grassland dominated by wallaby, kangaroo and spear grasses with forb food plants located in the inter-tussock spaces. Grass tussocks are used also to escape predators. The importance of dense tussocks for invertebrate shelter spaces during low temperature conditions such as frost have been highlighted by Bossenbroek *et al.* (1977). Nymphs of another ACT species, the Wingless Grasshopper *Phaulacridium vittatum*, seek shelter in tussocks from wind and low temperatures (Clark 1967). In contrast to most other grasshopper species in the ACT, including the Wingless Grasshopper, nymphs of the Perunga Grasshopper are present during winter, and grass tussocks may be essential for protection against low temperatures.

Invasion by exotic plants is a major threat to the floristic composition of natural temperate grasslands and is therefore likely to be a threat to habitat quality for Perunga Grasshopper. However, the ecological requirements of the species are still poorly understood and the effect of weed invasion on habitat and food plants of Perunga Grasshopper is unknown.

The species has persisted in areas that have been lightly grazed or regularly mown (e.g. Canberra International Airport, Belconnen Naval station), suggesting that these land management practices are compatible with the maintenance of habitat for the species. More intensive agricultural practices involving ploughing, application of fertiliser, sowing of introduced pasture species or cultivation are destructive to native grasslands. The effect of fire on the species or its key habitat parameters is not well understood. It is probable that infrequent patchy burns in grassland habitat are not a threat to the species. Frequent fires, or fire regimes that result in loss of wallaby grasses, kangaroo and spear grasses, or loss of food plants (forbs) are likely to pose a threat to the remaining populations of Perunga Grasshopper.

The effect that predators and parasites may have in reducing population numbers of Perunga Grasshopper is unknown. Parasitic wasps (*Scelio* spp.) in south-eastern Australia have been shown to regulate some populations of other acridid grasshoppers (Baker *et al.* 1996) and predators such as birds may reduce grasshopper populations as shown in other studies of grasshopper assemblages (e.g. Belovsky and Slade 1993).

CONSERVATION OBJECTIVES

1. Protect in perpetuity the existing viable populations of Perunga Grasshopper in secure native grassland habitat across the range of the species in the ACT.
2. Maintain the potential of the species for evolutionary development in the wild.

CONSERVATION ACTIONS

See s. 2.3.6.

2.3.6 Conservation Actions: Threatened Grassland Fauna Species in the ACT

The following conservation actions for threatened grassland fauna species (mostly undertaken by Environment ACT) are framed within the actions for the Strategy as a whole in Table 4.1.

INFORMATION

- Maintain alertness to the possible presence of threatened grassland fauna species when undertaking surveys in appropriate habitat. Although all large areas of potentially suitable habitat in the ACT have been surveyed, further surveys are required to determine more accurately the area of occupancy of populations.

  (Grassland Earless Dragon, Striped Legless Lizard, Golden Sun Moth)
- Collect information on the distribution of the **Perunga Grasshopper**. Limited information exists on the distribution of the species and abundance in

known sites of occurrence. Currently, no practical method exists for systematically surveying the distribution or abundance of this species and information so far has been obtained from opportunistic observations.

MONITORING AND RESEARCH

- Encourage, support, coordinate, and where practicable, undertake research into the biology and ecology of **Grassland Earless Dragon** and **Striped Legless Lizard** as the basis for managing the species and their habitats. More specifically, research and monitoring is required to better understand:
  - — seasonal home range area, habitat use (including daily shelter sites and over-wintering sites) and movements, based on sex and age;
  - — seasonal activity and behaviour, including intra-specific interactions, territoriality, dominance, reproductive behaviour;
  - — breeding requirements, oviposition sites, reproductive rates, survivorship, sources of mortality and dispersal;
  - — preferred food and availability;
  - — impact of barriers such as roads;
  - — land management practices compatible with, or required for, maintaining suitable habitat;
  - — sensitivity of habitat to trampling or other potential damage from multiple use;
  - — susceptibility to fires and seasonal effects, optimum fire regimes, value and use of firebreaks;
  - — efficient methods for monitoring abundance, absolute population size and relationship to trapping indices, long-term population trends and magnitude of seasonal/annual fluctuations; and
  - — relative importance of predation by native, feral and domestic animals.
- Encourage, support, coordinate, and where practicable, undertake research into the biology and ecology of **Golden Sun Moth** and **Perunga Grasshopper** as the basis for managing the species and their habitats. More specifically, research and monitoring is required to better understand:
  - — biology: life cycle, reproductive rates, survivorship, sources of mortality and dispersal;
  - — habitat requirements of **Golden Sun Moth**: relationship to wallaby grasses and other flora, subterranean larval stage requirements, oviposition sites;
  - — micro-habitat requirements of **Perunga Grasshopper**: relationship to floristic composition and habitat structure, oviposition sites, soil requirements, nymph stage requirements;
  - — diet and food availability for **Perunga Grasshopper**, possible competition from abundant grasshoppers such as *Phaulacridium vittatum*;
  - — ability to move between fragmented habitat;
  - — genetic variability, minimum viable population size;
  - — land management practices compatible with, or required for, maintaining suitable habitat, including grazing, mowing and soil disturbance;
  - — susceptibility to fires and seasonal effects, optimum fire regimes, value and use of firebreaks;
  - — efficient methods for monitoring abundance, absolute population size, long-term population trends;
  - — effect of predators on population sizes.
- Continue to monitor habitat (vegetation composition) and **Golden Sun Moth** populations at major sites, including impacts of management practices.
- Continue to monitor habitat (vegetation composition) at known **Perunga Grasshopper** locations, including impacts of management practices, particularly grazing.

PROTECTION AND MANAGEMENT

- Encourage management to be undertaken in an adaptive framework, and facilitate the incorporation of research results into management of species and their habitats.
- Seek protection of key habitat known to support viable populations of threatened species across their range in the ACT, noting that:
  - — at present there is insufficient known about what constitutes a viable population of **Grassland Earless Dragon**, **Striped Legless Lizard**, **Golden Sun Moth**, **Perunga Grasshopper**;
  - — information on the distribution and abundance of **Perunga Grasshopper** in the ACT is incomplete;
  - — much of the known habitat for **Grassland Earless Dragon** and **Striped Legless Lizard** is on land under Commonwealth control;
  - — some of the known habitat for **Golden Sun Moth** and **Perunga Grasshopper** is on land under Commonwealth control.
  - — some areas of degraded native pasture or exotic pasture provide habitat for **Grassland Earless Dragon** and **Striped Legless Lizard**, or serve as buffers and habitat connections.

REGIONAL AND NATIONAL COOPERATION

- Maintain links with, and participate in, regional and national recovery efforts for threatened grassland fauna species to ensure that conservation actions are coordinated with regional and national programs.
- Liaise with interstate agencies involved in protection and management of threatened and uncommon grassland fauna species with the aim of increasing knowledge of their biology, and habitat and conservation requirements

2.3.7 Conservation Actions: Uncommon Grassland Fauna Species in the ACT

Species not listed under ACT legislation as vulnerable or endangered may be also of conservation concern and it is important that their status be monitored over time and threats minimised. Some animal species in native grassland are naturally rare or have become uncommon due to clearance or disturbance. Some species may also be considered to be 'declining', if there is a suspected or recorded decrease in population numbers (population decline).

Grassland species that are uncommon in the ACT region include Pink-tailed Worm Lizard (listed as threatened nationally), Canberra Raspy Cricket, Lewis's Laxabilla, Key's Matchstick Grasshopper, Shingleback Lizard, Stubble Quail, Brown Quail, Singing Bushlark and Brown Songlark. These species are uncommon because they are either at the margin of their distribution, they occur naturally at low density or they have declined in abundance. Some of these species are of conservation concern because declines (in the ACT or elsewhere) may be continuing and because small populations tend to be more vulnerable to disturbance. The conservation status of uncommon species needs to be considered in a regional context. The ACT and areas immediately to the east near Queanbeyan and in the Yarrowlumla Shire have been better surveyed than the region as a whole (Rehwinkel 1997).

CONSERVATION OBJECTIVE

1. Uncommon fauna species in ACT natural temperate grassland are maintained in viable populations in perpetuity.

CONSERVATION ACTIONS

The following conservation actions for uncommon grassland fauna species (mostly undertaken by Environment ACT) are framed within the actions for the *Strategy* as a whole in Table 4.1.

INFORMATION

- Maintain alertness to the possible presence of uncommon grassland fauna species when undertaking surveys in appropriate habitat.
- Maintain a database of known occurrences and abundance of uncommon grassland fauna species to enable analysis of changes in distribution and abundance.

MONITORING AND RESEARCH

- Maintain a watching brief on ACT populations of uncommon grassland fauna species and evaluate their conservation status in a regional context.
- Facilitate and encourage research that will provide information on status of uncommon grassland fauna species and management requirements.

PROTECTION AND MANAGEMENT

- Seek to ensure known populations of uncommon grassland fauna species are protected from inadvertent damaging actions (e.g. by advising landowners and managers of their presence).
- Prepare management guidelines for uncommon grassland fauna species where necessary.
- Manage sites, and provide advice to other landowners and managers, to maintain optimum habitat (where known) for uncommon grassland fauna species.
- Consider nomination for ACT listing if uncommon grassland fauna species show evidence of local decline in extent and abundance.

REGIONAL AND NATIONAL COOPERATION

- Liaise with interstate agencies involved in protection and management of uncommon grassland fauna species with the aim of increasing knowledge of their biology, and habitat and conservation requirements.

3 Lowland Native Grassland: Planning and Management for Conservation

3.1

Recovery Planning for Lowland Native Grassland in the ACT

The *Lowland Native Grassland Conservation Strategy* builds upon earlier initiatives for grassland conservation in the ACT and region, and incorporates those currently underway. Implementation of a four year recovery plan for natural temperate grassland in the ACT (Wildlife Research Unit 1991, 1992) commenced in 1993 with funds from the Commonwealth Endangered Species Program and the Plan was subsequently supported for a further three years. The primary goal of that Recovery Plan was to reduce the threat to the ecological community. Achievements of the recovery program included the mapping and surveying of the floristics of ACT grasslands; ecological research on grassland floristics and some threatened plant and animal species; research on impacts of herbicides on selected native grasses; development of a management plan; establishment of a long-term monitoring program; compilation of a data base; and provision of seminars and educational materials (Sharp 1997, 1999; Sharp and Shorthouse 1996).

The management plan (Wildlife Research Unit 1994) prepared as part of the Recovery Plan process provided the first holistic management framework, guidelines and prescriptions for all the known natural temperate grassland areas in the ACT and threatened species found in the grasslands. It provided the basis for conservation management while survey, monitoring and research, in the ACT and elsewhere, built the information base to refine management approaches.

The achievements of the Recovery Plan (Wildlife Research Unit 1991) provided a substantial basis for defining the objectives of the Action Plan for natural temperate grassland prepared by Environment ACT, following declaration of the ecological community as endangered in the ACT (ACT Government 1997a). New developments under the Action Plan included establishing grassland reserves at Gungahlin and Dunlop and a Special Purpose Reserve at Mugga Mugga; signing of Memoranda of Understanding between Environment ACT and Commonwealth land management agencies in the ACT; undertaking surveys that have located new populations of threatened grassland species; completion of management plans for grassland reserves; preparation of management plans by agencies with whom Environment ACT has Memoranda of Understanding; management oriented research e.g. burning experiments; regional liaison on grassland conservation; weed surveys and weed control programs; contribution to the preparation and production of a grassland flora field guide for the Southern Tablelands (Eddy *et al.* 1998).

Regionally, Environment ACT has been closely involved with the 'Joint biodiversity survey of grassy ecosystems of the South Eastern Highlands project' (Rehwinkel 1997) that culminated in the *Planning Framework for Natural Ecosystems of the ACT and NSW Southern Tablelands* (Fallding 2002) as well as the *National Recovery Plan for Natural Temperate Grassland of the Southern Tablelands (NSW and ACT)* (Environment ACT 2005). Objectives and actions in the 2005 National Recovery Plan are complementary to those in this *ACT Lowland Native Grassland Conservation Strategy*. As a consequence of new surveys, altered management, and continuing development of Canberra, there have been a number of changes to the inventory of ACT grasslands.

3.2

Botanical Significance Rating (BSR)

A botanical significance rating system has been applied to the remaining lowland native grassland in the ACT. This system was based initially on analyses of data from Victorian grasslands (Stuwe 1986) and has been modified over time by Environment ACT (Wildlife Research and Monitoring) and relates to the responses of plant species to different levels of disturbance (Table 3.1). This system was applied also to the understorey of woodland sites in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a). A more detailed description of the ratings and of the species typical of different levels of disturbance in grassy ecosystems is provided in Appendix 1. Application of the botanical significance rating to ACT lowland native grassland sites is shown in Table 3.2.

3.3

Remaining Lowland Native Grassland in the ACT

Vegetation surveys were undertaken at all ACT native grassland sites in 2003–04 as part of the preparation of this *Strategy* and the data compared with data from surveys undertaken previously. As a result, a review of the condition, diversity and spatial extent of all sites was undertaken. Further information on the survey methods is in s. 2.1.3.

Sites may contain areas of native grassland in varying condition, and may include several floristic associations, areas of native pasture and areas of exotic vegetation (such as in drainage lines that are weedy and disturbed). Sites that contain no natural temperate grassland (native pasture and/or exotic pasture) are included in this *Strategy* where they contain populations of threatened species.

In Table 3.2 the land use, total area, the area of the major floristic associations, native pasture and the botanical significance ratings are listed for each site. At some sites, patches of grassland occur that have higher or lower botanical significance ratings than the majority of the site. The botanical significance ratings of these smaller patches are indicated in brackets. Sites that do not contain natural temperate grassland, but are known habitat for threatened species are indicated in italics.

The number of sites containing native grassland (which may or may not be assessed as natural temperate grassland) is 47, totalling 2172 hectares (Figure 2.2 and Table 3.2). Of these 47 sites, 42 (totalling 1534 ha) contain 991 hectares of natural temperate grassland (Botanical Significance Rating (BSR) 1–4, see Table 3.1). This represents about 5% of the estimated original area of 20 000 hectares. These sites also contain areas of native pasture (385 ha, BSR 5) and exotic grassy vegetation (157 ha). Vegetation on the other five sites is not assessed as natural temperate grassland because it lacks the native species diversity that is a characteristic of the ecological community in the ACT (see s. 2.1.5). These areas of native pasture (639 ha, BSR 5) provide habitat for some threatened grassland plants and animals and/or may be important buffers and corridors for native grassland species. As well as the grasslands listed in Table 3.2, there are small patches (less than 0.25 ha) of native grasses and in some instances, hardy native forbs such as the Common Everlasting *Chrysocephalum apiculatum* and

Table 3.1: Botanical Significance Rating (BSR) for Native Grassland

	BSR 1 Very High	BSR 2 High	BSR 3 Moderate	BSR 4 Low	BSR 5 Very Low	Exotic E
Diversity of native species	Very high	Very high	Medium	Low	Very low	Very low to none
Uncommon native species	Several to many	Several	Few	None	None	None
Disturbance tolerant native species	Several to many	Several to many	Many	Several (including some native forbs)	Several (mostly native grasses)	None
Cover of native grasses	High	High	High	High	High	Low to none
Cover of exotic species	Low	Low	Low to moderate	Low to moderate	Low to moderate	Moderate to high
Alteration due to disturbance	Minimal alteration	Some alteration	Moderate alteration	Much alteration	Substantial alteration	Severe to total alteration
Natural temperate grassland	Yes	Yes	Yes	Yes	No	No

Common Blue Bell *Wahlenbergia communis* scattered along some roadsides and through open space areas of Canberra.

3.3.1 Changes in Lowland Native Grassland Sites Since 1997

In spring 2003 all grassland sites were resurveyed, using a method that enables a detailed comparison between and within sites in regard to composition, condition and spatial distribution. This has resulted in a revision of the status and condition of the sites since they were reported in the original Action Plan for natural temperate grassland (ACT Government 1997a). There have been significant changes to some grassland sites in terms of size, botanical significance rating and condition. Changes to the area and number of sites identified as containing natural temperate grassland results from a number of factors. These include more accurate mapping, better information to guide the discrimination between primary grassland (natural temperate grassland) and secondary grassland (modified woodland), development of better methods of survey for identifying condition, identification of previously unknown sites and the loss of sites to development. Appendix 2 provides details of the changes that have occurred in grassland sites.

Overall, the amount of identified natural temperate grassland is about the same (approximately 1000 ha in 1997 as compared to 991 ha in 2005). A further 500 ha was identified in 1997 as being lower quality natural grassland. With further surveys having been undertaken, a total of 1180 ha of native pasture and exotic vegetation containing threatened species has been included in this *Strategy*.

Since 1997, five new areas of natural temperate grassland have been found. All are small (each less than one hectare in size), and together amount to 2.5 ha (Appendix 2 (1a)). Eight sites (97 ha) have been re-assessed as containing additional areas of natural temperate grassland (Appendix 2 (1b)). This is due to changes in condition at the site and also better application of condition analysis.

One site identified in the Action Plan as containing natural temperate grassland has been developed (GAP 4) and two other sites have been partially developed (a total loss of 8 ha (Appendix 2 (2a)). Parts of several sites have deteriorated beyond recovery through weed invasion or site disturbance resulting in a reduction in the size of the natural temperate grassland area (14 ha) (Appendix 2 (2b)). Another 145 ha have been reclassified from natural temperate grassland to native pasture or exotic vegetation as a result of the improved analyses undertaken in 2003. This has resulted in the exclusion of four sites previously identified as natural temperate grassland, and reduction in area at seven other sites (Appendix 2 (2c)). This includes two areas of grassland identified in Action Plan 1 as constituting the *Poa* floristic association. In the 2003 surveys these areas were assessed as being degraded native pasture, and therefore not representing the endangered ecological community.

Several secondary grasslands (totalling 102 ha) were previously misclassified as natural grasslands and are now included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a).

3.4

Conservation Planning for Lowland Native Grassland

As noted in s. 2.1, natural temperate grassland is one of Australia's most threatened ecosystems. In this context, the conservation of the remaining areas of lowland native grassland (including natural temperate grassland) is a critical task for national biodiversity conservation. The ACT retains significant remnants of the original extent of natural temperate grassland in the region; however, the small size and fragmented nature of the remaining grassland areas pose particular difficulties for conservation planning.

Canberra's growth as a city continues to exert significant development pressures on land in and around existing urban areas. Some land that is generally regarded as available for development may still retain natural features worthy of consideration for their potential contribution to the nature conservation estate or to enhancing the natural landscape of the city. Consideration needs to be given to the ecological, landscape and other values of the land so that an informed decision can be made on its future.

Management of grassland fragments to improve habitat qualities, to enhance ecological connectivity, or to increase the effective size of remnants will be an important management priority for some time to come. Linking grasslands with other natural ecological communities such as grassy woodlands, wetland areas and forests increases the overall conservation value of areas by building habitat heterogeneity in the landscape.

Planning for, and management of conservation areas in the ACT must take into account the potential impact of land uses and other activities on adjacent land and in some instances, on the same land. Compatible land uses or management practices will help to moderate

Table 3.2: Native Grassland in the ACT: List of Sites Grouped by Geographic Location

Name of each site by geographic area	Site No. (GAP)	Land use	Area (ha)	Floristic Association (NTG) Dominant grasses (native pasture)	Flor. Assn Area (ha)	BSR
GUNGAHLIN—Total native grassland area: 410.1 ha. Area of natural temperate grassland: 179.2 ha.						
Mulanggari Nature Reserve	GU01 (GAP 6)	Reserve	68.5	*Austrodanthonia* Wet *Themeda* Native pasture (*Austrodanthonia*) Native pasture (*Austrostipa*) Exotic vegetation	51.1 7.5 0.9 8.5 0.5	2(3)
Gungaderra Nature Reserve	GU02 (GAP 9)	Reserve	187.3	*Austrodanthonia* *Austrostipa* Wet *Themeda* Native pasture (*Austrodanthonia*) Native pasture (*Austrostipa*) Native pasture (*Poa*) Exotic vegetation	4.3 21.9 15.7 0.1 109.3 5.8 30.2	5 (2,4)
Crace Nature Reserve	GU03 (GAP 13)	Reserve	136.0	*Austrodanthonia* Dry *Themeda* Wet *Themeda* Native pasture (*Austrostipa*) Exotic vegetation	35.9 3.1 22.5 41.1 33.3	3(5)
North Mitchell	GU04 (GAP 10)	Vacant	15.9	*Austrodanthonia* *Austrostipa* Exotic vegetation	1.4 13.4 1.2	3(4)
Mitchell	GU05 (GAP 10)	Rural (agisted)	1.6	Dry *Themeda*	1.6	3
Belconnen Pony Club	GU06 (GAP 14)	Rural	0.3	*Austrodanthonia*	0.3	4
Wells Station Road	GU07	Roadside	0.2	*Austrostipa*	0.2	4
Nicholls	GU08 (GAP 8)	UOS	0.3	*Austrostipa*	0.3	4
MAJURA VALLEY—Total native grassland area: 641.3 ha. Area of natural temperate grassland: 208.9 ha.						
Majura Training Area	MA01 (GAP 28)	Defence	126.6	*Austrodanthonia* Wet *Themeda* Native pasture (*Austrostipa*) Exotic vegetation	106.9 6.8 5.8 7.1	2(1)
Air Services Beacon	MA02 (GAP 28)	Airport Services	10.7	Wet *Themeda*	10.7	2(4)
Canberra International Airport	MA03 (GAP 28)	Airport	203.6	*Austrodanthonia* Native pasture (*Austrostipa*) Exotic vegetation	73.6 62.9 67.1	3(1, 2,5)
'Malcolm Vale'*	MA04	Rural lease	155.4	Native pasture (*Austrostipa*)	155.4	5
Campbell Park	MA05 (GAP 27)	Defence	11.7	*Austrodanthonia* Exotic vegetation	10.9 0.8	3(2)
Majura West*	MA06	Rural lease	133.3	Native pasture (*Austrostipa*)	133.3	5
JERRABOMBERRA VALLEY—Total native grassland area: 697.1 ha. Area of natural temperate grassland: 267.4 ha.						
'Mugga Mugga'	JE01 (GAP 39)	Reserve	15.0	*Austrodanthonia* *Austrostipa*	1.4 13.7	4(3)
'Callum Brae'*	JE02 (GAP 36)	Rural lease/ Reserve	162.7	Native pasture (*Austrodanthonia*) Native pasture (*Austrostipa*)	89.3 73.4	5
'Woden Station'/ Jerrabomberra West Reserve	JE03 (GAP 36)	Reserve	116.9	*Austrodanthonia* *Austrostipa* Native pasture (*Austrostipa*)	62.8 52.4 1.7	3
Woods Lane	JE04 (GAP 37)	Roadside	10.3	Dry *Themeda*	10.3	3
'Woden Station' East/ Jerrabomberra East Reserve	JE05 (GAP 37)	Reserve	72.0	*Austrodanthonia* *Austrostipa* Native pasture (*Austrostipa*) Exotic vegetation	44.2 18.0 7.8 2.0	4(3)
Harman Bonshaw South *	JE06 (GAP 37)	Defence, Rural lease	105.7	Native pasture (*Austrostipa*)	105.7	5
Harman Bonshaw North	JE07 (GAP 37)	Defence, Rural lease	114.6	*Austrodanthonia* Native pasture (*Austrostipa*)	46.3 68.3	5(4)
'Cookanalla'*	JE08	Rural lease	81.5	Native pasture (*Austrostipa*)	81.5	5
Amtech	JE09 (GAP 35)	Vacant	18.0	*Austrodanthonia*	18.0	4
Tennant St, Fyshwick	JE10	Agisted	0.3	Dry *Themeda*	0.3	3

(Continued) ▶

Table 3.2: *(Continued)*

Name of each site by geographic area	Site No. (GAP)	Land use	Area (ha)	Floristic Association (NTG) Dominant grasses (native pasture)	Flor. Assn Area (ha)	BSR
BELCONNEN—Total native grassland area: 387.5 ha. Area of natural temperate grassland: 300.1 ha.						
Ginninderra Experimental Station	BE01 (GAP 2)	Research	19.4	Dry *Themeda* Exotic vegetation	18.9 0.5	4
Dunlop Nature Reserve	BE02 (GAP 3)	Reserve	81.9	*Austrodanthonia* Wet *Themeda*	77.0 4.9	3(2)
'Jarramlee'	BE03 (GAP 15)	Rural (agisted)	52.0	*Austrostipa* Wet *Themeda*	47.3 4.7	4(3)
Umbagong Park, Florey	BE04 (GAP 16,17)	UOS	15.5	*Austrodanthonia* *Austrostipa* Dry *Themeda* Native pasture (*Austrodanthonia*) Native pasture (*Themeda*) Exotic vegetation	0.8 0.2 8.0 1.2 0.6 4.7	4 (3,5)
Evatt Powerlines	BE05 (GAP 18)	UOS	1.1	Dry *Themeda*	1.1	3
Lake Ginninderra	BE06 (GAP 19)	UOS	1.9	*Austrodanthonia* Dry *Themeda*	0.1 1.7	3
Lawson Territory	BE07 (GAP 20)	Rural (agisted)	59.2	*Austrodanthonia* Dry *Themeda* Native pasture (*Austrostipa*) Exotic vegetation	2.2 1.1 46.9 9.1	5(3)
Lawson Commonwealth	BE08 (GAP 20)	Defence	120.3	*Austrodanthonia* *Austrostipa* Dry *Themeda* Wet *Themeda*	91.2 9.8 16.5 2.9	2 (3,4)
Kaleen east paddocks	BE09 (GAP 21)	Rural (agisted)	28.2	*Austrodanthonia* Native pasture (*Austrostipa*)	4.0 24.2	5(3)
Caswell Drive	BE10 (GAP 22)	UOS	5.8	Dry *Themeda* Wet *Themeda*	3.5 2.3	2
Glenloch interchange	BE11 (GAP 23)	UOS	2.2	Dry *Themeda*	2.2	2
CANBERRA CENTRAL and TUGGERANONG—Total native grassland area: 36.5 ha. Area of natural temperate grassland: 35.8 ha.						
CSIRO Headquarters, Campbell	CC01 (GAP 25)	CSIRO	3.0	Dry *Themeda*	3.0	3
Constitution Ave, Reid	CC02 (GAP 26)	UOS	0.7	Dry *Themeda*	0.7	3
St Johns Church, Reid	CC03	Urban Lease	0.9	*Austrodanthonia*	0.9	4
ACCC, Barton	CC04 (GAP 33)	Urban Lease	1.9	Dry *Themeda*	1.9	1
York Park, Barton	CC05 (GAP 34)	UOS	0.4	*Austrodanthonia*	0.4	4
Yarramundi Reach	CC06 (GAP 24)	UOS	21.2	*Austrostipa* Dry *Themeda*	16.4 4.8	4(3)
Lady Denman Drive, Yarralumla	CC07 (GAP 29)	Roadside	0.4	*Austrodanthonia*	0.4	3
Dudley St, Yarralumla	CC08 (GAP 30)	UOS	2.2	*Austrodanthonia* Wet *Themeda* Exotic vegetation	0.6 0.9 0.7	3
Kintore St, Yarralumla	CC09	Vacant	0.8	Dry *Themeda*	0.8	3
Novar St, Yarralumla	CC10 (GAP 31)	UOS	0.2	*Austrostipa*	0.2	4
Black St, Yarralumla	CC11 (GAP 32)	UOS	3.6	Dry *Themeda*	3.6	3
Isabella Pond, Monash	TU01 (GAP 38)	UOS	1.2	Dry *Themeda*	1.2	2
Total			**2172**			

Notes:
(1) Site No: In the *Strategy*, site numbers have been assigned to all native grassland sites (including sites containing natural temperate grassland and native pasture) to identify the geographic region in which they occur. The 'Site No.' column shows the GAP (Grassland Action Plan) location numbers from Action Plan 1 (ACT Government 1997a). The Site Numbers supersede the GAP numbers.
(2) UOS = Urban Open Space
(3) Floristic association: for explanation, refer to section 2.1.4.
(4) Natural Temperate Grassland (NTG) contains areas with a Botanical Significance Rating (BSR) of 1 to 4. Native Pasture has a BSR of 5 and does not meet the definition of the endangered ecological community (refer to section 2.1.8, Table 3.1). Where a site contains small patches of vegetation with a higher or lower BSR than the majority of the site, these ratings are indicated in brackets.
(5) *—Denotes native grassland sites that do not contain natural temperate grassland.

adverse external influences on nature conservation values. Conservation management supported by research, monitoring and community participation are identified as key actions for this *Strategy* (Table 4.1).

3.4.1 Conservation Planning Principles

In developing a systematic approach to conservation planning and strategic options for native grassland conservation in the Gungahlin area of the ACT, Williams et al. (1995, pp. 8–18) set out a number of steps each with associated conservation planning principles.

The steps are:

- set goals and objectives;
- assess knowledge of the species, communities and sites of concern;
- delineate possible areas for conservation and consider environmental inter-linkages;
- develop strategy options and management guidelines.

The conservation planning principles include:

- areas that have the highest conservation values should be protected;
- consideration of size (viability), diversity, representativeness, distinctiveness (rarity) and naturalness is required;
- replication of conservation areas in fragmented habitats is necessary as a precaution against catastrophic and/or unpredictable local extinction;
- integration of smaller systems within broader conservation systems increases their conservation value; and
- regional conservation planning based on remnants must consider the constraints and opportunities provided by the present and future land use patterns.

The ACT Government adopted this approach in 1995 when reviewing the planning for Gungahlin Town Centre. The principles and associated methodology were used to identify high priority areas for grassland conservation, based on vegetation qualities and habitat for threatened species. Subsequently three nature reserves were established in the Gungahlin area with the primary aim of protecting natural temperate grassland and habitat for the Striped Legless Lizard (*Delma impar*). Grazing management in these reserves has been altered to promote conservation values, with some success (see s. 3.6.3).

The *Lowland Native Grassland Conservation Strategy* recognises the importance of addressing the conservation needs of threatened, declining and/or uncommon plants and animals in an integrated way, and not separated from consideration of the ecological communities of which they are a part. An understanding of the key life history properties and habitat requirements of species, the dynamic processes operating within ecosystems, and the importance of connectivity in making fragmented communities more viable across a variety of local and regional scales are accepted as being essential to sound conservation planning. For highly fragmented communities such as natural temperate grassland, connectivity can often only be considered in terms of links to other ecological communities, which together build a network.

In order to bring together the information on grassland type, vegetation condition, habitat features and occurrences of threatened and declining flora and fauna species with the relevant conservation planning and management issues, the following attributes, derived from the principles outlined above, have been incorporated into the material that is the basis for Chapters 3 and 4 of the *Strategy*:

- **Regional context:** regional biodiversity conservation significance;
- **Ecological characteristics:** vegetation condition; resident populations(s) of threatened species; habitat heterogeneity;
- **Physical data:** size; area/perimeter ratio;
- **Landscape context:** connectivity with other native vegetation; altitudinal range; and
- **Planning and management:** compatible land uses within and adjacent to sites; potential for regeneration and restoration management.

3.4.2 Survey, Monitoring and Research

Williams *et al.* (1995) list the following additional principles for sound conservation planning:

(a) knowledge of key life history properties of species and dynamic processes within the ecological communities is essential (Principle 3);

(b) spatial scale is important when assessing the value of published knowledge of species and communities (Principle 4);

(c) common as well as rare species have a bearing on conservation planning (Principle 5);

(d) the quality of available data and therefore its value to conservation planning varies depending on its taxonomic and spatial resolution, seasonal biases and temporal representation (Principle 6).

SURVEYS

As described in s. 2.1.3 extensive vegetation surveys have been undertaken in native grassland sites in the ACT since 1991. While the majority of lowland native grassland sites in the ACT have been documented and surveyed, there may be smaller sites or more degraded sites that have not yet have been investigated. If new sites are identified, they will be surveyed, information added to the database of sites and actions undertaken that are consistent with this Strategy. The majority of sites have been surveyed on several occasions, providing information about changes resulting from seasonal conditions and management. Additionally, vegetation surveys have also been undertaken in conjunction with reptile trapping sites to provide more detailed information about immediate habitat.

All known threatened plant populations have been mapped and surveyed on several occasions, providing information on fluctuations in distribution and abundance.

While many sites in the Southern Tablelands in NSW have also been surveyed, these have been mainly restricted to government land. Consequently, there is incomplete information on which to make regional comparisons. However, there have been few areas of grassland of the same size as the larger ACT sites found to date in NSW.

Extensive fauna surveys were also undertaken in this period, focussing on threatened and uncommon grassland species, particularly reptiles (summarised up to 1996 in Rehwinkel 1997, pp. 48–53). Edwards (1994) surveyed lowland grassland sites for the Golden Sun Moth (*Synemon plana*). These surveys resulted in a good knowledge base for threatened species, but there is still limited knowledge of other species, especially invertebrates. More recent surveys include those for *Keyacris scurra* (Rowell and Crawford 1999) and grassland canopy insects (Farrow 1999) (see s. 2.3.3). Surveys carried out in association with annual monitoring have found new populations of some threatened species e.g. (a) Perunga Grasshopper at West Belconnen, Yarramundi Reach, Crace Nature Reserve, Campbell Park and Jerrabomberra West; (b) Button Wrinklewort at Crace Grassland Reserve and a more extensive population at Campbell Park.

MONITORING

Monitoring is vital to understanding trends in grassland communities and is an essential component of a sound approach to conservation management of native grassland. Long-term monitoring of the flora of the ecological community in the ACT commenced in 1993 under the Recovery Plan program (Sharp and Shorthouse 1996) and continues on an annual basis. Fourteen permanent monitoring sites have been established that include the main floristic associations and the range of land uses and management practices in the ACT. This long term monitoring is designed to identify slow, largely imperceptible changes in the flora of the ecological community. The monitoring results are entered into the grassland database held by Wildlife Research and Monitoring (Environment ACT), reported to the Flora and Fauna Committee, and are essential to devising and refining the management regimes for grassland areas.

Populations of threatened plant species are monitored annually and their condition assessed. In addition, Button Wrinklewort and Ginninderra Peppercress populations are assessed for abundance and distribution at two to five year intervals.

Populations of threatened animal species are monitored for their continued presence at grassland sites. Annual monitoring surveys are conducted for Grassland Earless Dragon, Striped Legless Lizard and Golden Sun Moth. In addition to monitoring the distribution of these species in grasslands, techniques are currently under trial to assess the feasibility of quantitatively monitoring changes in abundance. The lack of a practical field method for monitoring the presence/absence or abundance of the threatened Perunga Grasshopper means that information on the distribution of this species is obtained from incidental observations.

RESEARCH

The original Action Plan for Natural Temperate Grassland (ACT Government 1997a, p. 13) noted that the emphasis of ACT grassland research to date had been to improve knowledge of the distribution and ecology of grassland and selected (plant and animal) species. Implementation of the Action Plan required management-oriented research. There was also a need for research on the basic ecological requirements of selected grassland plants and animals, including threatened species. Subsequently, some research in both these directions has been undertaken and management has also drawn on research from grasslands elsewhere. A literature review on the role of grazing for conservation management of native grasslands has been prepared (Lunt 2005).

Research has been undertaken in the ACT and region on the ecology, taxonomy, survey methodology, management and conservation of grassland threatened species, especially reptiles (Rehwinkel 1997). The following is a brief summary of the research undertaken:

- Grassland Earless Dragon (*Tympanocryptis pinguicolla*): A reasonably good, basic knowledge of this species has been developed through research over the last decade including genetics/taxonomy (Scott and Keogh 2000; Smith 1994; Smith *et al.* 1999), ecology and conservation (Benson, 1999; Langston, 1996; Nelson 2004).
- Striped Legless Lizard (*Delma impar*): There has been less research on *Delma impar* and its life history remains largely unknown (Smith and Robertson 1999). Research on the biology/ecology of the species has been mostly undertaken in Victoria (Melbourne Zoo and University of Technology). ACT studies on the ecology of the species include those by Nunan (1995) and Osmond (1994).
- Perunga Grasshopper (*Perunga ochracea*): The behaviour and biology of this species has been documented by Rentz (1996). Stephens (1998) also studied aspects of its ecology. The dietary requirements of the species are not fully understood and no research has been undertaken on population sizes or specific predators.
- Golden Sun Moth (*Synemon plana*): Edwards (1994) documented ACT populations of this species and a population at York Park, Barton was surveyed over the period 1992–3 to 1994–5 (Cook and Edwards 1993, 1994; Harwood *et al.* 1995) (see Appendix 5.3). While the life history of *Synemon plana* is not fully understood, genetic research by Clarke (1999) has helped identify and determine the conservation significance of moth populations in the ACT. This research shows that ACT populations are genetically very similar, probably reflecting recent fragmentation. Maintaining or increasing population sizes is a major conservation issue for this species and this is directly related to maintaining and increasing the cover of the larval food plant, *Austrodanthonia*. Clarke and Dear (1998) documented the regional distribution of the species and their survey has also provided insights into the ecological parameters determining that distribution.
- Button Wrinklewort (*Rutidosis leptorrhynchoides*): Due to its high conservation profile within an endangered ecosystem, and its amenability as a research model, *Rutidosis leptorrhynchoides* has been the subject of considerable ecological and genetic research aimed at understanding the factors that limit population viability. Most of this is reviewed in Young *et al.* (2000). Issues and options for the genetic conservation of the species are contained in Young (2001).
- Ginninderra Peppercress (*Lepidium ginninderrense*): Almost nothing is known about the general biology of *Lepidium ginninderrense*, and there is a need for research into this basic information. Based on extrapolation from other genetic studies of rare plants and evidence of good seed set, Young (2001) suggests that the species may still contain significant genetic variation for broadly based seed collections to form the basis of a conservation strategy.

3.4.3 Protection

A primary objective of the *Strategy* is the establishment of a comprehensive, adequate and representative system of protection for grassland in reserves or by other measures where reservation is not practicable or desirable (see s. 4.2 and s. 4.3.1). Generally these areas will be those with the highest value in terms of meeting local, regional and national objectives. Assessment of conservation value includes concepts of size (viability), diversity, representativeness, distinctiveness (rarity), naturalness and habitat value. Given the small proportion of the estimated original extent of natural temperate grassland that still remains in the ACT, it is not possible for a comprehensive, adequate and representative system to conserve a predetermined proportion of the original ecological community. However, the principles can be adapted to the circumstances regarding ACT native grasslands and used to guide decisions relating to protection.

The objective is to establish, as far as is practicable, a system of reserves and other protected areas that is:

1. **Comprehensive:** It will include the full range of the five floristic associations identified for ACT natural temperate grassland.
2. **Adequate:** It will replicate ecologically viable natural grassland communities, species and populations.
3. **Representative:** It will reasonably reflect the biological diversity of the ecological community.

The conservation planning principles derived from Williams *et al.* (1995) (see s. 3.4.1) complement the above.

MEASURES FOR PROTECTION

Adequate protection of lowland native grassland sites in the ACT, including those that may be of low botanical significance rating but important animal habitat is critical to attaining the goals of this *Strategy*.

Sites with remnant native grassland in the ACT occur on land under a variety of tenures, including urban open space (generally Public Land under *The Territory Plan*), rural leasehold Territory Land, unleased Territory Land, and Commonwealth-owned and managed National Land. Grassland remnants are often small in size, and may be isolated from one another by areas used for urban, agricultural or other purposes. For some sites, the combination of small size, isolation and the impacts of adjacent land uses may preclude or severely limit prospects for their long-term viability, irrespective of protection or other conservation measures. Other sites may have good prospects for long-term viability, but are unavailable for formal inclusion in a reserve system due to land ownership or use.

Protection of sites on Territory land containing native grassland is achieved through the provisions of the *Land (Planning and Environment) Act 1991* and the *Territory Plan*. For National Land, Memoranda of Understanding with Commonwealth Government agencies have been established, however, these do not provide the same level of statutory protection afforded to those areas that are formally recognised by reservation as part of the nature conservation estate. The existing Memoranda of Understanding aim to ensure that sites with high conservation value are managed so as to maintain their conservation values in perpetuity while other compatible land uses, defined in each MOU, continue. There is also an obligation to consult if any change in land ownership or land use is contemplated. The provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) also apply where Commonwealth actions may have a significant impact on nationally listed threatened species or ecological communities (see s. 1.5.2)

Environment ACT will continue to work with the ACT Planning and Land Authority and the National Capital Authority to promote land uses in areas adjacent to grassland areas that are compatible with conservation objectives and to minimise any adverse impacts. In the context of the strategic objectives for protection set out in Table 4.1, the following are specific objectives:

- a core set of Territory Land sites that have the highest priority for conservation are protected in nature reserves (including the grassland reserves already established);
- Memoranda of Understanding (MOU) between Environment ACT, Department of Environment and Heritage, Department of Defence, National Capital Authority, and CSIRO for the protection and management of high conservation value native grassland on National Land, under the control of these Commonwealth agencies, are maintained; and MOUs with the National Transmitting Authority and Canberra International Airport are prepared and maintained;
- management agreements with the lessees of small sites with high conservation value are prepared and/or maintained (e.g. Australian Centre for Christianity and Culture, Barton).

3.4.4 Management

Management activities in grassland sites require a long-term strategic approach based on clear objectives that are developed from scientific principles. These principles are identified from scientific studies of the ecology of the native grassland community and of component species undertaken in the ACT and elsewhere in Australia. The basis for managing an area of grassland is a management plan (Eddy 2002) regardless of whether or not the preparation of such a plan is a statutory requirement e.g. for Public Land in the ACT. For more detail on native grassland management, see s. 3.7.

Development of a management plan is based on the identification of the dominant grassland and weed species at a site or location, information about any species of conservation concern, an understanding of drainage, soil patterns and past management of the site, activities that will be undertaken aimed at biodiversity conservation, and monitoring programs. There is limited knowledge about the long-term effects of management practices on grassland biodiversity, including the most appropriate forms of defoliation management. An adaptive management approach is therefore necessary (see s. 3.7).

Some investigation of the impacts of management practices on the biodiversity and dynamics of grasslands is being undertaken in the ACT. In general, previous management practices are continued at a site until alternative practices are deemed to better fulfil objectives. Options for management of plant biomass include grazing by domestic stock, mowing, slashing or burning. Herbicides are the main control method for weeds.

Native grassland sites may have other values in addition to the natural values associated with the ecological community. Examples of other values include Aboriginal and European cultural values. Management of other values is integrated into statutory management plans, and in some instances, may require separate protection or joint management arrangements. An important aspect of management planning for native grassland is the identification of community interest in both the grassland and the places where it occurs (AHC 2003). This *Strategy* identifies the Conservation Management Network approach as being the means to connect all those with an interest in the conservation management of native grassland (see s. 3.8.3 and Table 4.1).

As noted in s. 1.7, the *Lowland Native Grassland Conservation Strategy* is not a management plan and the forms that management plans take will vary according to land tenure, use and ownership. For nature reserves, grassland conservation is formally incorporated into the statutory management plans (see s. 1.7). For leased land, management advice is provided to landholders where native grassland is present on their land. Under the MOUs with Commonwealth agencies, it is the responsibility of landholders to prepare management plans that incorporate the conservation requirements for threatened species and the ecological community. Canberra Urban Parks and Places have developed management guidelines for all unleased urban sites that contain grasslands or threatened species, with the aim of maintaining their conservation values.

The remaining ACT grassland sites require management arrangements appropriate to their tenure and conservation goals. Management plans for individual sites need to take into consideration factors such as historical and current land uses and management, size, weed infestations, presence of threatened or uncommon species, surrounding land uses and vegetation (see s. 3.7.1). Priority for the development of management plans should be based on the significance of sites and the potential for threats to reduce conservation values. Management plans are being implemented at all grassland Nature Reserves (managed by the ACT Parks and Conservation Service), all sites managed by Canberra Urban Parks and Places, and land managed by the Department of Defence. The Capital Airport Group has prepared a grassland management strategy for the Canberra International Airport. Management actions being undertaken include weed control at sites managed by Commonwealth and Territory agencies. This is based on a priority list of weed species and areas developed by the ACT Weeds Working Group. Environment ACT regularly provides advice on grassland management to managers of grasslands on all tenures.

3.4.5 Ecological Restoration

Restoration means 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 reinstatement (AHC 2002). The success of restoration activities is likely to be inversely related to the degree of degradation of particular grasslands. Where grassland is fragmented, restoration may be considered as a means of increasing overall size, buffering and interconnection (Williams *et al.* 1995, p. 15, Principle 14). In particular, it is now possible to establish native grass swards, though establishment of other grassland species is less well understood. Weed control is a key management problem for restoration activities and supply of seed or plants of suitable provenance to maintain genetic integrity is an ongoing issue (Eddy 2002, p. 19).

It is not yet possible to recreate the grassland ecological community in areas where it has been wholly or mostly removed, nor is it possible to move a grassland community from one site to another.

The comments by Ross (1999, p. 8) on grassland restoration are pertinent:

> The uninformed view that native grasslands are relatively simple systems can encourage the notion that they can be easily re-created as a substitute for conservation of existing remnants. While there clearly is a role for restoration of existing remnants as part of overall management strategies, the 're-creation' of native grasslands is impossible (or at least unfeasible) with current funding, knowledge and technology. Accordingly, projects that attempt to 're-create' native grasslands are of low value in pursuing current conservation goals and objectives.

Restoration of the natural integrity of existing grassland areas is a higher priority than widespread replanting; however, replanting may be undertaken on a limited scale, for example:

- at sites where weed removal or other management has caused extensive bare areas;
- in areas designated as buffer zones;
- at selected roadside sites e.g. where adjacent land contains native grassland of conservation value and the road corridor could be a source of weed invasion; and
- at sites where there is an identified need to increase the population size of particular species of plants and/or animals for conservation purposes e.g. increasing the cover of suitable *Austrodanthonia* spp. in areas supporting *Synemon plana*.

This is an area for further research with economic opportunities. In particular there is scope to establish seed orchards in rural areas for species of both natural temperate grassland (grasses and forbs) and lowland woodland species.

Revegetation guidelines that provide information on the development of work programs appropriate to the types of revegetation that occur are currently being drafted (Butler, in prep.).

3.4.6 Key Characteristics of ACT Lowland Native Grassland Sites

In relation to conservation planning, key characteristics of the 47 remaining lowland native grassland sites in the ACT are:

(a) sites range from those that are small and isolated to large areas with high heterogeneity of habitat;

(b) sites are fragmented; and

(c) weeds have invaded all sites and this is a major on-going threat.

SIZE OF GRASSLAND REMNANTS

Native grassland sites range in size from less than one hectare to approximately 200 ha. Although 40% of the native grassland sites are small (19 are less than five hectares and nine of these, or 19% of sites, are less than one hectare), there are eleven sites (23%) over 100 hectares in size (Table 3.2).

Eight sites contain natural temperate grassland in moderate to good condition (mainly BSR 1–3) and are over 50 ha in size (Table 3.2). They are:

- Canberra International Airport (MA06) 204 ha
  BSR 3(1, 2, 5, E)
- Crace Nature Reserve (GU03) 136 ha
  BSR 3(5)
- Majura Training Area (MA01) 127 ha
  BSR 2(1)
- Lawson (Commonwealth) (BE08) 120 ha
  BSR 2(3, 4)
- 'Woden Station'/Jerrabomberra West Reserve (JE03) 117 ha
  BSR 3
- Dunlop Nature Reserve (BE02) 82 ha
  BSR 3(2)
- Mulanggari Nature Reserve (GU01) 69 ha
  BSR 2(3)
- 'Woden Station'/Jerrabomberra East Reserve (JE05) 72 ha
  BSR 4(3)

(Where a site contains small patches of vegetation with a higher or lower BSR than the majority of the site, these ratings are indicated in brackets.)

Remnant size is a critically important factor in conservation planning. Among those attributes positively correlated with size of habitat area are diversity of vegetation types, the likelihood of occurrence of rare or specialised habitats, the richness of plant and animal species, the size of populations and the sustainability of natural disturbance regimes. In particular, the maintenance of natural patch-dynamic processes in fragmented landscapes is critically dependent on the presence of areas of sufficient size to sustain a mosaic of habitats that correspond to different states (Bennett 1999, p. 15).

The integration of smaller remnants into larger conservation systems increases their conservation value (Williams *et al.* 1995, p. 15, Principle 15). Five grassland areas take the form of contiguous patches (Majura Valley East and West, Jerrabomberra East and West, and Lawson). These account for 1484 hectares or 68% of the 2172 hectares of native grassland in the ACT. Five sites connect with extensive areas of other native vegetation (Majura Valley East and West, Jerrabomberra Valley East and West, and Caswell Drive).

FRAGMENTATION OF GRASSLAND REMNANTS

Remaining areas of lowland native grassland in the ACT have survived largely by chance, following the earlier period of pastoral use of ACT lands and the later development of Canberra. Urban Canberra was built over much of the entirely treeless grassland identified by Pryor (1938). The distribution of the remnants is highly fragmented and further fragmentation, especially of the larger areas, still constitutes a major threat to the ecological community.

Some areas exist in an extensive matrix of developed land uses with no possibility of restoring connectivity (e.g. urban sites such Australian Centre for Christianity and Culture, Barton and York Park, Barton). Thirteen of the 47 sites are isolated within a highly modified urbanised landscape. With planned urban development in Gungahlin and Belconnen, another seven sites will become similarly isolated, resulting in almost half of all sites being in this situation.

The setting aside of areas for public institutions and government offices resulted in small grassland areas remaining in the Central National Area of Canberra (Frawley 1995). Examples include the Australian Centre for Christianity and Culture, Barton (1.9 ha) containing very high quality *Themeda* grassland, and York Park, Barton (0.4 ha), an *Austrodanthonia* grassland containing a population of the endangered Golden Sun Moth *Synemon plana*.

Other sites, though isolated to varying degrees from other grassland, are located close to other native vegetation e.g. lowland woodland. Important woodland/grassland interfaces occur at the Caswell Drive and Glenloch Interchange grasslands, Majura East and West and Jerrabomberra West. In some instances, there is potential to connect to other habitat. An example is the actual and potential connectivity from Black Mountain/Aranda Bushland (open forest)—

Aranda Bushland/Glenloch (lowland woodland, native grassland)—Yarramundi Peninsula (native grassland)—Lake Burley Griffin (riparian and aquatic communities).

The locations with large areas of grassland (Lawson, Majura Valley East and West, Jerrabomberra Valley East and West) have some internal fragmentation but still represent critical habitat for both grassland and some threatened plant and animal species. The conservation value of these areas may be enhanced by complementary management of linking areas even if these areas are not high quality natural temperate grassland, or by undertaking restoration activities (see 'Ecological Restoration' in s. 3.4.5). It is important to maintain the natural integrity of these areas by avoiding further fragmentation.

WEED INVASION

The proneness of grassland to weed invasion and ongoing threats are discussed in s. 2.1.7. Weed control is a key element in conservation planning and management of remaining native grasslands (see s. 3.7.5).

The weed species that are of particular threat to the integrity of native grasslands are Serrated Tussock (*Nassella trichoma*), Chilean Needle Grass (*N. neesiana*), both of which are Weeds of National Significance, African Love Grass (*Eragrostis curvula*) and St Johns Wort (*Hypericum perforatum*). While there are many more species that are far more common in the grasslands, these species are highly invasive and can become extremely dense, sometimes forming monocultures, in even the least disturbed sites. Woody weeds, particularly Briar Rose (*Rosa rubiginosa*), are common in grasslands but these are relatively easy to control.

3.5

Assessing the Conservation Value of Native Grasslands

In order to be able to determine the conservation significance of each grassland site and, where appropriate, to compare sites with different characteristics, it is necessary to develop criteria that enable the available data to be evaluated. Criteria used to assess the conservation significance of sites have been developed from principles defined in Williams *et al.* (1995) (see s. 3.4.1).

The primary criteria used in this *Strategy* for native grassland sites are:

- botanical significance rating (s. 3.2, Appendix 1);
- size and shape (which affects viability, ability to withstand disturbance and species diversity); and
- significance as threatened species habitat (see below).

Secondary criteria that assist in assessing conservation value are:

- the presence of more than one grassland association or threatened species;
- integration of smaller areas into larger units;
- distribution throughout the ACT;
- connectivity with other native vegetation (e.g. lowland woodland).

Data and other relevant information for each grassland site against these criteria is summarised for each district in Tables 3.4–3.8. For the purposes of this *Strategy*, the size of an area is considered to be:

- large if it is greater than 100 ha;
- medium if between 100 ha and 10 ha;
- small if between 10 ha and 1 ha; and
- very small if less than 1 ha.

Grassland sites in the ACT (Table 3.2) have been grouped into three categories based on the above criteria. These are discussed in s. 3.5.1 to s. 3.5.3 (below).

ASSESSMENT OF THREATENED SPECIES HABITAT

Native grasslands provide important habitat for threatened species. Threatened species habitat is identified from known occurrences of species, relative population sizes/distributions and from knowledge of the biology and habitat requirements of species. In addition to native grassland habitat, other areas (including exotic pasture or degraded native pasture) may be important in providing connections between habitats or acting as buffers to adjacent incompatible land uses.

In this *Strategy*, habitat supporting a threatened species population that is considered viable in the medium to long-term (at least 50 years) is considered key habitat. As discussed by Williams et al. (1995), to assess the viability of populations requires extensive and detailed knowledge of population structure (e.g. sex ratio, age structure, age at first breeding, mortality rates) and the response of populations to disturbance. Response to disturbance or fragmentation is affected by genetic variation within and between populations, reproductive rates and dispersal patterns in relation to patches. Population viability also depends on the frequency of stochastic catastrophic events, such as bushfire, drought or disease outbreak.

Much of this information is not available for threatened species in the ACT, and consequently it is not possible to rigorously and quantitatively assess the long-term viability of their populations. Instead, a qualitative approach has been taken to assess key habitat, based on the following ecological principles relating to the viability of small populations:

- Larger populations are more likely to be viable in the long-term (more robust to demographic and environmental stochasticity and loss of genetic diversity).
- Larger areas of habitat with high 'area to perimeter' ratio (less 'edge' effect) are more likely to maintain their ecological condition in the long term (particularly if buffered from incompatible landuse) and are more likely to support a higher number of species.
- Higher quality habitat is more likely to support reproducing populations, and to buffer populations against poor seasonal conditions. For the threatened ACT grassland species, higher quality habitat is more likely to be grassland that is relatively less modified (i.e. higher BSR).

There is a clear connection between the principles relating to habitat (last two above) and principles relating to the conservation of vegetation communities. In addition to supporting viable populations, an area is considered to be key habitat if it supports a population that is important in terms of genetic diversity for a species.

3.5.1 Category 1: Core Conservation Sites

Sites in this category meet the following criteria:

- high botanical significance rating (BSR of 1 or 2, but may contain or adjoin areas of lower rating); or
- key threatened species habitat; or
- large sites (more than 100 ha) with a BSR of 3.

Nineteen sites in the ACT have been assessed as meeting these criteria. The total area of these sites is 1663 ha (comprising 808 ha of natural temperate grassland, 714 ha of native pasture, 141 ha of exotic pasture. The sites represent the core group of areas needed to ensure conservation of the best quality natural temperate grassland and the major habitats for grassland threatened species. They warrant the highest level of protection. The sites are (see also Figures 2.3–2.7):

- Majura Valley East (Training Area (MA01), Airport Services Beacon (MA02) and Canberra International Airport (MA03));
- Majura Valley West (Campbell Park (MA05) and Majura West (MA06))
- Jerrabomberra Valley East ('Woden Station' East (JE05), Harman Bonshaw South (JE06), Harman Bonshaw North (JE07));
- Jerrabomberra Valley West ('Callum Brae' (JE02) and 'Woden Station' (JE03);
- Lawson (Commonwealth) (BE08));
- Dunlop Nature Reserve (BE02); and
- Gungahlin grassland reserves (Mulanggari (GU01), Gungaderra (GU02), Crace (GU03)).

Four sites (totalling 11 ha) with a high BSR are each relatively small in size:

- Caswell Drive (BE10) and Glenloch Interchange (BE11):
  —These sites have a BSR of 2 and are contiguous with woodland, including Snow Gum Lowland Grassy Woodland.
- Australian Centre for Christianity and Culture, Barton (CC04):
  —This is the only site with a BSR of 1. Because of its low degree of disturbance and rarity, the site is considered to be of high conservation value even though it is a small site.
- Isabella Pond, Monash (TU01):
  —This small site has a BSR of 2.

For areas that are Territory Land, the appropriate level of protection is reservation under the *Land (Planning and Environment) Act 1991* (four sites totalling 474 ha are already protected in reserves). The ACT Government has identified a further two sites (totalling 177 ha) in the Jerrabomberra Valley as nature reserves. Sites managed by Canberra Urban Parks and Places are protected as Urban Open Space and are managed to maintain their conservation values. Where grasslands are located on National Land, Memoranda of Understanding with Commonwealth Government agencies have been established, though statutory reservation is desirable to ensure protection in the long term. MOUs cover 479 ha in five sites. For privately leased land (Australian Centre for Christianity and Culture, Barton; Canberra International Airport) protection provisions may be incorporated in lease conditions or other arrangements such as a Memorandum of Understanding.

3.5.2 Category 2: Complementary Conservation Sites

Sites in this category meet the following criteria:

—moderate botanical significance rating (BSR of 3, but may contain or adjoin areas of higher or lower rating); or

- threatened species habitat; or
- medium area sites (10–100 ha) and BSR of 4.

Grassland sites meeting these criteria are those with a history of greater modification than Category 1 sites (e.g. they exhibit reduced plant species diversity, loss of disturbance sensitive species and increase in disturbance tolerant species, and greater weediness) or those that do not contain key threatened species habitat. They are assessed as having a BSR of not higher than 3 as their long-term viability as conservation areas may be limited by virtue of their size, low area to perimeter ratio and/or impacts from surrounding land uses. Category 2 sites may contain threatened species habitat that is not key habitat, however, they may complement core conservation grassland, providing habitat and/or a buffer. Although populations of some threatened species occurring in these areas are small they are considered to be viable in the medium term.

Twenty-two sites in the ACT are assessed as being complementary conservation sites. The total area of these sites is 421 ha (comprising 175 ha of natural temperate grassland, 239 ha of native pasture, 7 ha of exotic pasture). The sites are (see also Figures 2.3–2.7):

- Rural sites:
  —Ginninderra Experimental Station (BE01) and 'Jarramlee' (BE03).
- Near-urban sites:
  —'Mugga Mugga' (Special Purpose Reserve) (JE01) and North Mitchell (GU04).
- Sites with threatened species, but not containing key habitat for those species:
  —York Park (CC05), St Johns Church, Reid (CC03), Lake Ginninderra (BE06), Constitution Ave, Reid (CC02), Woods Lane (JE04), Cookanalla (JE08), Amtech (JE09), Tennant St, Fyshwick (JE10), Malcolm Vale (MA04), and Yarramundi Reach (CC06).
- Isolated urban sites with BSR 3:
  —Umbagong (BE04), Evatt Powerlines (BE05), CSIRO Headquarters (CC01), Lady Denman Drive (CC07), Dudley St, Yarralumla (CC08), Kintore St, Yarralumla (CC09), Black St, Yarralumla (CC11) and Mitchell (GU05).

In addition to the above sites, important habitat for the Grassland Earless Dragon is located in degraded native pasture or exotic pasture surrounding Category 1 sites in the Jerrabomberra Valley (JE05, JE06, and JE07) (Figure 2.4). These areas do not contain natural temperate grassland, but are likely to provide a buffer for key habitat where the species is known to breed. In the case of Amtech where the Grassland Earless Dragon has been recorded, further work is required to determine whether the area should be retained or allowed to be developed.

Recognition and protection of these areas on Territory Land may be achieved through Public Land categories of the *Territory Plan* including Nature Reserve, Urban Open Space and Special Purpose Reserve. Thirteen, mainly small, grassland sites are located in Urban Open Space and one ('Mugga Mugga') in Special Purpose Reserve.

Activities permitted in these land use categories may be compatible with conservation of native grassland values, provided that appropriate conservation management is in place. In these cases maintenance of the conservation values of the site is the responsibility of the relevant ACT Government agency. Other similar land uses include road reserves and power-line easements.

For National Land, Memoranda of Understanding with Commonwealth Government agencies are appropriate. MOUs can embrace all native grasslands managed by these agencies, not only those that are core conservation sites. Land Management Agreements provide the primary means to achieve conservation management of these grasslands on rural leases.

3.5.3 Category 3: Landscape and Urban Sites

Category 3 sites have a lower conservation value than those in categories 1 or 2, but may still contribute to conservation of grassland biodiversity. They meet the following criteria:

- low to very low botanical significance rating (BSR of 4 or 5); and small to very small area (less than 10 ha); and
- may contain small populations of threatened species in marginal or fragmented habitat that is considered to be not viable in the medium to long term.

These sites tend to be very fragmented and have reduced viability as a grassland community. However, some have value as buffers or connections between higher conservation value sites, as landscape features within the urban fabric, or in providing opportunities for education or rehabilitation research.

Six sites in the ACT are categorised as landscape and urban sites. The total area of these sites is 88 ha (comprising 8 ha of natural temperate grassland, 71 ha of native pasture, 9 ha of exotic pasture). The sites are (see also Figures 2.4–2.7):

- Urban sites with BSR 4 or 5:
  —Lawson (Territory) (BE07), Novar St, Yarralumla (CC10).
- Isolated near-urban sites:
  —Kaleen East paddocks (BE09), Belconnen Pony Club (GU06), Wells Station Road (GU07), Nicholls (GU08).

OTHER AREAS INCLUDED IN CATEGORY 3

In addition to the above sites, there are areas of degraded native pasture or exotic pasture of insufficient quality to be included in the grassland inventory (Table 3.2), that contain records of threatened species. These areas are generally associated with higher quality native pasture or natural temperate grassland. Figures 2.3, 2.4, 2.5 and 2.7 show the distributions of threatened species habitat and their relationship to the various grassland types.

Where possible, sites with these characteristics should be retained and appropriately managed until their long-term future is determined. Each one needs to be assessed as part of the outline planning, environmental assessment and development approval process. Planning and management arrangements to protect and manage their natural values may include agreements with non-government landholders, property management agreements with rural lessees and protection of sites within the urban fabric.

These areas are:

- East Jerrabomberra (Block 2060 Jerrabomberra and adjoining Block 6 Section 53 Hume):
  —This area is situated between the Monaro Highway and JE06 (Figure 2.4). The area has records of the Striped Legless Lizard and forms a logical connection between habitat in east and west Jerrabomberra;
- East Jerrabomberra (Part of Block 49 Jerrabomberra):
  —This area is situated between JE06 and the ACT/NSW border (Figure 2.4) and is habitat for the Grassland Earless Dragon and to a lesser extent Striped Legless Lizard. It provides an opportunity to maintain a habitat connection across the ACT/ NSW border.
- West Majura (parts of Block 3 Section 9 and adjoining Block 2 Section 12 Pialligo):
  —Both sites are adjacent to Majura Road west of the airport (Figure 2.3). This area is also most likely to be habitat for the Striped Legless Lizard and provides an opportunity for a connection between grassland in east and west Majura.
- Gungahlin (Kenny):
  —An area of Striped Legless Lizard habitat in degraded native pasture east of Mitchell.
- Baptist Church (Parkes):
  —This area contains a small population of Button Wrinklewort.

3.5.4 Summary of Grassland Sites and Categories

The following table summarises the data on grassland type and area according to the three categories above (s. 3.5.1 to s. 3.5.3). Eighty-one per cent (808 ha) of the remaining natural temperate grassland meets the criteria for Category 1 sites (Core Conservation Sites) where there is a high level of protection in reserves and through Memoranda of Understanding.

Table 3.3: Grassland Types and Areas in Each Category of Grassland Sites in the ACT

	Hectares				
	No. of Sites	TOTAL	NTG	NP	EX
Category 1 (Core)	19	1663	808	714	141
Category 2 (Complementary)	22	421	175	239	7
Category 3 (Landscape and Urban)	6	88	8	71	9
Total	**47**	**2172**	**991**	**1024**	**157**

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **Ex**: Exotic

3.6

Planning and Conservation Issues for Lowland Native Grasslands and Threatened Species Habitats in the ACT

The areas of land in the ACT that contain remnants of the original natural temperate grassland and grassland habitat for species of conservation interest are located in five geographic areas: Gungahlin, Majura Valley, Jerrabomberra Valley, Belconnen, and Central Canberra. The only remaining site in Tuggeranong is included in the Central Canberra group. These areas are the remnants of the original valley floor distribution in the ACT of natural temperate grassland. Each geographic area, sub-units and the key species found in them are described in detail in sections 3.6.1 to 3.6.5.

Planning and conservation issues relevant to the remaining grassland are common across all or most locations and need to be considered regardless of the exact location. The issues are:

- ensuring the core conservation sites (Category 1) (see s. 3.5.1 and Table 3.2) are protected in perpetuity and other sites are afforded appropriate protection and conservation management consistent with their size, condition, location and tenure;
- avoiding, where possible, any further fragmentation of remaining sites through clearing for urban, industrial and infrastructure development and for agricultural purposes;
- providing for ecological connectivity where possible between separated sites, across common boundaries, and with other adjacent natural ecological communities (usually lowland woodland);
- ensuring that selection of protected areas takes into account any information about the genetic variability of remaining species populations;
- restoring (through revegetation or regeneration) patches of vegetation with a low botanical significance rating in natural temperate grassland sites;
- exploring opportunities for restoring substantially modified grasslands and habitats for threatened species;
- increasing the area of occupancy of threatened flora and fauna, particularly where these have small populations or restricted distributions; and
- taking into account the regional context of any grassland and habitat for threatened plants and animals.

3.6.1 Majura Valley

DESCRIPTION

The Majura Valley contains some of the most diverse and valuable areas of natural temperate grassland and habitat for threatened species left in the ACT (Figure 2.3, Table 3.4). The dominant floristic association is *Austrodanthonia* (191 ha), with a small area (17.5 ha) of Wet *Themeda*. Approximately 430 hectares of grassland habitat has been confirmed as supporting threatened species. The biodiversity significance of the area is recognised in the *Canberra Spatial Plan* (ACT Government 2004b). The existing Majura Road that will be upgraded in the future to parkway standard divides the valley into eastern and western sections. There has also been a proposal for a future railway connection from Sydney to the Canberra International Airport. This may be revived given the significant benefits for businesses in the ACT and surrounding NSW. Protection of remaining grasslands and their threatened species will be an important issue as these transport links are planned and constructed, and when subsequent development and employment opportunities are realised.

On both the eastern and western sides of the valley, natural grassland merges with Yellow Box–Red Gum grassy woodland. Woodland–grassland ecotones such as these were identified in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a) as being a priority for protection. The western example is more disturbed than the eastern one due to the intrusion of the Campbell Park offices, Northcott Drive and previous land management practices that have significantly reduced the area of natural temperate grassland. However, habitat for the Grassland Earless Dragon and other threatened species still exists along the woodland–grassland edge of Mt Ainslie Nature Reserve. Only about 12 ha of this area are assessed as being natural temperate grassland, but the extended area of native pasture contains habitat for the Grassland Earless Dragon and the Striped Legless Lizard.

Grassland habitat east of the Majura Road, including that at the Majura Training Area, the Canberra International Airport and Blocks 102 and 146 Majura (approximately 500 ha in total) is one of only a few large contiguous areas containing extensive samples of natural temperate grassland. The area contains *Austrodanthonia* and Wet *Themeda* floristic associations. These grasslands are highly diverse floristically and are habitat for five threatened species typical of natural grasslands (Button Wrinklewort, Striped Legless Lizard, Grassland Earless Dragon, Perunga Grasshopper and Golden Sun Moth).

Table 3.4: Majura Valley: Grassland Types and Conservation Significance

Majura Valley		Area (ha) and Grassland Type NTG, NP, E	Botanical Significance Rating	*Wet Themeda*	*Dry Themeda*	*Austrodanthonia*	*Austrostipa*	*Poa*	Grassland Earless Dragon	Striped Legless Lizard	Golden Sun Moth	Perunga Grasshopper	Button Wrinklewort	Comments	Conservation Category*
Majura Valley East (Majura Training Area)	MA01	113.7 NTG 5.8 NP 7.1 E	2(1)	6.8		106.9			K	K	K	✔	K	Links with extensive woodland	1
Majura Valley East (Air Services Beacon)	MA02	10.7 NTG	2(4)	10.7					K	K	K	✔		Surrounded on three sides by MA01	1
Majura Valley East (Airport)	MA03	73.6 NTG 62.9 NP 67.1 E	3 (1,2,5)			73.6			K		✔	✔		Contiguous with MA01	1
'Malcolm Vale'	MA04	155.4 NP							✔		✔			Contiguous with MA01	2
Campbell Park	MA05	10.9 NTG 0.8 E	3(2)			10.9			K	✔	✔	✔	✔	Links with woodland on Mt Ainslie and contiguous with MA06	1
Majura West	MA06	133.3 NP							K	✔	✔	✔		Links with woodland on Mt Ainslie and contiguous with MA05	1
Total Natural Temperate Grassland		**208.9**		**17.5**		**191.4**									
Total other threatened species habitat		**432.4**													

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **E**: Exotic; **K**: Key habitat; ✔: Species present. * Refer ss. 3.5.1–3.5.3.

Grasslands in the mid-valley floor, west Majura Road, and north of the Majura Training Area are now highly disturbed as a result of soil cultivation and cropping. One record of the Striped Legless Lizard near Majura Road might indicate that in former times the populations of this species (and probably others) were once joined. Maintaining or re-establishing such a link should be a long-term goal for conservation in the Majura Valley.

No natural temperate grassland areas of the Majura Valley have been destroyed or significantly degraded since publication of Action Plan 1 (ACT Government 1997a) although development at the Canberra International Airport has reduced the area of grassland. Surveys undertaken since then have revealed a population of the Striped Legless Lizard at Campbell Park, an extension of the known population of Button Wrinklewort at Campbell Park, and the presence of the Grassland Earless Dragon on Blocks 102 and 146 Majura, between the Training Area and Canberra International Airport. Development of runway infrastructure at the airport in 2001 reduced the area of grassland habitat and required the salvage of five specimens of Grassland Earless Dragon. Future planned works at the airport will have similar impacts.

PLANNING AND CONSERVATION ISSUES

In addition to the issues summarised above (s. 3.6), the following are specific to the Majura Valley:

- Resolving planning proposals, transport and other infrastructure development for the airport and its surrounds, including identifying boundaries of areas to be protected for nature conservation or managed with nature conservation as a primary objective.

  The ACT Planning and Land Authority is undertaking a detailed planning study of the north-south employment corridor along Majura Road (Majura Valley) and the Monaro Highway to the Hume industrial area (Jerrabomberra Valley). The study will identify areas that are significant for biodiversity conservation as well as identifying other environmental issues.
- Maintaining the integrity of the remaining areas and improving the condition of grassland habitats by selective revegetation and weed control, avoiding fragmentation, degradation and impacts from adjacent developments.
- Maintaining ecological connectivity between grasslands and adjacent woodlands at both the eastern and western valley fringes, and if feasible across the Majura Valley.
- Restoring habitat for threatened species on land adjacent to areas with high conservation value. This is particularly relevant to Blocks 53, 102 and 146 Majura adjacent to the Majura Training Area (MA01), to Blocks 687 and 655 near Campbell Park offices and to the Canberra International Airport (MA03).
- Implementing Environment Management Plans for those areas owned or occupied by private organisations or Commonwealth government agencies (Canberra International Airport (Capital Airport Group), Majura Training Area (Department of Defence)).

3.6.2 Jerrabomberra Valley

DESCRIPTION

The Jerrabomberra Valley is similar in many ways to the Majura Valley, with large and significantly diverse areas of natural temperate grassland, a range of threatened flora and fauna, and examples of the grassland–woodland interface. The dominant floristic association is *Austrodanthonia* (172 ha) with *Austrostipa* (84 ha) and Wet *Themeda* (11 ha). Another 430 ha are grassland habitat containing threatened species. The valley is also divided north-south by a major transport corridor, the Monaro Highway.
When considering planning and conservation issues in this valley, it is important to recognise similar natural areas in adjacent land in NSW, namely the Letchworth Nature Reserve and rural land known as 'The Poplars', separated from the ACT by the railway and railway easement.

West of the Monaro Highway is a large area (280 ha) of natural temperate grassland and other grassland habitat, with one of the largest remaining populations of Grassland Earless Dragon. Other threatened species found here are the Perunga Grasshopper, Golden Sun Moth and the Pink-tailed Worm Lizard (*Aprasia parapulchella*) (listed as Vulnerable under the EPBC Act (Cwlth)). This grassland was identified in Action Plan 1 (ACT Government 1997a) as being a core area for natural temperate grassland protection. In the south-western and north-western parts of the area, grassland merges with lowland woodland.

East of the Monaro highway, remnant patches of natural temperate grassland (119 ha) are surrounded by native pasture (the two categories totalling 374 ha). This area provides habitat for the Striped Legless Lizard and Grassland Earless Dragon and there are several populations of the Button Wrinklewort (in Woods Lane and Harman Bonshaw North, as well as in Letchworth and 'The Poplars'). Previous land use associated with the Defence communication facility is likely to have resulted in a management regime conducive to the survival of these species, particularly in those areas where there are communication aerials.

Table 3.5: Jerrabomberra Valley: Grassland Types and Conservation Significance

Jerrabomberra Valley		Area (ha) and Grassland Type NTG, NP, E	Botanical Significance Rating	Wet *Themeda*	Dry *Themeda*	*Austrodanthonia*	*Austrostipa*	*Poa*	Grassland Earless Dragon	Striped Legless Lizard	Golden Sun Moth	Perunga Grasshopper	Button Wrinklewort	Comments	Conservation Category*
'Mugga Mugga'	JE01	15.0 NTG	4(3)			1.4	13.7								2
'Callum Brae'	JE02	162.7 NTG	5						K					Contiguous with JE03 Links to woodland	1
'Woden Station'	JE03	115.2 NTG 1.7 NP	3			62.8	52.4		K		K	K		Links to woodland	1
Woods Lane	JE04	10.3 NTG	3		10.3								✔	Contiguous with JE05 and Links to Letchworth NR (NSW)	2
'Woden Station' east	JE05	62.2 NTG 7.8 NP 2.0 E	4(3)			44.2			K	K	K	✔		Links to Letchworth NR (NSW)	1
Harman-Bonshaw South	JE06	105.7 NP	5						K	K	✔	✔		Contiguous with JE05	1
Harman-Bonshaw North	JE07	46.3 NTG 68.3 NP	5(4)			46.3			K	K		✔	✔	Contiguous with JE06	1
'Cookanalla'	JE08	81.5 NP	5						✔						2
AMTECH, Fyshwick	JE09	18.0 NTG	4			18.0			✔	✔		✔		Isolated by major roads	2
Tennant St, Fyshwick	JE10	0.3 NTG	3		0.3								✔	Isolated	2
Total Natural Temperate Grassland		**267.4**			**10.6**	**172.7**	**84.1**								
Total other threatened species habitat		**429.7**													

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **E**: Exotic; **K**: Key habitat; ✔: Species present. * Refer ss. 3.5.1–3.5.3.

Providing for ecological connectivity between the high value areas east and west of the highway, across the ACT–NSW border and between grasslands and woodlands is a particular issue for the Jerrabomberra valley. The *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a) has also identified the importance of these areas for animal movements and maintaining ecological connectivity between and beyond the Majura and Jerrabomberra valleys. The ACT Government has identified Blocks 6 and 12 of Section 18 Jerrabomberra in the southern part of the valley as the location for the ACT prison, subject to environmental and other assessments. This is expected to provide an opportunity to maintain some habitat suitable for east-west connectivity between 'Woden Station' east and the prison. Protection of land known as Mikes Hill adjacent to the Letchworth Nature Reserve and 'The Poplars' provides another opportunity to maintain connectivity and achieve an enlarged area of occupancy for the Grassland Earless Dragon. There are several locations elsewhere in the valley where connectivity between grassland areas should be a consideration as planning and development proposals are progressed into specific developments.

In 2000 the ACT Government ruled out intensive development of the Jerrabomberra Valley to ensure the protection of its environmental values. The ACT Planning and Land Authority has undertaken a planning study of the valley that will inform government decisions about detailed development and conservation opportunities. The study identifies key areas where protection of nature conservation values will be the major objective. In order to ensure that habitat for threatened species is maintained on land leased for rural purposes, the Conservator of Flora and Fauna has issued Conservator's Directions, pursuant to s. 47 of the Nature Conservation Act 1980. These directions require landholders to obtain the prior agreement of the Conservator before carrying out activities (e.g. cultivating, fertilising, cropping) that may damage the conservation values of the land. During 2005, new grassland reserves will be established east and west of the Monaro Highway. They will be the first to ensure protection of Grassland Earless Dragon habitat in the ACT.

PLANNING AND CONSERVATION ISSUES

- Establishing the new nature reserves announced in July 2004 within the context of overall planning for the Jerrabomberra Valley.
- Maintaining the integrity of remaining areas and improving the condition of grassland habitats by selective revegetation and weed control, avoiding fragmentation, degradation and impacts from adjacent developments.
- Maintaining ecological connectivity between grasslands east and west of the Monaro Highway, between grasslands and adjacent woodlands west of the Monaro Highway and between adjacent grasslands on the ACT–NSW border near Queanbeyan.
- Enlarging the area of occupancy of threatened species by restoring suitable habitat on land adjacent to existing or future nature reserves.
- Preparing and implementing Environment Management Plans for those areas owned or occupied by private organisations or government agencies (Harman-Bonshaw (Department of Defence), Southcare Helicopter base, ACT Prison).

3.6.3 Gungahlin

DESCRIPTION

The natural vegetation of the Gungahlin valley was originally a mosaic of natural temperate grassland and lowland grassy woodland, primarily Yellow Box–Red Gum grassy woodland. The *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a) sets out the priorities for woodland conservation in the area, focussing mostly on the extensive band of woodland from the Federal Highway, through Gooroo and Mulligans Flat and westward to Kinlyside and Hall. Existing and future proposed reserves would protect a significant part (1500 ha) of this area.

In the valley floors natural grassland predominated prior to more recent rural use and urban development, which left three relatively large areas of native grassland and several very small and isolated fragments, to the south and south-east of the Gungahlin town centre. The dominant floristic association is *Austrodanthonia* (93 ha) with Wet *Themeda* (46 ha), *Austrostipa* (36 ha) and Dry *Themeda* (5 ha) (Table 3.6). As a result of a major planning study in 1995, three nature reserves were established (Crace, Gungaderra, Mulanggari) known collectively as the Gungahlin Grassland Reserves.

The location of the three nature reserves was determined on the basis of both the remaining fragments of natural temperate grassland and the known distribution of the Striped Legless Lizard. The reserves include about 160 ha of natural temperate grassland and another 230 ha of habitat occupied by the Striped Legless Lizard. Parts of each reserve are adjacent to one of the others, but are separated by Gungahlin Drive. In the Gungaderra Nature Reserve nearly 16 ha of Wet *Themeda* grassland is contained

Table 3.6: Gungahlin Valley: Grassland Types and Conservation Significance

Gungahlin		Area (ha) and Grassland Type NTG, NP, E	Botanical Significance Rating	Wet *Themeda*	Dry *Themeda*	*Austrodanthonia*	*Austrostipa*	*Poa*	Grassland Earless Dragon	Striped Legless Lizard	Golden Sun Moth	Perunga Grasshopper	Button Wrinklewort	Comments	Conservation Category*
Mulanggari Nature Reserve	GU01	58.6 NTG 9.4 NP 0.5 E	2(3)	7.5		51.1				K	K	✔		Linked to GU02; separated by major road	1
Gungaderra Nature Reserve	GU02	41.9 NTG 115.2 NP 30.2 E	5(2,4)	15.7		4.3	21.9	#		K	✔	✔		Linked to GU01, GU03; separated by major road Linked to woodland to the west; small patch of remnant Snow Gum woodland on one slope	1
Grace Hill Nature Reserve	GU03	61.6 NTG 41.1 NP 33.3 E	3(5)	22.5	3.1	35.9				K	K	✔	K	Linked to GU02; separated by major road	1
North Mitchell	GU04	14.8 NTG 1.2 E	3(4)			1.4	13.4				✔				2
Mitchell	GU05	1.6 NTG	3		1.6					✔					2
Belconnen Pony Club	GU06	0.3 NTG	4			0.3									3
Wells Station Road	GU07	0.2 NTG	4				0.2			✔					3
Nicholls	GU08	0.3 NP	4				0.3			✔					3
Total Natural Temperate Grassland		**179.2**		**45.7**	**4.7**	**93.0**	**35.8**								
Total other threatened species habitat		**230.9**													

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **E**: Exotic; **K**: Key habitat; ✔: Species present. * Refer ss. 3.5.1–3.5.3.

An area (6 ha) of degraded native pasture dominated by Poa remains in Gungaderra Nature Reserve.

within a fenced area occupied by the NTL Transmitting Station. A trunk sewer laid across the Gungaderra Nature Reserve in 2004 avoided any natural temperate grassland and minimised impact on the Striped Legless Lizard. The Commonwealth Government assessed the project for its environmental impact under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

Since these reserves have been established and the grazing management altered to promote conservation values, populations of Button Wrinklewort, Perunga Grasshopper, and Golden Sun Moth have been recorded during monitoring by Environment ACT ecologists. Vegetation surveys undertaken in 2003–4 indicate that in Crace Nature Reserve, the area dominated by native species has increased since 1995. The Gungaderra Nature Reserve protects a small example of the interface between grassland and woodland on the southern slopes of Gungahlin Hill, near the Barton Highway. The Grassland Earless Dragon has never been recorded in the Gungahlin Valley.

Small areas of natural temperate grassland are also located in Mitchell and north of Mitchell (west of the junction between Flemington Road and the future Wells Station Drive), at the foot of Percival Hill and on Wells Station Road. The Striped Legless Lizard is found in several locations across Kenny in habitat that no longer represents natural temperate grassland. Small populations have been recorded at Percival Hill, CSIRO (Sustainable Ecosystems), the Gungahlin Cemetery and at Palmerston, but never above 620 m asl.

PLANNING AND CONSERVATION ISSUES

The distribution of natural temperate grassland and related habitat for threatened species (particularly the Striped Legless Lizard) was the subject of a significant planning study by Williams *et al.* (1995) that resulted in a major change to the *Territory Plan* (ACTPLA 2003). As a result of this, the location for the Gungahlin Town Centre and other planned developments were moved to permit establishment of the Gungahlin Grassland Reserves. Consequently, the planning and conservation issues in Gungahlin are not as great as in other areas, although some remain. These are:

- Resolving the future status of natural temperate grassland at Flemington Road.
- Improving the condition of grassland habitats protected in reserves, particularly addressing impacts from adjacent residential developments as these are built.
- Providing ecological connectivity between the Gungahlin Grassland Reserves.
- Investigating the potential for small areas of habitat in Kenny occupied by Striped Legless Lizard to be retained as part of the urban fabric (road reserves, public parks, large area developments).
- Preparing and implementing Environment Management Plans for those areas owned or occupied by private organisations or government agencies (Gungahlin Cemetery, CSIRO (Sustainable Ecosystems)).

3.6.4 Belconnen

DESCRIPTION

The pattern of urban development in the area now occupied by Belconnen is similar to that seen elsewhere in Canberra, with large areas of former natural temperate grassland changed initially through rural land uses and subsequently cleared for residential development. Nevertheless, 175 ha of *Austrodanthonia*, 57 ha of *Austrostipa*, 53 ha of Dry *Themeda* and 15 ha of Wet *Themeda* remain in the area (Table 3.7). A much higher proportion of the remaining native grassland in Belconnen is assessed as natural temperate grassland compared with Gungahlin, and the Majura and Jerrabomberra valleys.

As a result of security fencing of land at Lawson for the Belconnen Naval Station (Department of Defence communications facility) and minimal disturbance, about 120 ha of natural temperate grassland (*Austrodanthonia*) remains in very good condition, supporting the largest population of the Golden Sun Moth in the region. In 1994, a previously undescribed species of herb was found on the site, and is the only known population of the species. It was named the Ginninderra Peppercress (*Lepidium ginninderrense*) and is now listed as an endangered species in the ACT and nationally. The Perunga Grasshopper has also been found there, but repeated searches for the Grassland Earless Dragon have failed to record any. In 2001 a small area of *Themeda* grassland containing the Striped Legless Lizard was found near Baldwin Drive during ecological studies associated with planning for the future suburb of Lawson.

It is anticipated that as a result of the planning studies for Lawson carried out by ACT and Commonwealth Government agencies, Category 1 grassland will be identified for declaration as a new nature reserve that protects a core ACT grassland site and the significant population of the Golden Sun Moth.

If a grassland nature reserve is established at Lawson, it is likely to retain an existing population of Eastern Grey Kangaroos. Whether this will remain a viable option in the long-term will depend upon development

Table 3.7: Belconnen: Grassland Types and Conservation Significance

Belconnen		Area (ha) and Grassland Type NTG, NP, E	Botanical Significance Rating	Wet *Themeda*	Dry *Themeda*	*Austrodanthonia*	*Austrostipa*	*Poa*	Grassland Earless Dragon	Striped Legless Lizard	Golden Sun Moth	Perunga Grasshopper	Button Wrinklewort	Comments	Conservation Category*
Ginninderra Experimental Station	BE01	18.9 NTG 0.5 E	4		18.9										2
Dunlop Nature Reserve	BE02	81.9 NTG	3(2)	4.9		77.0					✔			Important habitat for uncommon plant species in Wet *Themeda* area	1
'Jarramlee'	BE03	52.0 NTG	4(3)	4.7			47.3								2
Umbagong Park	BE04	9.0 NTG 1.8 NP 4.7 E	4(3,5)		8.0	0.8	0.2								2
Evatt powerlines	BE05	1.1 NTG	3		1.1										2
Lake Ginninderra	BE06	1.9 NTG	3		1.7	0.1					✔				2
Lawson (Territory)	BE07	3.3 NTG 46.9 NP 9.1 E	5(3)		1.1	2.2									3
Lawson (Commonwealth)	BE08	120.3 NP	2(3,4)	2.9	16.5	91.2	9.8			✔	K	✔	K		1
Kaleen east paddocks	BE09	4.0 NTG 24.2 NP	5(3)			4.0				✔					3
Caswell Drive	BE10	5.8 NTG	2	2.3	3.5									Links to Snow Gum Woodland and other woodland	1
Glenloch Interchange	BE11	2.2 NTG	2	2.2										Links to Snow Gum Woodland and other woodland	1
Total Natural Temperate Grassland		**300.4**		**14.8**	**53.0**	**175.3**	**57.3**								
Total other threatened species habitat		**87.2**													

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **E**: Exotic; **K**: Key habitat; ✔: Species present. * Refer ss. 3.5.1–3.5.3.

of a humane method for fertility control of the kangaroo population, an ability to protect kangaroos from domestic dogs, and successful management of visitors to the reserve. The existing buildings that are used to manage the communications facility may lend themselves to subsequent uses that complement the nature conservation objectives of the area.

At Glenloch interchange, small fragments of the former grassland now remain within the existing road network. Designs for development of this road system as part of the Gungahlin Drive extension project retain all of the grassland. Across Caswell Drive there is another area of natural temperate grassland that adjoins the Aranda Bushland, including areas of Yellow Box–Red Gum grassy woodland and Snow Gum woodland. This ecological interface was identified in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a) as being of significance and warranting protection. A small area of the natural temperate grassland on the roadside of Caswell Drive is to be removed as a part of the Gungahlin Drive Extension.

Elsewhere in Belconnen, land containing natural temperate grassland is found along the ACT–NSW border at 'Jarramlee', the Ginninderra Experimental Station and at Dunlop. An area of natural temperate grassland (containing Wet *Themeda* and *Austrodanthonia* floristic associations) and Yellow Box–Red Gum grassy woodland was excised from land proposed for residential development at Dunlop and included in the Dunlop Nature Reserve. Other small areas of natural temperate grassland are found in open space at Evatt and Florey e.g. Umbagong Park contains nine hectares of natural temperate grassland.

The Striped Legless Lizard has been recorded at several locations at Kaleen, in land between the existing suburb, the Barton Highway and the future Gungahlin Drive Extension. These animals are likely to have been connected to populations at Crace, and their ability to maintain a viable population is unknown.

PLANNING AND CONSERVATION ISSUES

- Resolving planning issues for the new suburb of Lawson, and protecting those areas that have natural values as future nature reserve or other open space.
- Preventing any future development or inappropriate activities on Umbagong Park (south) (requiring variation to the *Territory Plan*).
- Ensuring protection and conservation management of grassland remnants in close proximity to developments such as the Gungahlin Drive Extension.
- Improving the condition of grassland and threatened species habitats by appropriate management, including weed control.
- Establishing an appropriate management regime for any areas of grassland protected at Lawson, including management of the kangaroo population.
- Preparation of Environment Management Plans for those areas owned or occupied by private organisations or government agencies.
- Maintaining habitat for Striped Legless Lizard within the small fragmented areas in Kaleen.

3.6.5 Central Canberra and Tuggeranong

DESCRIPTION

Grasslands in the Central Canberra area now comprise only twelve, small remnants (totalling 37 ha), each well separated from the others. Restoring ecological connectivity between these remnants is impossible. However, some of the remaining areas are of high quality and retain sufficient suitable habitat to support small populations of some threatened species. These remnants are reminders, in the central part of the city, of the previous natural landscape.

The largest remaining native grassland remnant in Central Canberra is at Yarramundi Reach. A population of the Striped Legless Lizard (*Delma impar*) has been recorded and monitored for a number of years. It appears that there may be some inter-specific interaction with a related species *Delma inornata* that is displacing *Delma impar* from this habitat. It will be of interest to monitor this over time.

Both the Yarramundi and Glenloch interchange grasslands (Table 3.8) are included in a National Capital Authority study of land uses and land use policies in the western foreshores area of Lake Burley Griffin following the bushfires of December 2001 and January 2003 (Capital Planners Pty Ltd 2004).

Other small fragments of grassland are located in Yarralumla (Dudley St, Kintore St, Novar St, Black St and Lady Denman Drive adjacent to the Royal Canberra Golf Course), in Campbell (CSIRO corporate headquarters on Limestone Avenue) and in Reid (Constitution Avenue).

A small but significant area (BSR 1) of natural temperate grassland (Dry *Themeda*) in very good condition remains in Barton on land occupied by the Australian Centre for Christianity and Culture and the Anglican Church (St Marks Theological College). The site is unusual in that it is little disturbed by exotic weeds or human activities, and populations of Button

Table 3.8: Central Canberra and Tuggeranong: Grassland Types and Conservation Significance

Central Canberra/Tuggeranong		Area (ha) and Grassland Type NTG, NP, E	Botanical Significance Rating	Wet *Themeda*	Dry *Themeda*	*Austrodanthonia*	*Austrostipa*	*Poa*	Grassland Earless Dragon	Striped Legless Lizard	Golden Sun Moth	Perunga Grasshopper	Button Wrinklewort	Comments	Conservation Category*
CSIRO Headquarters, Campbell	CC01	3.0 NTG 0.5 E	3		3.0						✔				2
Constitution Avenue, Reid	CC02	0.7 NTG	3		0.7						✔				2
St John's Church Reid	CC03	0.9 NTG	4			0.9					✔				2
ACCC, Barton	CC04	1.9 NTG	1		1.9						✔		✔		1
York Park, Barton	CC05	0.4 NTG	4			0.4					✔				2
Yarramundi Reach	CC06	21.2 NTG	3(5)		4.8		16.4	#		✔ ?		✔			2
Lady Denman Drive, Yarralumla	CC07	0.4 NTG	3			0.4									2
Dudley Street, Yarralumla	CC08	1.5 NTG	3	0.9		0.6					✔				2
Kintore Street, Yarralumla	CC09	0.8 NTG	3		0.8								✔	Only one Button Wrinklewort present	2
Novar Street, Yarralumla	CC10	0.2 NTG	4				0.2								3
Black Street, Yarralumla	CC11	3.6 NTG	3		3.6						✔				2
Isabella Pond, Monash	TU01	1.2 NTG	2		1.2										1
Total Natural Temperate Grassland		**35.8**		**0.9**	**16.0**	**2.4**	**16.6**								
Total other threatened species habitat		**0.7**													

NTG: Natural Temperate Grassland; **NP**: Native Pasture; **E**: Exotic; **K**: Key habitat; ✔: Species present. * Refer ss. 3.5.1–3.5.3.

A very small remnant (less than 0.2 ha) of degraded native pasture dominated by *Poa* remains in the Yarramundi Reach site.
? Striped Legless Lizard was last recorded on the site in 1991. Surveys to determine presence are continuing.

Wrinklewort (approximately 100 plants) and Golden Sun Moth are located there. Considerable cooperative effort over several years by a range of government agencies and other organisations has endeavoured to retain the conservation values of the grassland while at the same time allowing for a major development in the immediate area. The lease for the area identifies the grassland as requiring conservation management according to an Environment Management Plan agreed to by the Conservator of Flora and Fauna. The Button Wrinklewort is also found in substantially modified native grassland in the grounds of the Baptist Church in Barton.

At York Park, Barton another very small fragment of natural temperate grassland (*Austrodanthonia*) that is highly modified is being maintained by the National Capital Authority. The half-hectare site contains a small population of Golden Sun Moth. The Authority carries out weed control and other management activities under an MOU with Environment ACT.

The original vegetation of what is now the Tuggeranong Valley was largely natural temperate grassland. Now, only one small area (about 1 hectare) of natural grassland remains next to Isabella Pond.

PLANNING AND CONSERVATION ISSUES

- Improving the condition of small grassland remnants and threatened species habitats by appropriate management, including weed control.
- Establishing an appropriate management regime for areas of grassland that are retained around Lake Burley Griffin, particularly at Yarramundi Reach.
- Preventing any future development or inappropriate activities on Isabella Pond, Monash (requiring a variation to the *Territory Plan*).
- Preparing and implementing Environment Management Plans for those areas owned or occupied by private organisations or government agencies (Yarramundi Reach (National Capital Authority), Australian Centre for Christianity and Culture, Barton (Anglican Church)).

3.7

Management of Native Grassland for Conservation

3.7.1 Best Practice Management and Adaptive Management

A central management objective for the remaining areas of native grassland in the ACT is to maintain or improve their ecological condition and habitat quality (see s. 4.2). Management that is regarded by experts in a particular field to be of the highest standards at the time is termed ‘best practice management’. In the context of biodiversity conservation, best practice management is that which promotes biodiversity and healthy ecosystem function. Details of a best practice approach to conservation of native grasslands are outlined in Ross (1999, pp. 25–42) who suggests five main elements for a systematic and comprehensive conservation program:

- knowledge gathering and processing;
- priority setting;
- strategic planning;
- developing the means to achieve conservation objectives; and
- stewardship and management.

The approach outlined by Ross is based on experience from grassland extension programs in Victoria and includes advice based on the ‘lessons’ learned from that program.

Guidance on protecting natural heritage through conservation planning, based on the principles, processes and practices outlined in the *Australian Natural Heritage Charter* (AHC 2002) is provided by the Australian Heritage Commission (AHC 2003). The following is based on this approach, adapted for native grassland:

- Obtaining and studying evidence about native grassland.
  (This includes evidence for: (i) the characteristics of the ecological community that existed prior to European settlement and the effects of Aboriginal people on the grassland environment; (ii) how the ecological community has changed since European settlement and what disturbance factors have been involved.)
- Identifying/involving ‘stakeholders’
  (Those people or groups with an interest in native grassland and those who have native grassland on lands they own or manage.)

- Assessing the physical condition of a native grassland area and identification of management issues.
  (This involves an assessment of the condition and natural integrity of the place and the threats to that natural integrity. A clear understanding of management issues is necessary to determine an appropriate conservation policy and required management actions in a management plan.)
- Determining the natural significance of a native grassland area.
  (This is derived primarily from an assessment of botanical significance and the presence of threatened/uncommon flora and fauna. Grassland areas may also have other values e.g. aesthetic, cultural heritage.)
- Developing conservation policy or objectives.
- Developing and implementing the conservation (or management) plan.
- Monitoring the results and reviewing the plan.

ADAPTIVE MANAGEMENT

Though there have been significant advances in knowledge of native grassland in south-eastern Australia over the last two decades, many aspects remain uncertain. Within an overall objective of maintaining and improving grassland biodiversity, an appropriate response to this uncertainty is to apply 'adaptive management' to remaining grassland areas. Adaptive management allows for the testing of management practices *in situ* to determine if they are achieving the desired outcomes, and adapting them as required. Adaptive management requires that clearly defined objectives be developed, based on current knowledge of the vegetation community, associated species and their responses to management. It is critical that both the management goals and on-ground management be subject to ongoing review (Bruce and Lunt 2003). The results of the management regime that is established must be monitored, so that its effectiveness can be assessed and management practices modified as required. Monitoring assists in distinguishing between seasonal fluctuations in the abundance of particular species and long-term changes to species and site characteristics (Sharp 1998).

An important part of this adaptive management approach is the recognition that flexibility is required in the management techniques applied to particular grasslands. Grassland structure and composition differ dramatically between sites in different regions, and between sites with different soils and management histories in the same region. Consequently, no single management regime will be suitable for all species and all sites in all regions (Lunt 1995). Where sites contain threatened species, management must take account of the requirements for their survival (Rowell 1994; Sharp 1995). There is now widespread acceptance by grassland ecologists of the need to adopt site-specific management approaches within the more general theoretical and empirical framework of native grassland management.

Environment ACT has adopted a step-by-step guide to the preparation and implementation of site-based management plans outlined in Sharp *et al.* (2005).

3.7.2 Key Aspects of Best Practice Management of Native Grassland

Increased attention given to the conservation of native grassland over the last two decades has resulted in a better knowledge of management requirements for long-term conservation though much still remains to be understood. A number of management guidelines have been published (Barlow 1998 (Victoria); Department of Conservation and Environment 1992 (Melbourne area); Diez and Foreman 1996 (Riverine Plains); Dorrough 1996 (Monaro); Eddy 2002 (based on NSW Southern Tablelands but written in general terms). A grassy ecosystem management kit (Sharp *et al.* 2005) provides a guide to developing management plans for native grassland based on current best practice and adaptive management. The kit highlights the importance of managing grass biomass in a way that is most suitable to individual remnants, rather than adopting the more prescriptive approaches that were sometimes advocated in the 1990s.

MANAGEMENT OBJECTIVES

It is essential to define specific management objectives for grassland remnants (Robertson *et al.* 2000; Sharp 2000). These objectives may vary from one remnant to another, within the broad goals and objectives for native grassland conservation. Specific management objectives may include: maintaining the structure and integrity of the community; managing biodiversity and/or particular flora and/or fauna species; removing or controlling threats; and maintaining a certain amount of biomass. Sharp (1995) and Sharp and Rehwinkel (1998) recommended a site-specific management approach. Where sites contain threatened species, management must take account of their requirements for survival (Sharp 1995; Rowell 1994).

The broad management goal for natural temperate grassland in the ACT is to maintain it in perpetuity as a viable and well-represented ecological community (Table 4.1). Achieving this goal and supporting objectives requires maintaining ecosystem processes

(Williams *et al.* 1991; Williams *et al.* 1995), maintaining dominant species, and maximising or enhancing species diversity and structural complexity (ACT Government 1997a; Rowell 1994; Sharp 1995; Sharp and Rehwinkel 1998). It also requires maintaining soil and existing drainage conditions, controlling plant introductions and weediness, removing biomass through appropriate defoliation regimes to enable native plants to flower, set seed and allow their seedlings to establish, and if possible maintaining connectivity between natural temperate grassland remnants and between them and other native grassland, woodland or naturally vegetated areas (ACT Government 1997a; Environment ACT 2005). Where native tree species are a natural component of the grassland, these should be managed as an integral part of the community (Eddy 2002; Sharp and Rehwinkel 1998).

Ideally, management actions should be tailored to the specific habit, habitat and life cycle requirements of individual species in the grassland (Wildlife Research Unit 1994; Williams *et al.* 1995). Such information is generally available for threatened plants and animals in various action plans and recovery plans (see ACT Government 1997a-c, 1998 a-b, 1999, 2004a; NSW NPWS 2000; Osborne and Jones 1995; Robertson and Cooper 2000; Smith and Robertson 1999; Zich *et al.* 1995). However it is rarely available for all the component species in a grassland remnant. In these situations categorising species into broad ecological types (for example dominant tussock grasses, inter-tussock perennial forbs, and inter-tussock annuals) may assist in the development of particular management regimes (Lunt 1995).

Where growth-form data allow the effect of different forms of management to be predicted; Lunt (1995), McIntyre (1995) and Tremont and McIntyre (1994) noted that such knowledge might also be useful in developing specific management regimes. For example, Lunt (1995) noted that mowing or grazing generally select for small rather than tall species, while low rosette plants or creeping species will survive best where there is little competition for light from dominant grasses. Small annuals will generally increase in abundance in open grazed areas, while tall upright species have a greater ability to survive thick grass. Barrer (1993) noted that mowing can discriminate against taller and slower-maturing species, and considered that herbs such as the endangered Button Wrinklewort (*Rutidosis leptorrhynchoides*) were unlikely to survive annual mowing.

In the absence of detailed knowledge about the requirements of individual species in grasslands and the effects of management activities on them, a ‘default’ management approach has been widely espoused (e.g. ACT Government 1997a). This involves continuing the previous management at particular sites, if it has resulted in the maintenance of high quality grassland and/or the continued presence of threatened species. However, given the threatened status of the natural temperate grassland ecological community and species within it, the continuing spread of weeds, and the possibility that the past disturbance regime has been causing a slow loss of biological diversity, this approach needs to be kept under review for each site. As noted in s. 3.2.1, a literature review on the use of grazing for management of biomass in native grasslands has been prepared (Lunt 2005).

DISTURBANCE

Natural temperate grassland remnants require active management and monitoring, in part because their small size leads to greater external impacts and likelihood of species becoming locally extinct (Williams *et al.* 1991;Williams *et al.* 1995). It is widely accepted that natural temperate grasslands need appropriate disturbance as part of a specific management regime, both on- and off-reserve to maintain their conservation values (ACT Government 1997a; Eddy 2002; Environment ACT 2005; Lunt and Morgan 2002; McIntyre 1995).

The main type of disturbance needed for management is highlighted in a ‘model’ of *Themeda triandra* dominated natural temperate grassland, developed by Lunt and Morgan (2002). These authors note that grasslands are characterised by the following features:

- A dominant, vigorous perennial grass that rapidly out-competes associated species (mostly forbs) through the accumulation of biomass which reduces the amount of light available for inter-tussock species.
- Inter-tussock spaces that provide the habitat for many smaller forb species. These are predominantly perennials; growing, flowering and setting seed in spring and early summer and dying back to buds or tubers at or below ground level over summer. This vegetative ‘bud and tuber bank’ is critical for the persistence of the species.
- Many perennial native inter-tussock species that possess small, transient soil seed banks, and whose seedling recruitment appears to occur infrequently;
- With appropriate climatic conditions, plants that flower and set seed abundantly when biomass levels are low.
- Many plants that will die beneath the dense grass sward if the biomass is not removed. In the absence of a persistent soil seed bank, the species

may become locally extinct, especially in small isolated remnants.

Under this model, the key disturbance required is managing the biomass of the dominant grass (e.g. by burning, mowing/slashing and/or grazing) to maintain its health and retain a high diversity of forb species (Lunt and Morgan 2002). These authors comment that perennial grasses such as *Austrodanthonia* and *Austrostipa* typically have less biomass and shorter life spans than *Themeda triandra* or *Poa* species, and thus removal of their biomass through management actions is not necessarily required in order to retain the floristic diversity of the communities they dominate.

Although the above model was based predominantly on detailed studies of natural temperate grassland in southern Victoria, it appears to be generally applicable to the natural temperate grassland in the Southern Tablelands (R. Purdie pers. comm.). For example, grasslands on the Monaro also contain a high proportion of forbs that are perennials with protected reproductive buds (Costin 1954), and biomass control is a critical aspect of the proposed management of natural temperate grassland remnants (e.g. Environment ACT 2005; see also Benson 1997; Rowell 1994). Sharp (pers. comm.) considers that biomass management should be based on removing biomass 'as often as is necessary' (i.e. without causing adverse effects) to maintain inter-tussock species, noting that the frequency of biomass removal will vary with different dominant grasses and seasonal variation.

Activities that should generally be avoided in conservation based disturbance of grassland include ploughing, earthworks that alter drainage patterns, clearing, rock removal, cultivation, pasture improvement, adding fertiliser, excessive livestock grazing, topsoil removal, and stockpiling, dumping or spreading of soil (Eddy 2002; Wildlife Research Unit 1994; Sharp and Rehwinkel 1998). Prolonged intensive uses that may reduce plant cover and cause soil compaction, disturbance or erosion should also be avoided (ACT Government 1997a). Exotic or non-local tree or shrub species should not be planted, and self-sown exotic or non-local trees and shrubs removed (Eddy 2002). Introduced pest animals such as rabbits, cats, pigs and foxes should also be controlled (Eddy 2002). It is important to avoid grassland areas becoming shaded from tree planting or the construction of buildings (Dorrough 1996; Environment ACT 2005).

MOSAIC MANAGEMENT

When using destructive management practices to remove biomass, a mosaic management approach should be adopted. This is preferable to applying such practices uniformly across entire remnant areas (Dorrough 1996; Sharp and Dunford 1994; Sharp and Rehwinkel 1998). Williams *et al.* (1991) and Williams *et al.* (1995) also stressed the importance of maintaining a diversity of patch types (e.g. burnt and unburnt) between remnants as well as within high conservation value areas. Such mosaics or patchiness are needed to ensure that features reported to be important for grassland conservation, such as structural diversity and optimum habitat for animal and plant species are always present (Rowell 1994; Sharp 2000; Williams *et al.* 1991).

In natural temperate grassland in southern Victoria, Lunt (1995) noted that the regular use of any particular management regime (e.g. frequent mowing or grazing) would strongly select for some species and lead to a reduction in species diversity and structural complexity. He advocated the use of a combination of management techniques, such as integrated burning or mowing with seasonal grazing or selective applications of herbicides.

Sites adjacent to high quality grassland remnants need to be managed sympathetically to avoid adverse effects such as run-on of water containing fertilisers, herbicides or pollutants, weed invasion, unplanned fires and trampling (Sharp and Dunford 1994; Sharp and Rehwinkel 1998; Williams *et al.* 1995). Williams *et al.* (1995, p. 66) noted that each adjacent land use had a characteristic set of possible impacts on conservation areas. They provided a table showing the level of compatibility of a range of adjacent uses with conserving the threatened Striped Legless Lizard (*Delma impar*). This approach can be applied more widely to other threatened species.

MONITORING

The importance of monitoring in a best practice management regime for grassland areas has been discussed in s. 3.4.2.

3.7.3 Rehabilitation, Regeneration and Restoration of Native Grassland

As noted in s. 2.1.7, some form of degrading disturbance threatens all grassland remnants even those in permanent reserves, and it is difficult to find sites not invaded by weeds. In this context, the rehabilitation of grassland remnants will take an increasingly important role in grassland management. The small size, fragmentation and proneness to weed invasion of remaining grassland areas pose particular difficulties for management (see s. 3.4.6).

Native grasslands are highly dynamic by comparison with other vegetation communities in which a higher proportion of the biomass is relatively 'fixed' in woody tissue that can stand for many years. Perennial grasses form the structural backbone to the ecological community, yet this structure can fluctuate dramatically with the seasons and in response to soil moisture, temperate, frost, grazing, fire and human activities. Though most of the plants in the grassland community are perennials, many of them can reach productive maturity in their first growing season, and produce seed and recruit new plants under favourable conditions. Because native grasslands can show such a high rate of turnover, of both biomass and individual plants, disturbance to either the biomass or plant population can change substantially the structure or composition of the grassland in a short period (Eddy 2002). The dynamics of grassland, including the rapid response to changed management or climatic conditions, and the difficulty in distinguishing between short-term fluctuations and long-term detrimental change, highlight the need for regular monitoring (Sharp 1999).

Rehabilitation of native grasslands may involve regeneration, restoration or reinstatement that represent progressively greater degrees of human intervention. Definitions adopted for this *Strategy* are from the *Australian Natural Heritage Charter*, 2nd Edit. (AHC 2002).

- *Regeneration* means the natural recovery of natural integrity following disturbance or degradation.

Regeneration is essentially dependent on natural processes. It does not include physical intervention, but should be accompanied by monitoring and protection measures that do not create degradation. However, intervention is now required in native grasslands, particularly with regard to defoliation management. Native grasslands have evolved under a defoliation and disturbance regime (burning, defoliation by large and small animals, and ground disturbance by animals and in some grassland areas by Aboriginal people harvesting edible tubers). Defoliation is a requirement for natural regeneration and the appropriate type for individual grassland sites is a major management issue. While current management of native grasslands is directed mainly towards a self-sustaining condition based on natural regeneration, increased intervention to deal with threats such as weed invasion will be necessary for many significant grassland areas.

- *Restoration* means 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 reinstatement.

Native grassland restoration is discussed also in s. 3.4.5. A restoration process implies sufficient evidence of an earlier state to guide the conservation process. While historical and other records, and the existence of sites that appear relatively undisturbed provide some guidance, the actual species composition of the pre-European grasslands is unknown. Restoration activities, consistent with the natural significance of the place, should therefore be focussed on maintaining and improving the biological diversity of the site and improving the overall condition of the remnant (Kirkpatrick *et al.* 1995, p. 87). Restoration activities mostly involve grass and litter removal to promote growth and survival of inter-tussock herbs, weed control, and specific actions to provide suitable conditions for the survival of threatened plant and animal species (Kirkpatrick *et al.* 1995; Lunt 1995; Ross 1999).

- *Reinstatement* means to introduce to a place one or more species or elements of habitat or geodiversity that are known to have existed there naturally at a previous time, but that can no longer be found at that place.

For the foreseeable future, reinstatement is unlikely to be part of native grassland management except on a very small scale or for particular purposes. While there is clearly a role for restoration of existing remnants that might include some specific reinstatement, large-scale expansion or ‘re-creation’ of native grasslands is not feasible with current knowledge, technology and funding (Ross 1999). However, establishment of native grass swards, using seed stock of known provenance, is becoming a practical and economic proposition in buffer areas to native grassland. This approach has been used in parts of the ACT e.g. Barton Highway road verges near Crace Grassland Reserve.

PURPOSES OF REHABILITATION

Generalised purposes of rehabilitation of native grasslands include:

- maintaining and restoring native grassland as a unique Australian ecosystem;
- providing for, or increasing connectivity for animal movement (this may include connectivity through areas of lower quality native grassland and to other ecological communities e.g. lowland woodland);
- increasing the size of remnants to improve resilience to external threats, increase animal habitat, increase landscape heterogeneity and minimize the impact of edge effects from adjacent land uses;
- restoring specific habitat elements for reptiles, birds, small mammals and invertebrates especially for threatened species;
- mitigating against erosion and to control salinity;

- rehabilitating weed infested areas in otherwise good sites; and
- replacing inappropriate introduced species.

PRINCIPLES FOR RESTORATION

Principles for undertaking regeneration and plant restoration activities (after Eddy 2002 and McIntyre *et al.* 2002) are:

- ensure that the reasons for undertaking the activities are clear, that the project is viable, and that the activities will achieve the desired outcomes;
- consider managing to increase natural regeneration before undertaking planting to recreate habitat;
- encourage natural regeneration by controlling grazing and weeds, using fire, and preventing erosion or soil compaction;
- where possible, collect seed for restoration activities from local populations to maintain local genetic provenances;
- avoid soil disturbance when undertaking rehabilitation activities;
- avoid tree planting in native grassland areas. Remove self-sown exotic trees and native trees where these have not been previously part of the grassland;
- use restoration to provide buffer areas to core conservation areas, to increase size of remnants and to enhance connectivity; and
- minimise opportunities for re-invasion by introduced species after rehabilitation.

RESTORATION OF HABITAT FOR FAUNA

To restore habitat for fauna, an essential management objective for native grassland is to maintain or improve the diversity of its structure and species composition (see s. 3.4 and Fauna Habitat Management in s. 3.7.5). Williams *et al.* (1995) suggest that rehabilitation of fragmented habitats be considered as a means of increasing overall size, buffering and interconnection. There are few examples of projects in native grassland aimed specifically at restoration of habitat. This reflects limited knowledge of species requirements, uncertainty surrounding outcomes, and the high initial and ongoing cost of such activities. There is a need for ongoing research into, and experimentation with methods of rehabilitating grassland habitats.

An attempt to re-establish *Austrodanthonia* grassland and re-introduce the Golden Sun Moth at the Victorian Open Range Zoo (Werribee, Victoria) indicates some of the challenges involved in such an activity including site preparation, sourcing of seed, and obtaining female moths (O’Dwyer 2003).

3.7.4 Defoliation Management

As noted previously, some form of defoliation is essential to maintaining the structure and botanical composition of most native grasslands (Eddy 2002). Without regular removal of some herbage, excess grass will accumulate and die, and can inhibit the growth of many plant species in the sward. Inter-tussock forbs are particularly affected; however there may be also loss of vigour of dominant grasses e.g. Kangaroo Grass. The amount of defoliation required is related to the productivity of the site and the dominant grass species found there. Productive areas carrying Kangaroo Grass or *Poa* tussock will need more intensive treatment than areas of poorer soils carrying spear and wallaby grasses which have much less biomass and shorter life spans (Eddy 2002; Lunt and Morgan 2002).

The three main forms of grassland defoliation are grazing, mowing and slashing, and burning. Eddy (2002) has outlined recent thinking on best practices for grassland management and much of the following and s. 3.7.5 has been drawn from his management guide. This guide and the references cited in s. 3.7.2 should be consulted for more detail.

GRAZING

Natural temperate grassland evolved under the influence of grazing herbivores. Since European settlement, grazing by domestic livestock has been, and is likely to continue to be, the primary use and main method of defoliation in native grasslands. Grazing by domestic stock has had an incalculable effect on the composition and structure of lowland grasslands and grassy woodlands (Lunt 1991) and to the ecosystems as a whole (Freudenberger 2000). Grazing by domestic stock, kangaroos and rabbits is not indiscriminate in its effects on plants (Sharp and Rehwinkel 1998). Grazing by sheep is considered to be more destructive than by cattle (Moore and Biddiscombe 1964 in Lunt 1991). All native grasslands are affected by grazing but this depends on its timing, selectivity, intensity and duration.

The effects of stock grazing in native grasslands have been:

- soil compaction and erosion;
- selection pressures that eliminate more palatable species and allow the less palatable to survive;
- loss of taller and more succulent species (e.g. lilies and orchids) and palatable forbs (e.g. Yam Daisy *Microseris lanceolata*);
- increases in nutrients, especially stock camps that become dominated by exotic weeds; and

- change in community dominants e.g. tall perennial grasses such as Kangaroo Grass are replaced by spear and wallaby grasses and then by introduced, annual grasses and herbs.

(Eddy 2002; Lunt 1991, 1995; Sharp and Rehwinkel 1998)

Where native grassland sites have been maintained under light grazing, continuation of grazing may be the best form of management (Scarlett *et al.* 1992). In some situations, this may be the best way known to control specific weeds or to retain control over biomass production, where alternatives such as burning and mowing may not be possible. In some instances, it may be appropriate to re-orient the management activity e.g. by changing the purpose of grazing from just animal production to also achieving conservation objectives (Sharp and Rehwinkel 1998). Good management of grazing pressure in grasslands requires sound stock proof fencing (Eddy 2002). The use of grazing as a management tool should be carefully monitored and literature on the effects of grazing kept under review. Total grazing pressure needs to be considered (domestic stock, native and feral animals) to ensure a holistic approach to grazing management.

In designing a suitable grazing management regime, the timing, selectivity, intensity and duration of grazing need consideration (Eddy 2002):

- *Timing:* Native grassland must be allowed to grow freely enough to replenish root reserves, flower and set seed or it will inevitably deteriorate. During flowering and seed production (mainly late spring to early summer), grazing should be light or completely removed.
- *Selectivity:* All grazing animals have preferences for certain species and parts of plants over others. Grazing animals are most selective under continuous light set-stocking. Higher stocking for a shorter period can reduce this effect, however stock management of this type is more intensive and must be undertaken carefully.
- *Intensity and duration:* Maximising the harvest of herbage by livestock in order to maximise production tends to result in loss of the tall and diverse structure of grasslands and a shorter and more even grassland structure. The consequences are loss of species, habitat and ecosystem resilience. When herbage quality or quantity becomes too low to maintain livestock condition, stock should be moved rather than supplementary fed, to protect the grassland from over-grazing and excessive trampling.

MOWING AND SLASHING

Mowing and slashing are used in small grassland remnants such as urban areas and cemeteries and on roadsides where there may be small grassland patches. Biomass removal is often based on landscape aesthetics, pedestrian access, and fire hazard reduction. Mowing has the effect of maintaining open structured grassland conducive to the germination of a wide range of wildflowers associated with native grasslands. Any mowing/slashing regime should allow for periods of good plant growth between each mowing and permit the grassland species to flower and set seed at least every few years. Grassland should not be mowed when significant plant species are flowering or setting seed, or when animals likely to be harmed by mowing are active, and depend on the vegetation for shelter or food (Sharp and Rehwinkel 1998).

Important considerations for a mowing/slashing regime include disposal of clippings, impacts of machinery, season/height prescriptions, and seed collection:

- *Clippings:* The creation of 'windrows' or clumps of grass clippings should be avoided by using flail mowers that spread out mulched litter, by catching the clippings, or raking and removing them.
- *Machinery:* Machinery should not be used when the ground is wet to avoid soil compaction, creation of ruts and damage to 'soil crust' lichens and bryophytes (cryptogams). In particular, machinery should be cleaned prior to use to avoid the spread of weed seeds.
- *Season/height prescriptions:* Various prescriptions on height (with a minimum of 10 cm above the ground) and mowing seasons have been advocated previously (Dorrough 1996; Sharp and Rehwinkel 1998). Current best practice is to manage biomass on a site-specific basis in the appropriate season, however, generally applicable guidelines have been developed for *Austrostipa*, *Austrodanthonia*, *Poa* and *Themeda* dominated grasslands respectively (S. Sharp pers. comm.). Groves and Lodder (1991) noted that the vigour and persistence of native grasses is reduced if mowing is performed more than once or twice in any 12-month period.
- *Seed collection:* Where mowing is used as part of a management strategy for collecting seed for grassland restoration, the removal of seed must be monitored to avoid over-collection (Wildlife Research Unit 1994).

BURNING

Changed and inappropriate fire regimes in natural temperate grassland are discussed in s. 2.1.7.

Fire has been an integral part of the evolution of native grasslands and is used as a management tool to maintain plant diversity in *Themeda triandra* grasslands, especially in southern Victoria (Lunt and Morgan 2002). It is less commonly used elsewhere. For the ACT region, Sharp and Dunford (1994) suggested that fire should be used as a management tool only in grassland remnants that have been burnt regularly in the past or where it is recommended for specific purposes. In general, long unburnt patches should not be burnt (Sharp and Rehwinkel 1998) or burnt in patches to allow the fire impacts to be monitored (Rowell 1994).

Considerable uncertainty exists with regard to use of fire as a management tool and with the extrapolation of the results of burning from one site to another. In their review of fire regimes in temperate lowland grasslands, Lunt and Morgan (2002) note that there is only one study that compares the effects of frequent burning against the exclusion of fire and other disturbances (e.g. grazing). This study, over a 17-year period (1978–1995) was of productive *Themeda* grassland in western Melbourne (Lunt and Morgan 1999). The frequently burnt area retained a much higher native cover and low exotic cover compared with the unburnt area. The exotic daisy *Hypochaeris radicata* (Catsear or Flatweed), which attained 33% mean cover of the unburnt zone, had only minimally invaded the burnt area.

If burning is to be used as a management tool, similar considerations apply as for the other means of defoliation, viz. timing, intensity, frequency, fauna impacts, fire breaks, weeds:

- *Timing:* Fires should be timed to allow grassland species to flower and set seed. Some species (e.g. Small Purple Pea *Swainsona recta*) may require fire for germination and establishment (Sharp and Rehwinkel 1998). Eddy (2002) suggests burning between the end of seed set (mid to late summer) and when the plants begin to produce flowers in spring. This is often the only time the grassland will carry a fire. Groves and Lodder (1991) noted that fires could be used between June and August to rejuvenate the grass sward in communities dominated by *Austrodanthonia*, *Poa* and *Themeda*. The season of burn may need to take account of the requirements of individual plant and animal species in particular grassland remnants (Dorrough 1996; Rowell 1994; Sharp 1994).
- *Intensity:* Hot, dry summer conditions and a large dry grass biomass can result in fires that are too hot. These can destroy seeds and burn down into the soil. Fires should only be lit when the soil is reasonably moist and temperature and wind conditions will enable the fire to be kept under control (Eddy 2002).
- *Frequency:* Burning should be carried out only as often as is needed to reduce excessive biomass. In the ACT and Southern Tablelands, a burn frequency of once every two or three years has been recommended, but on low productivity sites may never or only occasionally be necessary (Eddy 2002; Groves and Lodder 1991; Wildlife Research Unit 1994). Current best practice is not to adhere to a prescriptive fire regime, but be guided by the level of biomass present and factors such as the history of the site and presence of particular flora and fauna that may be either advantaged or adversely affected by a certain fire frequency.
- *Fauna impacts:* Fire can threaten small native fauna within grassland remnants. For this reason, patch burning is recommended to ensure unburnt patches are left as faunal refuges (Eddy 2002; Dorrough 1996, Sharp and Rehwinkel 1998). This should be followed by monitoring of potentially affected species.
- *Fire breaks:* If the accidental spread of fire into or from a native grassland is considered a risk, then a firebreak should be mown or slashed around the perimeter. It should not be ploughed or sprayed, which will create an entry point for weed species.
- *Weeds:* When fire is proposed as a management tool, the risk of promoting weed species needs to be assessed, as the benefits of fire to native plant diversity may be overwhelmed by post-fire weed invasion (Morgan and Lunt 1999; Rowell 1994). The soil seed store in some grasslands may be dominated by exotic species which are likely to become dominant after fire. Particularly in degraded remnants, burning promotes many exotic species (Lunt 1990). Sharp and Rehwinkel (1998) noted that burning may enhance invasion by the perennial grass weed African Lovegrass (*Eragrostis curvula*). Fire also promotes the spread of Chilean Needlegrass (*Nassella neesiana*), which is one of the most threatening invasive plants of grassy ecosystems in south-eastern Australia (Muyt 2001).

3.7.5 Other Management Activities

WEED MANAGEMENT

All remaining natural temperate grassland is invaded to varying degrees by weeds (see s. 2.1.7), the control of which is a critical component of management. It is impractical to remove all exotic species, so the aim of management should be to reduce populations of the most invasive weeds present (Sharp and Rehwinkel

1998). The majority of weeds are annual or biennial grasses or forbs that are not particularly troublesome if their populations are kept low. These types of weeds are nearly impossible to completely remove as they germinate, develop and set seed quickly and there is already a large seed store in the soil. The best way to keep their populations low is to maintain a dense groundcover of native plants, particularly in late autumn and winter when most weed species are germinating and establishing (Eddy 2002). However, apparently bare areas containing a cryptogamic crust should not be planted, or disturbed by machinery or vehicles.

Perennial weeds are of greater concern and there are a number that have made significant impacts on native grasslands and remain a threat (see s. 2.1.7). Woody weeds can also make an impact over a long period, but can easily be controlled in small areas and by early action before populations increase. Mechanisms for weed control include hand weeding, strategic grazing, mowing or burning and spot spraying (Dorrough 1996; Sharp and Dunford 1994; Sharp and Rehwinkel 1998; Wildlife Research and Monitoring 1994). A particular problem for weed control is that activities targeting a particular species may create disturbance that facilitates further weed invasion (Rowell 1994).

A key aspect of weed control is to avoid management activities that facilitate weed introduction or expansion including too-frequent burning, burning sites with a soil bank of weed seeds, additions of fertilisers or excess water, heavy grazing for too long a period, importing soil or organic material (e.g. straw), cultivation of fire breaks, excessive vehicle use, and using machinery that has not been cleaned (Dorrough 1996; Eddy 2002; Rowell 1994; Sharp and Rehwinkel 1998).

SOIL MANAGEMENT

To maintain native grassland areas, soil disturbance should be minimised as disturbance is followed by significant colonisation by exotic species (Lunt 1991). Disturbance includes physical disturbance (e.g. dam construction and maintenance, laying pipelines), changes in soil structure (e.g. compaction or changed drainage patterns), chemical disturbance (e.g. addition of fertilisers), and stockpiling, dumping and spreading materials such as soil or gravel. If disturbance is necessary in a native grassland remnant, follow up rehabilitation should be undertaken including levelling, weed removal and encouragement of native plant species from the adjacent vegetation (Eddy 2002).

FAUNA HABITAT MANAGEMENT

Natural temperate grassland has a rich diversity of invertebrates, reptiles, amphibians, birds and mammals (see s. 2.3). As a general principle, to maximise the habitat value of native grassland for all faunal groups, the grassland should be managed to maintain or improve the diversity of its structure and species composition. The backbone of the food chain is the plants, and the greater the diversity of plant species, the greater the variety of food types available to support fauna (Eddy 2002). For example, herbivores include folivores such as kangaroos and grasshoppers, granivores such as ants and birds (including Quail, Superb Parrot and Diamond Firetail) and there are numerous insect pollenators. Habitat elements include the grass tussocks and inter-tussock spaces, soil cracks and holes, rocks, wet areas and watercourses, specific micro-habitats (e.g. basking sites for reptiles), plant litter, trees and shrubs. The habitat value of native grassland will be greater where it adjoins or forms a mosaic with other ecosystems such as woodland, forest or wetland (Eddy 2002).

Where grassland contains a diverse flora and threatened fauna, the major management challenge is to maintain an open vegetation structure to maintain plant diversity, while maintaining viable animal populations (Lunt and Morgan 2002). Remaining grassland areas tend to be small in area and highly fragmented. Populations of animals (especially less mobile species) in such areas are at greater risk of extinction through too-frequent burning or a very hot fire, as areas of protective habitat may be reduced and re-colonisation from adjacent areas is not possible.

Management of fauna habitat should be site specific, based on animals (particularly threatened species) known to be present and their habitat and life cycle requirements. Examples of specific management adaptations to maintain habitat include:

- A grassland defoliation regime modified to maintain habitat e.g. for the Striped Legless Lizard (*Delma impar*), not mowing when the lizards are active, mowing on a rotational basis so that in any one season mown and un-mown areas adjoin, and not burning the whole of a site at one time (Rowell 1996).
- For the Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and Golden Sun Moth (*Synemon plana*), maintaining the short, more open grasslands dominated by *Austrodanthonia* spp. (Osborne *at al.* 1995; Sharp 1995). Management actions would include not allowing such sites to become wetter or nutrient enriched so that the *Austrodanthonia* was out-competed by other native species or weeds.

For reptiles generally, maintaining night and day shelter sites, basking sites, foraging areas, food, micro-habitats for reproduction and avoidance of predators, and over-wintering habitats (Osborne *et al.* 1995). Threats to these habitat requirements include grassland defoliation, use of machinery, vehicle traffic, collection of bushrock and ground disturbance (e.g. ploughing).

Trees and shrubs, where naturally present as part of the community, provide important habitat for many animal, notably birds and mammals. The interface between grassland and woodland is particularly important to a range of species that require both habitat components e.g. Hooded Robin (*Melanodryas cucullata*) and Flame Robin (*Petroica phoenicea*). Particular attention should be given to managing the ecotones where native grassland adjoins forest, woodland or wetland.

TREE MANAGEMENT

Natural temperate grassland is naturally treeless or has a low tree cover (less than one mature tree per hectare) (see s. 2.1.4). Trees can have a strong influence on grassland structure and species composition through competition for light, moisture and nutrition. Trees also provide nutrition to plants under their canopy through litter fall and by attracting birds and other animals that leave droppings under the tree. Natural populations of native trees should be retained and managed as an integral part of the grassland ecological community (Eddy 2002).

Tree planting in grasslands can have an effect on grassland species composition especially due to shading. In general, tree planting should not be undertaken in natural grasslands, but may be part of reinstatement in secondary grasslands (ACT Government 2004a). Self-sown exotic trees (e.g. pine wildings) should be removed while they are still young. Consideration should also be given to removing older exotic trees, possibly replacing them with local native species (Eddy 2002).

FERAL ANIMAL MANAGEMENT

Feral animals can have deleterious impacts on native grasslands. Rabbits have a strong dietary preference for smaller and more succulent plants and plant parts. These are often the more vulnerable native forb, lily and orchid species. Cats and foxes prey on smaller native animals potentially contributing to local extinctions or affecting the composition of local fauna populations. Feral pigs can have a severe impact on grassland areas. Especially favoured are low elevation areas that contain the more sensitive and less well-conserved types of native grassland. Grasslands adjacent to the shelter of tree cover are more prone to damage (Eddy 2002). These animals should be the subject of control programs in conjunction with adjacent land holders. Rehabilitation of grassland will be necessary after some activities e.g. ripping of rabbit burrows.

3.8

Management Agreements and Networks

3.8.1 Land Management Agreements

Land Management Agreements (LMAs) are required under the *Land (Planning and Environment) Act 1991* for all non-urban leases in the ACT. Linked to the granting of long-term leases (20 and 99 years), the purpose of LMAs is to establish a co-operative management regime for non-urban land in the ACT. Over seventy agreements between lessees and Environment ACT were in place in 2003. Except for the Jerrabomberra Valley (Table 3.2), there are few areas of natural temperate grassland on rural leases in the ACT, though patches of native pasture and particular native grassland species occur on many leases.

The principal objective of LMAs is to establish management practices on leases that support the land management aims of both the lessee and the ACT Government. This involves agreement on general management goals and responsibilities; documentation of the current state of the property (including nature conservation, cultural heritage or other significant values); and identification of land management issues and the means for their resolution. Environment ACT provides environmental information to lessees, drawing attention to conservation issues, in particular, presence of, or habitat for, threatened species and ecological communities.

Lessees are required to address the following objectives in the LMA within a framework of sustainable agricultural and pastoral land use practices:

- retain or improve the ecological functioning and integrity of the natural and modified resources of the leased area;
- preserve the extent and character of any threatened ecological community or population of a threatened species;
- pursue all development and management of the land in a way that is consistent with any Action Plan for a threatened species or ecological community;
- manage vegetation identified in the LMA as being of significant conservation value, with the aim of maintaining its structure, floristics and habitat value; and

- ensure that any activities do not adversely impact on riparian or other wetland areas.

The LMA also provides for Land Action Plans to be prepared for a range of issues, including drought risk management, pest plants and animals, sites of significant natural or cultural heritage value, maintenance of water quality, and protection of riparian zones and other native vegetation. Lessees are required to ensure that a flexible grazing strategy is in place designed to achieve conservation objectives.

In 2005, the ACT Government established the Land Keepers program, which will target practical biodiversity conservation outcomes through on-ground works, an education program or demonstration project, or the gathering of information about conservation assets and their management requirements. Funded projects are typically on-ground works e.g. fencing to protect native vegetation remnants or better managing grazing pressure, off-stream watering facilities to protect streamlines, and revegetation to provide habitat links. Where the project involves a continuing commitment by a lessee to a particular management strategy, relevant details of the commitment are entered in the Land Management Agreement for the land in question. The intention is to protect the investment that has been made and to ensure longer-term conservation outcomes.

3.8.2 Voluntary Agreements

Voluntary agreements enable landholders to acknowledge the conservation values of their land through mechanisms designed to provide a level of protection but allow for current land uses to continue. Some involve arrangements that are binding on future landholders, some are binding for current landholders while others can be revoked by landholders at any time. Examples of some of the arrangements that exist in NSW are Voluntary Conservation Agreements, Joint Management Agreements and Wildlife Refuges. Similar arrangements do not exist in the ACT, although Memoranda of Understanding with major Commonwealth landholders in the ACT (Department of Defence, CSIRO and National Capital Authority) are in place, and these provide protection for areas of land that contain natural temperate grassland. Some of these areas are the largest remaining examples of natural temperate grassland in the ACT.

Landholders with such agreements contribute land, their skills, labour, time and materials towards the conservation of native ecosystems, which in turn provide of a range of ecosystem services such as clean water and air and healthy soils (Stephens 2002). For such voluntary agreements to work well, it has been shown that landholders require sufficient support, particularly on-ground labour, advice on non-financial as well as funding sources, technical advice, evaluation of remnant vegetation and habitat values, and links with other landholders (Stephens 2002).

The Conservation Management Network described below can provide such support, and is therefore seen as a way of maintaining management agreements and assisting in their implementation.

3.8.3 Conservation Management Networks

A Conservation Management Network (CMN) is a network of remnants of an ecological community, their owners and managers as well as other people with an interest in that community (Rehwinkel 2002). There is a particular focus on sites, including encouragement of protection measures and the adoption of conservation management. The CMN provides opportunities for information dissemination (including regular newsletters) and participation in knowledge sharing and decision-making. A CMN can assist land managers to access technical and funding assistance, develop site management plans, establish formal protection measures such as voluntary agreements, and link up with people with similar interests. Membership can provide a sense of being part of a larger system, and facilitate access to a range of quality sites (Oliver 2003).

One of the most important goals of CMNs is to help integrate conservation principles and practices into land use management. CMNs are a potential way of developing an integrated conservation estate that is more than the existing nature conservation estate on public land, where the existing landholders continue to manage their own sites, with support and advice from the CMN (Oliver 2003).

In the ACT region, CMNs have been developed for White Box Woodlands in NSW, Monaro Grasslands and Southern Tablelands (NSW) Grasslands. There is potential for Environment ACT to link with this initiative of the NSW Department of Environment and Conservation and become part of an enlarged ACT and Southern Tablelands CMN for grassy ecosystems. Formation of a Conservation Management Network for natural temperate grassland sites in the ACT and New South Wales is an objective of this *Strategy* (see Table 4.1).

4 The Lowland Native Grassland Conservation Strategy

4.1

Introduction

The *Lowland Native Grassland Conservation Strategy* is intended to fulfill a number of roles. These are:

- action plans for species and ecological communities listed as threatened under the *Nature Conservation Act 1980*;
- a multi-species/ecological community strategy for native grassland conservation;
- a source document on native grassland for ACT and Commonwealth Government agencies with responsibilities for nature conservation, planning and land management; and
- a source document for community and other stakeholders with an interest in native grassland conservation.

As an Action Plan prepared under the *Nature Conservation Act 1980*, the *Strategy* addresses the requirement in section 23 of the Act, that it *'shall include proposals to ensure, as far as is practicable, the identification, protection and survival of the species, or the ecological community; or proposals to minimise the effect of any process which threatens any species or ecological community'*.

The *Strategy* provides information, strategic direction and performance criteria for a variety of government planning exercises, including:

- Proposals in *The Canberra Plan* (ACT Government 2004c) (Theme 'Living with the Environment—Our Bush Capital), which state that areas of high conservation value will be enhanced and protected.
- Proposals in *The Canberra Spatial Plan* (ACT Government 2004b). An objective of the *Spatial Plan* (p. 72) is to:

  Protect and enhance biodiversity through nature reserves and maintaining connectivity between them.

  In particular the *Spatial Plan* notes that development in the new employment corridor in Majura, Symonston and Jerrabomberra, including around the airport, will take into account the areas of native grassland and habitat for threatened species that are of significant nature conservation value.
- Proposals in *The Social Plan* (ACT Government 2004d): **(Priority 7 Respect and protect the environment)** '7.4 *Ecological protection and urban development*: The Government will help protect our threatened species and ecological communities as part of best practice planning for urban development'; and

  '7.5 *Conservation strategies*: The Government will continue to ensure that key biodiversity assets are identified, protected and managed through preparation of conservation strategies for lowland woodlands (2003), native grasslands (2004) and aquatic and riverine communities (2005)'.
- Preparation of the Outline Plan for the Jerrabomberra Valley.
- Preparation of any future land use proposals including those involving variations to *The Territory Plan* and amendments to the *National Capital Plan*, the shape and location of urban development and the use to be made of land surrounding metropolitan Canberra.

As part of these planning processes, decisions will be made by the ACT Government as to whether grasslands will be protected as Public Land (Nature Reserve), will remain without formal protection in other tenures under the *Territory Plan*, but subject to management requirements, or be modified or destroyed as pressures for urban expansion are addressed. This *Strategy* will be used by all agencies and others involved in land use planning decisions as one source of information on the values and significance of remaining grassland areas. The

Strategy also identifies and places in context, grassland areas on National Land in the ACT which are managed by Commonwealth agencies. These areas remain outside of the management arrangements provided for under the *Land (Planning and Environment) Act 1991* (see s. 1.5.2). Memoranda of Understanding are in place regarding conservation planning and management of most of these areas (see s. 3.4.3 and 3.4.4).

Other natural and cultural values of particular areas of native grassland, such as evidence of Aboriginal occupation, recreational use, aesthetic amenity, educational and special scientific features are normally taken into consideration during the planning phase before specific proposals are developed by government agencies. Management of these values is set out in management plans for particular areas or groups of areas, such as the *Canberra Nature Park Management Plan* (ACT Parks and Conservation Service 1999) (see s.1.7).

Presenting information on these values is beyond the scope of the *Strategy*. It is recognised that other values placed on native grassland areas by interested expert bodies, community groups and individuals may be important in their own right and complement the nature conservation values, thus adding to the overall significance of particular areas of grassland. The ACT Government takes these values into account through a variety of mechanisms, including environment impact assessment, and public consultation on proposals to amend the *Territory Plan*, Action Plans such as this *Strategy*, and Management Plans for Public Land prepared under the *Land (Planning and Environment) Act 1991*.

4.2

Vision, Goals, Objectives and Actions for the *Lowland Native Grassland Conservation Strategy*

As outlined in chapters 2 and 3, detailed surveys, research work and annual monitoring over a ten-year period have enabled the development of a good understanding of the location, extent, floristics and conservation significance of the ACT's native grasslands and their regional context in the Southern Tablelands. Based on this information, a vision statement, conservation goals and objectives, actions necessary to achieve the objectives, and performance criteria were prepared in draft form for consideration at a public forum in March 2004 (s. 1.6). These have been refined, based on comment received at the forum and on the draft *Strategy* (Table 4.1). The statements in Table 4.1 are grouped into: Information, Protection, Threats, Planning, Management and Community/ Landholder Involvement and are set out in a format similar to that adopted by some Australian jurisdictions for recovery plans for threatened species. Actions related to particular threatened or uncommon plant and animal species are included at the end of Table 4.1.

Performance Criteria have been developed as an aid to future reviews of progress in implementing the *Strategy*. Achievement of targets depends on a number of factors including budget funding by the ACT Government, commitment by landholders, the involvement of community groups and other factors beyond the control of Environment ACT, which will take a leading role in coordinating the implementation of the *Strategy*.

Table 4.1: Vision, Goals, Objectives, Actions and Performance Criteria for the *ACT Lowland Native Grassland Conservation Strategy*

VISION

The Australian Capital Territory makes an outstanding contribution, regionally and nationally, to conservation of natural temperate grassland and grassland flora and fauna.

PROTECTION GOALS

Goal (Grassland)

Conserve in perpetuity all remaining core conservation sites and other viable areas of the natural temperate grassland ecological community in the ACT.

Goal (Fauna and Flora)

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

MANAGEMENT GOAL

Manage and rehabilitate natural temperate grassland and related habitat with appropriate regeneration, restoration, and reinstatement practices across all land.

(Continued) ▶

Table 4.1: *(Continued)*

Natural Temperate Grasslands

Before European settlement, the temperate grasslands of the ACT and region, and their associated flora and fauna, were part of an extensive band of grasslands in south-eastern Australia. Occurring across broad plains and in low elevation areas subject to cold air drainage, they formed a mosaic with lowland woodland and riparian and wetland communities. These grasslands and associated grassy woodlands were the natural resource base for the development of the Australian pastoral industry from the early 1800s. Their accessibility and productivity resulted in their almost complete transformation by the new pastoral economy. In the ACT, the development of Canberra in the valleys and on the plains during the 20th century destroyed most of the grassland that remained.

Natural temperate grassland is one of Australia's most threatened ecosystems. In south-eastern Australia, 99.5% of the estimated pre-European natural temperate grassland has been destroyed or grossly altered. Some form of degrading disturbance threatens all grassland remnants, even those in permanent reserves. Loss of grassland habitat and the fragmentation and degradation of the remaining areas has had a severe impact on plants and animals that are dependent on grasslands. Characteristic species of grasslands such as the Grassland Earless Dragon and the Striped Legless Lizard now survive only in small and disconnected populations. The once extensive 'wildflower' displays provided by species of inter-tussock forbs are restricted to remnants of relatively undisturbed grassland.

The *ACT Lowland Native Grassland Conservation Strategy* builds on more than ten years of survey, monitoring, research, conservation planning and management in relation to lowland native grasslands in the ACT and region. From a slim knowledge base in 1990, a good understanding has been developed of the remaining grasslands in the ACT and some of their component species. Some grasslands have been placed in reserves and there are good prospects for conserving other areas. The *Strategy* provides the strategic context for the ongoing protection, management and restoration of this unique Australian ecosystem.

NOTE: (i) See end of table for abbreviations and footnotes
(ii) Bracketed items at end of each Action indicate primary responsibility for, or significant participation in the Action

1. Information

Objective	Actions	Performance Criteria
(a) The location, type and ecological condition of all natural temperate grassland and habitat for threatened species in the ACT are described and the information kept current. (b) A comprehensive database of natural temperate grassland and component species in the ACT is maintained. (c) ACT data is included in national, state and community databases. (d) Ecological information is used to underpin adaptive management.	(a) Undertake monitoring to maintain up to date information on the ecological condition of all remaining natural temperate grassland in the ACT (EACT). (b) Maintain the ACT database for vegetation and grassland species to support planning, management and research (EACT). (c) Assess priorities and address gaps in information on native grassland and grassland species. (d) Link data collection to national, state (especially NSW) and community databases and to *National Recovery Plans for Natural Temperate Grassland of the Southern Tablelands, Striped Legless Lizard, Grassland Earless Dragon, Button Wrinklewort, Ginninderra Peppercress* (NSW and ACT) (EACT, NSW, Cwlth, community). (e) Assess the implications of research results for management.	**2005–2007** ■ Location, type and condition assessments of native grassland remnants completed and are kept up to date. ■ Survey and other relevant data entered into ACT vegetation database within 6 months of collection. ■ Priorities reviewed and data deficiencies addressed. ■ *Integrated Nature Conservation Plan** includes up-to-date ecological data on native grassland and grassland species. ■ Data exchange protocols established with other priority database managers and regular exchange takes place. ■ Extent to which management recommendations arising from research outcomes are adopted. * The *Integrated Nature Conservation Plan* is the central repository for information related to nature conservation in the ACT. Based on a Geographical Information System it shows, for example, all ACT reserves, distribution of threatened species and cological communities, important fauna habitat and locations where major works are planned or being undertaken.

(Continued) ▶

Table 4.1: *(Continued)*

2. Protection

Objective	Actions	Performance Criteria
(a) A comprehensive, adequate and representative (CAR) system of natural temperate grassland areas in the ACT is protected by reservation, or other measures where reservation is not practical or desirable. (b) All Category 1 native grasslands (Core Conservation Sites) are afforded the highest available level of protection, relevant to their tenure. (c) All Category 2 native grasslands (Complementary Conservation Sites) are afforded appropriate protection, and conservation management is undertaken where compatible uses are permitted on these sites. (d) Category 3 native grasslands (Landscape and Urban Sites) are maintained and managed according to their values (e.g. as buffers, landscape features and habitat). (e) Key habitat for threatened grassland flora and fauna species is protected including where this may involve lower conservation value grassland areas. (f) Land development proposals affecting natural temperate grassland and component species are assessed for their ecological impact and if proceeded with adverse impacts are minimised to an acceptable level. (g) The ACT Heritage Places Register includes natural temperate grassland and key habitats for threatened grassland species.	(a) Evaluate the extent to which protected and other areas managed for conservation contribute to a CAR system. (b) Develop and support appropriate proposals that will protect areas identified for reservation representing: (i) the geographic and ecological extent of natural temperate grassland including representation of all floristic associations; (ii) key habitat for threatened, uncommon and declining grassland species; (iii) important areas for improving connectivity or acting as buffers for high conservation value grasslands; and (iv) elements that will achieve a CAR protected area system (EACT, community). (c) Determine the most appropriate form of protection (e.g. through LMAs, MOUs, voluntary agreements) for ecologically important off-reserve areas. Include protection requirements in agreements and monitor the effectiveness of the agreements (EACT, ACTPLA, Cwlth). (d) Ensure land development proposals are assessed under relevant environmental impact and nature conservation legislation. (e) Work with the ACT Heritage Council to identify natural temperate grassland and threatened species habitat suitable for nomination to the ACT Heritage Places Register. Prepare nominations (EACT, ACTPLA, ACT Heritage Council).	**2005–2007** ■ CAR principles are satisfied across the nature conservation estate. ■ Area of natural temperate grassland cleared or significantly modified by land development proposals. ■ Extent to which ecological connectivity is maintained or enhanced. ■ Natural temperate grassland and threatened species habitat identified as being essential for the ACT's reserve and off-reserve nature conservation system is appropriately protected. ■ Natural temperate grassland and threatened species habitat that qualify for the ACT Heritage Places Register are listed. ■ Extent to which protection agreements are in place for important off-reserve natural temperate grasslands and the effectiveness of the agreements in protecting the values of these grasslands.

3. Threats

Objective	Actions	Performance Criteria
(a) Substantially reduce or eliminate threats to natural temperate grassland through appropriate planning and management actions. (b) Reduce the impact and occurrence in grasslands of weeds of concern.	(a) Identify and monitor threats (including urban expansion, fragmentation, overgrazing, weed invasion, unplanned fire, other damaging disturbance) to natural temperate grassland and component species (EACT, ACTPLA, Cwlth, community). (b) Prepare and implement threat abatement responses (EACT, ACTPLA, Cwlth, community). (c) Monitor effect of threat abatement measures (EACT, ACTPLA, Cwlth, community). (d) Prepare and implement control programs for weeds of concern (all landholders)	**2005–2007** ■ Actions to address priority threats to natural temperate grassland are in place and being implemented. ■ Area of grassland occupied by weeds of concern is reduced. **2008–2010** ■ Priority threats to natural temperate grassland and component species are substantially reduced or decreasing.

(Continued) ▶

Table 4.1: *(Continued)*

4. Planning

Objective	Actions	Performance Criteria
(a) The *Lowland Native Grassland Conservation Strategy* and up-to-date ecological information is the major basis for assessing planning decisions impacting on conservation of native grassland and component species. (b) Government and non-government organisations recognise the biodiversity conservation values of natural temperate grassland and component species and incorporate their conservation requirements in planning, development and land management activities. (c) Native grassland remnants are assessed for their potential to contribute to the ACT's protected area system, conserving threatened species and maintaining ecological connectivity across the ACT. (d) Natural temperate grassland conservation contributes to targets established in the *Murrumbidgee Catchment Blueprint* through meeting targets in the *ACT Natural Resource Management Plan* (ACT NRM Board 2003). (e) Co-ordinated arrangements for the protection of native grassland are established across the region.	(a) Consult with all government and non-government parties participating in ACT and regional planning processes to ensure that information on the conservation significance of natural temperate grassland and component species is incorporated: (i) into strategic planning for the ACT and region; (ii) at an early stage into planning for urban and other development in the ACT; and (iii) into development control and management plans (EACT, ACTPLA, NSW, Cwlth, community). (b) Proposals assessed under the *Land (Planning and Environment) Act 1991* include appropriate information on natural temperate grassland and their component species. (c) Work with other agencies (development and infrastructure) and landholders (especially rural lessees and Commonwealth agencies) to: (i) prevent or minimise further fragmentation; (ii) maximise connectivity of natural temperate grassland; and (iii) encourage activities aimed at improving viability of natural temperate grassland remnants (EACT, Cwlth, landholders, community). (d) Work with NSW agencies to develop, implement and promote measures for protection of native grassland communities in the region (EACT, NSW).	**2005–2007** ■ All ACT planning and urban development decisions involving natural temperate grassland and habitat for component species are based on the *Lowland Native Grassland Conservation Strategy* and up to date ecological information. ■ Extent to which protection of natural temperate grassland communities contribute to regional targets for protection and connectivity. ■ Planning and development proposals in NSW affecting natural temperate grassland and grassland species have regard to ACT information and the regional context. **2008–2010** ■ The majority of ACT native grasslands under a range of tenures are part of a regional Conservation Management Network (CMN).

5. Management

Objective	Actions	Performance Criteria
(a) 'Best practice' management is applied to natural temperate grassland in the ACT across all land tenures with particular attention to grassland habitat of threatened, uncommon and declining species. (b) The ecological condition and habitat quality of the remaining natural temperate grassland communities in the ACT is maintained or improved. (c) Rural and other private landowners manage natural temperate grassland and habitat for threatened species in a way that preserves its natural values.	(a) Have in place management plans (Public Land) or similar arrangements (for other tenures) that reflect commitment to active and effective conservation of natural temperate grassland remnants. (b) Continue to develop and promote 'best practice' management of natural temperate grassland and its component species (with particular attention to declining and threatened species in the ACT) by: (i) Promoting research into conservation management of natural temperate grassland including the functional role and dynamics of the grassland and key component species and research focused on best management practice (EACT);	**2005–2007** ■ Area of natural temperate grassland with management plans or similar arrangements for 'active' conservation management. ■ 'Best practice' guidelines for natural temperate grassland restoration are prepared and regularly updated to take into account restoration experience and relevant research. ■ Effectiveness of management actions in protecting the conservation values of the grassland areas. ■ A register of suitable sites supports regeneration/restoration* activities and guides priority setting.

(Continued) ▶

Table 4.1: *(Continued)*

5. Management *(continued)*

Objective	Actions	Performance Criteria
* *Regeneration* means the natural recovery of natural integrity following disturbance or degradation. *Restoration* means 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 reinstatement. *Reinstatement* means to introduce to a place one or more species or elements of habitat or geodiversity that are known to have existed there naturally at a previous time, but that can no longer be found at that place (*Australian Heritage Commission* 2002).	(ii) Identifying and prioritising activities and sites for regeneration and restoration* of natural temperate grassland (EACT); (iii) Developing and applying an 'adaptive management' approach linking research and monitoring to management (EACT); (iv) Monitoring the effectiveness of management actions applied as part of 'best practice'; (v) Providing up to date 'best practice' management guidelines for managers of all land tenures and community groups to apply when undertaking natural temperate grassland restoration* activities (EACT, Cwlth, landholders, community); (vi) Taking into account the known conservation requirements of component flora and fauna species (in particular, declining and threatened species) in management of natural temperate grassland (EACT, Cwlth, landholders, community). (c) Liaise with Commonwealth agencies responsible for managing National Land containing natural temperate grassland and habitat for threatened species, and keep the MOUs with those agencies under review (EACT, Cwlth).	■ Area of natural temperate grassland subject to restoration/regeneration management. ■ Extent and nature of liaison with Commonwealth agencies, and effectiveness of MOUs in protecting natural temperate grassland and associated species on National Land. **2008–2010** ■ Research and monitoring are continuing and the results used to inform managers of measures to improve ecological condition and habitat qualities.

6. Community/landholder involvement

Objective	Actions	Performance Criteria
(a) Landholders, community groups and others are actively involved in native grassland conservation. (b) Native grassland sites, their managers and the community are linked together in a Conservation Management Network.	(a) Encourage the involvement of landholders, community groups and others in the protection and management of native grasslands (EACT). (b) Facilitate information and skills exchange between stakeholders aimed at achieving best practice management of native grasslands (EACT, NSW, Cwlth, landholders, community). (c) Encourage the formation of an ACT and NSW regional Conservation Management Network (CMN) for natural temperate grassland, building upon the existing NSW CMNs (EACT, NSW, landholders, community).	**2005–2007** ■ A Conservation Management Network (CMN) of sites with links to NSW CMNs is established. ■ Number and type of opportunities for managers of natural temperate grassland sites to exchange information about 'best practice' management. ■ Availability and take-up of agreements and incentives to conserve natural temperate grassland and undertake 'best practice' management. ■ Number and type of opportunities for community groups to participate in grassland conservation and restoration activities. *(Continued)* ▶

Table 4.1: *(Continued)*

6. Community/landholder involvement *(continued)*

Objective	Actions	Performance Criteria
	(d) Investigate opportunities for voluntary agreements, and incentives for land managers to conserve natural temperate grassland and component species (EACT, landholders). (e) Raise community awareness through community liaison and public education, with the aim of fostering protection of native grasslands.	

7. Threatened or Uncommon Plants

(see s. 2.2.2 and Parts 1–6 of this table for more detail)

(Button Wrinklewort, Ginninderra Peppercress and any other threatened or uncommon grassland plant)

Actions	Performance Criteria
INFORMATION (Survey, Monitoring, Research) ■ Maintain alertness to the possible presence of threatened or uncommon grassland species when undertaking surveys in appropriate habitat (EACT). ■ Maintain a database of known occurrences and abundance of threatened and uncommon grassland species to enable analysis of changes in distribution and abundance (EACT). ■ Maintain a watching brief on ACT populations of threatened and uncommon grassland species and evaluate their conservation status in a regional context (EACT). ■ Review research by the CSIRO directed towards understanding how genetic variations influence the viability of small populations, for its potential to be applied to the conservation management of threatened and uncommon species in the ACT (EACT). **PROTECTION AND MANAGEMENT** ■ Protect threatened and uncommon grassland species through the provisions of the *Land (Planning and Environment) Act 1991*, *The Territory Plan,* Memoranda of Understanding and other management agreements (EACT, Commonwealth and other land managers). ■ Seek to ensure known populations of threatened and uncommon grassland species are protected from inadvertent damaging actions (e.g. by advising landowners and managers of their presence) (EACT, LMA). ■ Prepare management guidelines for threatened and uncommon grassland species if required (EACT). ■ Manage sites, and provide advice to other landowners and managers, to maintain optimum habitat (where known) for threatened and uncommon grassland species (EACT). ■ Consider nomination for ACT listing if uncommon grassland species show evidence of local decline in extent and abundance (EACT). **REGIONAL AND NATIONAL COOPERATION** ■ Maintain links with, and participate in, regional and national recovery efforts for threatened grassland species to ensure that conservation actions are coordinated with regional and national programs (EACT). ■ Liaise with interstate agencies involved in protection and management of threatened and uncommon grassland species with the aim of increasing knowledge of their biology, and habitat and conservation requirements (EACT). **COMMUNITY INVOLVEMENT AND EDUCATION** ■ Encourage the community to assist in the conservation of native grasslands and their component species, and provide community education materials (EACT).	**2005–2007** ■ Grassland flora is a key component of grassland monitoring programs. ■ Conservation status of grassland flora is kept under review. ■ Environmental impact assessment of native grassland sites includes threatened and uncommon species. ■ Relevant genetic research is applied to the management of threatened and uncommon grassland plants. ■ The extent and type of protection for habitat supporting threatened and uncommon grassland plants. ■ Management guidelines have been prepared for threatened and uncommon grassland plants (as required). ■ The extent of community involvement in the protection and management of threatened and uncommon grassland plants *(Continued)* ▶

Table 4.1: *(Continued)*

8. Threatened and Uncommon Animals

(see s. 2.3.6 and 2.3.7 and Parts 1–6 of this table for more detail)

(Striped Legless Lizard, Grassland Earless Dragon, Golden Sun Moth, Perunga Grasshopper and any other threatened or uncommon grassland animal)

Actions	Performance Criteria
INFORMATION (Survey, Monitoring, Research) ■ Maintain alertness to the possible presence of threatened or uncommon grassland species when undertaking surveys in appropriate habitat (EACT). ■ Maintain a database of known occurrences and abundance of threatened and uncommon grassland species to assist in detecting changes in distribution and abundance (EACT). ■ Maintain a watching brief on ACT populations of threatened and uncommon grassland species and evaluate their conservation status in a regional context (EACT). ■ Facilitate and encourage research that will provide information on status of threatened and uncommon grassland species and management requirements (EACT). **PROTECTION AND MANAGEMENT** ■ Seek to ensure known populations of threatened and uncommon grassland species are protected from inadvertent damaging actions (e.g. by advising landowners and managers of their presence) (EACT, LMA). ■ Prepare management guidelines for threatened and uncommon grassland species where necessary (EACT). ■ Manage sites, and provide advice to other landowners and managers, to maintain optimum habitat (where known) for threatened and uncommon grassland species (EACT). ■ Consider nomination for ACT listing if uncommon grassland species show evidence of local decline in extent and abundance (EACT). **REGIONAL AND NATIONAL COOPERATION** ■ Maintain links with, and participate in, regional and national recovery efforts for threatened grassland species to ensure that conservation actions are coordinated with regional and national programs (EACT). ■ Liaise with interstate agencies involved in protection and management of threatened and uncommon grassland species with the aim of increasing knowledge of their biology, and habitat and conservation requirements (EACT). **COMMUNITY INVOLVEMENT AND EDUCATION** ■ Encourage the community to assist in the conservation of native grasslands and their component species, and provide community education materials (EACT).	**2005–2007** ■ Grassland fauna are a key component of grassland monitoring programs. ■ Conservation status of grassland fauna is kept under review. ■ Environmental impact assessment of native grassland sites includes threatened species. ■ Best Practice Guidelines include information relevant to management of grassland animals.

ABBREVIATIONS:

EACT	Environment ACT
NSW	Relevant NSW government agencies primarily the Department of Environment and Conservation
Cwlth	Commonwealth agencies responsible for managing National Land in the ACT (Department of Defence, National Capital Authority, CSIRO)
ACTPLA	ACT Planning and Land Authority
LMA	Land Management Agreement (for rural leases in the ACT)
MOU	Memorandum of Understanding
CMN	Conservation Management Network

4.3

Policy Guidelines for Lowland Native Grassland Conservation in the ACT

4.3.1 A Comprehensive, Adequate and Representative Reserve System

ACT Government policies for conservation of the diversity of ecological communities in the Territory are set out in documents such as *The Territory Plan*, *The Canberra Spatial Plan*, *The ACT Nature Conservation Strategy* (ACT Government 1998c), and specifically for natural temperate grassland, Action Plan No. 1 (ACT Government 1997a). Statements in these documents point towards a system of protection for the ACT that places its natural environments within a regional context and reflects national priorities. The latter are contained in several inter-governmental agreements: *Australian Guidelines for Establishing the National Reserve System* (Commonwealth of Australia, 1999), a *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996) and related documentation.

A key objective of this *Strategy* is the establishment of a comprehensive, adequate and representative system of protection of grassland in reserves or by other measures where reservation is not practicable or desirable (Table 4.1). This recognises that in the ACT, high conservation value grasslands and areas forming a core of critical habitat occur on National Land and unless the status of the land changes, these areas are unavailable for incorporation into the ACT reserve system.

The origin of the comprehensive, adequate and representative (CAR) principles for reservations for biodiversity conservation was in the *Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia* (JANIS 1997) produced to meet a commitment in the *National Forest Policy Statement* (NFPS) (Commonwealth of Australia 1992) for the establishment of a national forest reserve system. While the CAR criteria were initially developed in the context of conserving forest ecosystems, the principles are generic in nature and can be applied generally to establishment of a CAR reserve system, together with other protection measures, for conservation of biodiversity (ACT Government 2004a).

Socio-economic considerations may preclude protection of all currently unprotected occurrences in the ACT of natural temperate grassland and grassland habitat for threatened species. However, advantage can be taken of some urban planning opportunities and primary land uses compatible with conservation to modify land use proposals that would otherwise result in loss of small areas of grassland. The fragmented nature of much of the remaining unprotected natural temperate grassland points to off-reserve conservation measures as a supplementary option to pursue. The guidelines for the National Reserve System program (Commonwealth of Australia 1999) call for decision making processes to integrate long-term and short-term environmental, economic, social and equity considerations; and endorse the principle of 'least cost', where an optimal reserve configuration can be established with the minimum economic and social cost to the community.

The following definitions apply to the comprehensive, adequate and representative reserve system principles:

Comprehensiveness—sampling the full range of communities/ecosystems. In the ACT this would include the full range of the five floristic associations identified for ACT natural temperate grassland (see s. 2.1.4).

- Comprehensiveness should be addressed in a biogeographical context (i.e. using IBRA regions (Thackway and Cresswell, 1995; Environment Australia 2000)) and at an appropriate scale. For natural temperate grassland, the appropriate regional scale is the 'Southern Tablelands' as defined in Environment ACT (2003).
- All remaining occurrences of endangered ecosystems should be reserved or protected by other means as far as is practicable.

  An endangered ecosystem is one where its distribution has contracted to less that 10% of its former range, or the total area has contracted to less than 10% of its former area, or where 90% of its area is in small patches which are subject to threatening processes and unlikely to persist.

Flexibility in the application of reserve criteria is needed to ensure that the reserve system delivers optimal nature conservation outcomes as well as acceptable social and economic outcomes. Reserve design criteria should, therefore, be considered as guidelines rather than mandatory targets. For example, the effort to achieve reservation of all occurrences of an endangered community may reach a point of diminishing return and nature conservation objectives may be more efficiently and effectively achieved through other strategies. If socio-economic impacts are such that trade-offs are required to meet all criteria for reserve design, optimisation of biodiversity protection should take precedence.

Adequacy—the maintenance of ecological viability and integrity of populations, species and communities. An adequate protected area system will replicate ecologically viable natural temperate grassland communities, species and populations.

- Extent and replication of samples of populations, species and communities in the reserve system across their range such that their viability is ensured, particularly as a safeguard against catastrophic events (e.g. the 2003 ACT bushfires). Two key principles are: (a) the greater the extent reserved, the more likely that the ecological functioning and species composition of an ecosystem will be maintained; (b) ecosystems are represented within the protected area network at more than one site.

Decline in range and area of the community (reserved or otherwise) and fragmentation of the remnants are important reasons why natural temperate grassland and associated species are threatened with extinction. It follows that adequacy is a limiting factor in the ACT's contribution to a bio-regionally adequate reserve system. A systematic approach is called for to compensate, involving reservation where possible and an increased emphasis on off-reserve conservation measures such as protection of habitat links, special protection measures for occurrences on private land and sympathetic management of adjacent land.

Representativeness—sample areas included in the reserve system or other protected areas should reasonably reflect the biological diversity of the communities.

- Consider the range of species that comprise the community, especially those that depend on reservation for protection. The objective is to maximise their viability in a region through adequate reservation, not reserve every ecosystem in which they have been recorded. Consider the range of floristic and structural mixes that are found in the community.

In the ACT there is scope for greater representation of natural temperate grassland and habitat for threatened grassland species in the reserve system, with strong complementary measures for off-reserve occurrences. The ACT reserve system should sample natural temperate grassland as a component of the regional ecosystem. Representative coverage of regional ecosystems can only be satisfied at a bioregional scale.

In the context of this *Strategy*, the terms 'comprehensive', 'adequate' and 'representative' need to be described in ways relevant to the level and scale of decision-making by government and other stakeholders in the ACT. Planning and conservation issues outlined in Chapter 3 have been reviewed and reference made to the scope of explanations for the terms included in the National Reserve System guidelines to derive the following elements for an assessment of the ACT's contribution to a CAR reserve system:

A 'comprehensive' protected area system will contain the full range of natural temperate grassland types in the ACT including:

- natural temperate grassland across the full range of altitude, soil types, and aspect;
- all five floristic associations; and
- areas where natural temperate grassland intergrades with Yellow Box–Red Gum Grassy Woodland.

An 'adequate' reserve system will include areas of natural temperate grassland that retain viable ecological communities and populations of their component species including:

- large areas of natural temperate grassland preferably with small perimeter/area ratios;
- replicated samples of each of the natural temperate grassland floristic associations; and
- natural temperate grassland areas that are well connected to other native grassland or other native ecological communities to ensure ecological processes are maintained to the greatest possible extent.

A 'representative' protected area system that encompasses the diversity of species and habitats including:

- threatened and uncommon grassland plants and animals;
- the geographic range of species.

These elements have been assessed in terms of the degree to which they are demonstrated or included in the five grassland complexes (s. 3.6). These assessments, together with a summary of the priority tasks necessary to achieve an improved CAR reserve system for the ACT are outlined in Table 4.2.

The extent to which the priority tasks are addressed will be a measure of the contribution made by the ACT nature reserve system and off-reserve measures in achieving the Vision and Goals identified for this *Strategy*. A strong, representative reserve system will be complemented by off-reserve conservation measures. The latter should be aimed at improving ecological connectivity, providing opportunities for restoration and regeneration of grasslands, and conserving habitat for those species that range widely across the landscape either in migratory movements, in response to climatic conditions or because home ranges are larger than the protected areas system. For this to be successful managers of land that provides connectivity must first recognise that maintaining and/or enhancing connectivity should be a part of their management practices.

4.3.2 Other Policy Guidelines for Lowland Native Grassland Conservation in the ACT

In addition to guidelines for a comprehensive, adequate and representative protected area system, policy frameworks for the upper Murrumbidgee River catchment as part of the Murray–Darling Basin are relevant to nature conservation in the ACT region.

Targets of the Integrated Catchment Management Policy for terrestrial biodiversity in the Murray–Darling Basin are: maintaining key ecological processes; maintaining or re-establishing viable populations of native species and the integrity of ecological communities (especially vegetation); and controlling threats to biodiversity (MDBC, 2001). The ACT is a participant in the Murray–Darling Basin initiative, and is involved in a number of programs of relevance to the ACT, such as the sustainable rivers audit.

At the sub-regional level, the *Murrumbidgee Catchment Blueprint* (Murrumbidgee Catchment Management Board 2003) has been prepared to satisfy legislative requirements in the NSW *Catchment Management Act 1989* and in response to arrangements under the *National Action Plan for Salinity and Water Quality* (COAG 2000). Although the *Murrumbidgee Catchment Blueprint* is inclusive of the ACT at the broader catchment level, the ACT has a separately identified component that reflects the ACT's different governmental arrangements, land tenure system, and urban focus. ACT aspects are dealt with in the *ACT Natural Resource Management Plan* (ACT NRM Board 2003)

The ACT targets, actions and activities have been prepared through a process of community and government consultation. They provide direction for future natural resource management investment and will enable the ACT to assign funding to address issues of concern to the Territory as well as to participate in projects spanning more than one catchment. However, each jurisdiction needs to deal with natural resource management within its own policy and planning framework.

For the Murrumbidgee Catchment as a whole, a target of the *Blueprint* (p. 32) is to manage for biodiversity conservation a minimum of 30% of the area of each of the *remaining* native vegetation communities of the Murrumbidgee Catchment by 2012. The proposed ACT contribution to the catchment target is to manage for biodiversity conservation a minimum of 30% of the *pre-European* extent of each vegetation community in the ACT (ACT NRM Board 2003, p. 15). The *Natural Resource Management Plan* notes that this may not always be feasible, as is the case with natural temperate grassland where only about 5% of the estimated original area of 20 000 ha remains in a moderate to good condition (see s. 3.3).

ACT management targets in the *ACT Natural Resource Management Plan* relevant to the natural temperate grassland conservation are:

- by 2006, have in place biodiversity targets that enable on-going assessment and protection of biodiversity values;
- all protected areas of the ACT managed for the conservation of ecosystems and ecological processes 100% of the time;
- by 2005, all significant remnant vegetation on rural land in the ACT is managed to maintain and enhance its biodiversity values;
- by 2005, have in place targets for urban biodiversity; and
- by 2006 incorporate urban biodiversity targets into integrated urban ecological function targets.

4.4

The State of Protection of Natural Temperate Grassland and Other Grassy Habitats in the ACT

As outlined previously (see ss. 2.1.3, 2.1.7, 3.3), most of the original extent of natural temperate grassland in the ACT and region has been cleared since European settlement for pastoral and agricultural use and for the development of Canberra as the National Capital. In this context, all remaining areas of the ecological community in the ACT warrant serious consideration for their conservation potential, either in the case of core conservation areas (s. 3.5.1) as part of the ACT's nature conservation estate or as a secondary land use in areas where statutory protection is not practicable.

In addition to protection of habitat as nature reserves, opportunities also need to be sought to improve the ecological condition of the more degraded areas, to supplement core sites with buffers (particularly where the core area is small) and to ensure that their potential role as habitat for threatened flora and fauna is considered. Such restoration work can make an important contribution to conservation, even in places where the habitat no longer qualifies as natural temperate grassland endangered ecological community

Recognition of natural temperate grassland and the need to conserve it has only developed recently (over the last 15 years) as public policy. The fragments remaining of this once extensive ecological community and the few areas protected for nature conservation reflect this lack of recognition. However, the ACT is now in a good position to conserve the last remaining viable examples of grassland and threatened species habitat (some of which are relatively large in area) as part of the ACT's nature conservation estate. The challenge will be to manage these areas to improve their ecological condition and to enhance the habitat of threatened species so that populations increase to levels where their viability may be more certain.

The remaining 991 ha of natural temperate grassland in the ACT is about 5% of the estimated pre-European extent in the ACT of 20 000 ha. If the more highly modified areas containing areas of native pasture and exotic grasslands and associated threatened species are included (Tables 2.1, 3.2–3.8), the remaining area totals about 2172 ha or about 10% of the pre-European extent.

In the region defined by Fallding (2002), which includes the ACT (see s. 1.1), about 9% of the pre-1750 area of grassland in various conditions remains, only a portion of which would now qualify as the natural temperate grassland endangered ecological community. For the Southern Tablelands as a whole, less than 3% remains. Virtually all these grasslands are threatened in some way, even in reserves, especially by weed invasion.

An important precursor to sound conservation planning (including protection) is knowledge of the resource. The need for grassland surveys in the ACT was recognized in the early 1990s, and with support initially from Commonwealth funding, comprehensive surveys were carried out between 1991 and 1996. These formed the basis for the Action Plan for natural temperate grassland (ACT Government 1997a) (see s. 3.1). Survey of ACT grasslands is now largely complete, in terms of the flora and vertebrate fauna.

As elsewhere, there is limited knowledge of grassland invertebrates (see s. 2.3.3), although quite extensive invertebrate studies have been undertaken in the ACT, which is far better surveyed for invertebrates than most of the southern tablelands grassland ecosystems. Lack of knowledge of invertebrates is related to complexity of sampling, enormous diversity and large, short-term fluctuations due to climate, management and other disturbance factors. Recent surveys have shown improvements in the condition of some of the grasslands (e.g. Crace Nature Reserve), as well as new or extended populations of some threatened species (e.g. in the Majura Valley, see s. 3.6.1).

Sites where natural temperate grassland and other grassy habitat for threatened species now remains are shown in Figures 2.3–2.7 as at 1 March 2004, and a summary for each geographic area is in Table 4.2. The summary information allows an assessment to be made of the state of grassland conservation across the ACT and to identify priorities for conservation action.

Significant conclusions for the ACT include:

(a) About 991 ha of natural temperate grassland (partially or moderately modified) are now left in a condition that meets the definition of this endangered ecological community. This represents about 5% of the estimated original area in the ACT.

(b) An additional 542 ha of highly modified and exotic grassy vegetation is closely associated with the sites containing the endangered ecological community. Another 639 ha of grasslands are known habitat for threatened species.

(c) By deduction about 19 000ha of former natural temperate grassland have been destroyed or substantially changed during the development of Canberra or as a result of other land uses. This represents about 95% of the original area.

(d) In the regional context, the remaining area of natural temperate grassland endangered ecological community in the ACT (991 ha) represents approximately 1% of the original area (estimate 83 000 ha) and about 6% of what is left in 2000 (estimate 15 500 ha) (regional data from Fallding 2002 and Environment ACT 2003). By any measure this is a very small amount of a once extensive native grassland community.

(e) About 799 ha (37%) of the remaining natural temperate grassland and other grassland habitat (2172 ha) are protected within Public Land (Nature Reserve) areas. Another 531 ha (24%) are managed under MOUs with Commonwealth or other agencies.

(f) Significant areas of natural temperate grassland and other grassy habitat are not protected (Category 1: 258 ha and Category 2: 447 ha). Almost all this land is in the Majura and Jerrabomberra valleys.

(g) Another 136 ha are in small fragments that have been assessed as Category 3 or Landscape and Urban fragments. Almost all of this land is located in the Belconnen area.

Table 4.2: Summary of Lowland Native Grassland Data Showing Areas Remaining Under Various Categories of Land Use, Presence of Threatened Species and Conservation Planning Issues

All areas in hectares	Area of Natural Temperature Grassland	Area of other grassy habitat	Total area grassland and grassy habitat	Area protected in Public Land (Nature Reserve)	Area managed under MOU	Area not formally protected in each Conservation Category (s 3.5)—includes area managed by CUPP*			Threatened Species present in native grassland and other suitable habitat	Issues for identifying priority tasks for conservation of grasslands and threatened grassland species
	(a)	*(b)*	*(c)*	*(% of (c))*	*(% of (c))*	*1*	*2*	*3*		
Total for ACT	**991 (542)**	**639**	**2172**	**799 (37%)**	**531 (24%)**	**258**	**447**	**136**		
Gungahlin	179 (231)	0	410	392 (96%)	0 (0%)	0	17.5	0.8 (*0.3)	Golden Sun Moth Perunga Grasshopper Striped Legless Lizard Button Wrinklewort	Key habitats identified and protected. Resolve planning around Mitchell. Priority to manage to improve condition.
Majura	209 (144)	289	641	0 (0%)	138 (22%)	348	155	0	Grassland Earless Dragon Striped Legless Lizard Golden Sun Moth Perunga Grasshopper	No threatened species or natural temperate grassland formally protected. Priority to protect and manage to improve condition. Road and airport developments a threat.
Jerrabomberra	267 (80)	350	697	325 (47%)	220 (32%)	42	110	0.3	Grassland Earless Dragon Striped Legless Lizard Golden Sun Moth Perunga Grasshopper	Priority to manage to improve condition.
Belconnen	300 (88)	0	388	82 (27%)	139 (36%)	8	71 (*18.6)	87	Golden Sun Moth Perunga Grasshopper Ginninderra Peppercress Striped Legless Lizard	Largest Golden Sun Moth habitat in the region a priority for protection.
Canberra City and Tuggeranong	36 (1)	0	37	0 (0%)	26 (70%)	1.2 (*1.2)	8.6 (*6.2)	0.2 (*0.2)	Golden Sun Moth Button Wrinklewort	Most sites are vulnerable to neglect and lack recognition as assets. Further fragmentation and weed invasion threaten survival in the long term.

Notes:
(a) Includes Natural Temperate Grassland and, in brackets, area of closely associated native pasture (BSR 5) and exotic grassland
(b) Other grassland habitat (BSR 5) containing threatened species
(c) Total, all grassland and grassy habitat types ((a) + (b))
CUPP: Canberra Urban Parks and Places

(h) The largest area of unprotected native grassland and threatened species habitat is in the Majura Valley. There has been significant recent improvement in protection in the Jerrabomberra Valley. About 150 ha remain unprotected in both the Jerrabomberra Valley and Belconnen areas respectively. The remaining native grassland and threatened species habitat in these three areas are the planning and/or management responsibility of either the ACT or Commonwealth Governments, or of a private landholder (Canberra International Airport and rural lessees).

(i) Almost all natural temperate grassland and other grassland habitats in the Gungahlin area (96%), a high proportion in Jerrabomberra (79%) (following the recent establishment of reserves), and much of this habitat in the Belconnen (58%) and Canberra City (66%) areas have protection by virtue of either their status as nature reserves or as land subject to MOUs with Commonwealth agencies.

4.4.1 Actions to Improve Conservation of Lowland Native Grassland in the ACT

Significant early actions to improve grassland conservation in the ACT were:

- developing and implementing (from 1993) the *Recovery plan for lowland native grasslands in the ACT* (Wildlife Research Unit 1991) (see s. 3.1); and
- protecting about 400 ha of natural temperate grassland and other grassland habitat in the Gungahlin grassland reserves (Mulangarri, Crace, Gungaderra) (1995).

Since the first Action Plans for natural temperate grassland and component threatened species were adopted, beginning in 1997, there have been several Government decisions implementing some of the priority actions identified in these plans. These are:

- Removing about 82 ha of natural temperate grassland, including some Wet *Themeda* grassland from the Dunlop residential estate and adding it to Dunlop Nature Reserve (1997).
- Establishing Memoranda of Understanding with Commonwealth managers of National Land (see s. 3.4.3).
- Announcing (22 July 2004) protection in nature reserves of over 300 hectares of natural temperate grassland and other grassy habitat for threatened species (Grassland Earless Dragon) in the Jerrabomberra Valley.

In 2003–04 the ACT Planning and Land Authority, Land Development Authority and Environment ACT initiated work on an Outline Plan for the Jerrabomberra Valley. This 'Southern Broadacre Planning Study' is a comprehensive land use study of the Jerrabomberra Valley that will provide the framework and land use policies for this part of the ACT. The study has identified the need to establish new nature reserves to protect native grassland and habitat for the Grassland Earless Dragon. The study is expected to form the basis of a draft Variation to the Territory Plan (DVP) that will formally set out proposed land uses, including nature conservation.

Funding to establish the new reserves was included in the ACT Government's 2004–05 Budget. It will ensure protection of two core grassland sites and other key habitat for the endangered Grassland Earless Dragon. Parts of the foreshadowed reserves will join Yellow Box–Red Gum Grassy Woodland that are to be protected following an announcement in May 2003, as well as other grassland habitat at the Queanbeyan Nature Reserve (Letchworth) in NSW.

Notwithstanding the progress made to date, and until announced new reserves are formalised through a Variation to the Territory Plan, there is no part of the ACT that provides certain, long-term protection for three of the ACT's threatened species. These are the Grassland Earless Dragon, the Golden Sun Moth, and the Ginninderra Peppercress. Although work is in progress to rectify this situation for both the Jerrabomberra valley and at Lawson, long-term security for these species will not be assured until detailed planning is completed and management of their habitat is directed towards their conservation rather than being an adjunct to the primary land use. Implementation of protection and conservation management is the top priority.

4.4.2 Priority Tasks to Improve Conservation of Lowland Native Grassland and Component Threatened Species in the ACT

Priority tasks to improve the protection status of lowland native grassland (including the natural temperate grassland endangered ecological community), and the several plant and animal species that are regarded as grassland species are set out in Table 4.2. Making the decisions to implement any of these tasks is the responsibility of the ACT Government through its land planning and management actions. In summary the priority tasks are:

- Completing planning studies of those parts of the ACT where the long-term land use has yet to be defined, including identifying those areas that are best used as nature reserves.

The key areas for these studies are the Jerrabomberra and Majura Valleys and at Symonston. The 'Southern Broadacre Planning Study' has identified indicative boundaries for protection of grassland habitat for threatened species in the Jerrabomberra valley. This is in the context of competing demands for land capable of supporting alternative uses for an expanding city.

The Canberra Spatial Plan provides the strategic directions for the development of Canberra, which include protection in nature reserves of key nature conservation assets and threatened species. It also identifies the need for further investigations to be undertaken (to identify potential land for industrial and related employment purposes) in the corridor along the Monaro Highway in Jerrabomberra, Symonston and Majura.

- Protecting all grasslands assessed as being the core conservation areas (Category 1 sites), either as part of the ACT's nature conservation estate or through equivalent, secure management.
- Including in the protected area system, grassland habitat for threatened species not yet adequately protected:
  - — Grassland Earless Dragon in the Jerrabomberra and Majura valleys;
  - — Golden Sun Moth at Lawson; and
  - — Ginninderra Peppercress at Lawson.
- Providing for improved habitat connectivity for wildlife movement between grasslands and woodlands or other adjacent habitats. This complements the same connectivity consideration included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a). Important examples for grassland are between:
  - — Mount Ainslie Nature Reserve and Campbell Park paddocks (MA04);
  - — woodland and grassland at the Training Area in the Majura valley (MA01);
  - — woodland and grassland in the Jerrabomberra valley (JE02);
  - — Aranda Bushland and natural temperate grassland at Caswell Drive (BE10); and
  - — adjacent native grassland areas on either side of the ACT and NSW border at Queanbeyan (Mikes Hill (JE04), Woods Lane (JE06) (ACT)) and Queanbeyan Nature Reserve (Letchworth) (NSW).
- Reviewing management of native grassland areas in ACT nature reserves to ensure ecological condition is improved. A priority is managing invasive weeds such as Chilean Needlegrass and African Lovegrass.
- Assessing grasslands and threatened species habitats for their potential for listing on the ACT Heritage Places Register.
- Establishing mechanisms to assist in the application of best practice management (Conservation Management Networks, voluntary management agreements, guidelines) to facilitate conservation outcomes on reserve and off-reserve land.

Implementation of these priority actions depends upon a variety of government administrative processes. Briefly these are:

- Preparing recommendations from the Conservator of Flora and Fauna to the ACT Planning and Land Authority (ACTPLA) for those areas that should be protected, by including them in the ACT nature conservation estate.
- Including grassland conservation priorities in the principles and policies applied by ACTPLA when undertaking detailed planning for urban development (e.g. for Jerrabomberra valley, Lawson and East Gungahlin).
- Concluding agreements between the Conservator of Flora and Fauna and landholders, such as Memoranda of Understanding and Land Management Agreements (for rural leases).
- Implementing best practice management in grasslands managed by Environment ACT, including nature reserves, as well as in areas that are agisted and areas managed by other Territory agencies (Canberra Urban Parks and Places) and Commonwealth agencies (Department of Defence, National Capital Authority).
- Applying this *Strategy* and the information that it provides to future planning proposals for the ACT.
- Establishing Conservation Management Networks and investigating voluntary management agreements.
- Promoting cross border cooperation between ACT and NSW government agencies and other stakeholders so that coordinated conservation planning and management activities maximise the opportunities to achieve regional targets for biodiversity conservation.

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GLOSSARY

Abbreviations

asl	=	above sea level
km	=	kilometre
ha	=	hectare
m	=	metre
cm	=	centimetre
mm	=	millimetre
yr	=	year

Biodiversity

The variability among living organisms from all sources (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part) and includes diversity within and between species and the diversity of ecosystems (AHC 2002).

Buffer

A buffer is a form of vegetation or land use (e.g. road or other infrastructure) that acts as a barrier or absorbs the effects of an activity or another land use. It is undesirable to have high intensity land uses located next to areas of high conservation value, and low or medium intensity land uses may be used as buffers (MacLeod 2002).

Connectivity

Habitat connectivity is the degree to which an organism can move around the landscape due to the presence of suitable habitat. For fauna, connectivity has been defined as the 'degree to which the landscape facilitates or impedes movement among patches' (Bennett 1999).

Conservation Value

With regard to the natural environment, conservation value is an expression of the importance of a place in terms of its *natural significance*. *Natural significance* means the importance of ecosystems, biodiversity and geodiversity for their existence value or for present or future generations, in terms of their scientific, social, aesthetic and life-support value (AHC 2002).

Crown Cover Density

The percentage of the sample site within the vertical projection of the periphery of the crown i.e. the whole crown is treated as opaque.

Declining Species

Species that have a reduced extent of occurrence and/or decline in abundance, significant enough to raise conservation concern.

Disturbance

An event that removes organisms and opens up space that can be colonized by individuals of the same or different species (Begon *et al.* 1990). Examples include soil cultivation, herbicide use, tree removal, fire and grazing.

Dominant Species

Species that make up a large proportion of biomass, or numbers of organisms in a community (Begon *et al.* 1990).

Ecological Community

An assemblage of plant and animal species that occur together in space and time.

Ecological Processes

All the processes that occur between organisms, and within and between communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (AHC 2002).

Ecosystem

A dynamic complex of organisms and their environment, interacting as a functional unit (AHC 2002).

Ecosystem Function

In a functioning (or healthy) ecosystem, processes such as nutrient, energy and water flows, and the organisms and their populations, are maintained at levels appropriate to that system. A degraded or dysfunctional ecosystem has one or more of these processes disrupted (McIntyre *et al.* 2002).

Ecotone

Transition zone between two vegetation communities (e.g. between woodland and grassland).

Endangered

Means:

(a) in relation to a community—an ecological community that is in immediate danger of extinction unless the circumstances and factors threatening its distribution, composition and viability as an ecological unit cease.

(b) in relation to a species:
   (i) its likely extinction unless the circumstances and factors threatening its abundance, survival or evolution cease, or
   (ii) the reduction of its numbers or habitats to such a level that the species is in immediate danger of extinction. (*Nature Conservation Act 1980*).

Evolutionary Processes

Genetically-based processes by which life forms change and develop over generations (AHC 2002).

Exotic Species

A species of foreign origin; not native; introduced from abroad (Delbridge *et al.* 1996).

Forb

An herbaceous (non-woody) plant that is not a grass (Scarlett *et al*. 1992).

Fragmentation

The separation into parts, of an assumed previously continuous vegetation community.

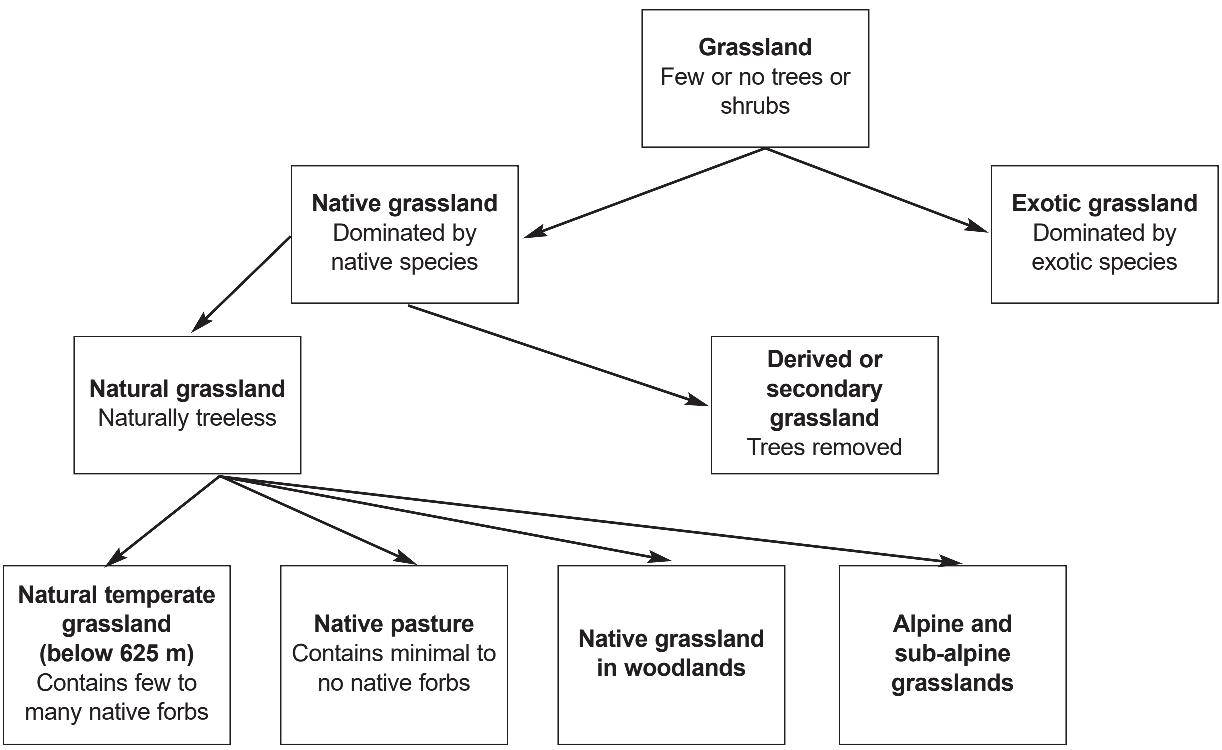
Geodiversity

The natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes (AHC 2002).

Grassland

Benson (1996 in Rehwinkel 1997) compiled a set of grassland definitions that would be universally accepted by grassland ecologists and those involved with grassland management, as follows:

- **Grassland**—vegetation dominated by grasses and forbs, <10% tree and shrub cover;
- **Native grassland**—grassland with >50% of vegetation cover composed of indigenous species, >50% of species are native, and minimum vegetation cover, alive or dead is >10%;
- **Natural grassland**—native grasslands occurring in regions considered to have had <10% tree and shrub cover at the time of European settlement (cf. secondary grassland below);
- **Secondary grassland**—a native grassland remaining after the removal or dieback of previously occurring trees and shrubs, where these occupy >10% cover;
- **Native pasture**—contains native and introduced species, where introduced species occupy >50%, but <75% of both cover and species present, where pasture species have been mechanically sown;
- **Exotic grassland**—where >75% of species and cover are introduced.



Native pasture and natural temperate grassland are considered in this *Strategy*.

A detailed definition for **natural temperate grassland** is contained in s. 2.1.4. This definition was developed as part of the nomination process that lead to natural temperate grassland being declared an endangered ecological community under the *Nature Conservation Act 1980* (ACT).

Habitat
The structural environments where an organism lives for all or part of its life, including environments once occupied (continuously, periodically or occasionally) by an organism or group of organisms, and into which organisms of that kind have the potential to be reinstated (AHC 2002).

Herbs
Plants without woody stems.

Land Management Agreement
An agreement between a lessee and the Territory establishing a co-operative management regime for non-urban land in the ACT.

Natural Integrity
The degree to which a place or ecosystem retains its natural biodiversity and geodiversity and other natural processes and characteristics (AHC 2002).

Organism
Any living being.

Projective Foliage Cover
The percentage of the sample site occupied by the vertical projection of foliage only i.e. gaps in the crown are excluded.

Protection
Taking care of a place by managing impacts to ensure that natural significance is retained (AHC 2002).

Regeneration
The natural recovery of natural integrity following disturbance or degradation (AHC 2002).

Relictual
Where a plant or animal species is now living in an environment that has changed from that which is typical for it.

Restoration
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 reinstatement (AHC 2002).

Riparian
Any land that adjoins, directly influences, or is influenced by a body of water (Lovett and Price 1999).

Secondary Grassland
An ecological community that develops when the tree canopy cover of grassy woodland or forest is removed or suffers dieback and natural regeneration is prevented (Benson 1996).

Species Diversity
The variety of species in a place (AHC 2002).

Taxa
Another term for species.

Threatened
An umbrella term for various categories of risk of premature extinction.

Vulnerable
In relation to a species, means a species that within the next 25 years is likely to become endangered unless the circumstances and factors threatening its abundance, survival or evolution cease (*Nature Conservation Act 1980*).

Weed
A plant that threatens human welfare by competing with other plants that have food, timber or amenity value (Begon *et al.* 1990). Environmental weeds are plants that threaten diversity and functioning in native ecosystems.

APPENDIX 1 Botanical Significance Ratings used for Natural Temperate Grassland Sites

The botanical significance ratings are based on a qualitative assessment of the naturalness of the vegetation community in grassland sites. They have been modified by Environment ACT (Wildlife Research and Monitoring) from Stuwe (1986) to assist with the identification of conservation values of sites. A further modification of the ratings as applied in Action Plan 1 (ACT Government 1997a) has been undertaken using a more thorough knowledge of the response of species of plants to disturbance. The ratings reflect the diversity of native and exotic plant species and the occurrence of species that are indicative of disturbance levels. Diversity is a measure of species richness measured over a specified area, such as species per hectare.

Botanical significance rating has been applied to polygons, which are the smallest units surveyed in 2003–04 and are identified as homogeneous areas in terms of vegetation structure and composition. The species identified in the polygons were used to enable interpretation of the extent to which sites are likely to have been modified. This was based on the diversity and abundance of species that have been identified as sensitive to disturbance. Studies undertaken by Prober and Thiele (1995) and Dorrough (Dorrough *et al.* 2004) have described which species occur more frequently in grazed and ungrazed areas. Plant ecologists from Environment ACT and the NSW National Parks and Wildlife Service have been analysing the frequency with which native species have been encountered during grassland and woodland surveys in over 700 sites in the ACT and NSW Southern Tablelands since 1991. These studies have provided information on those species that are less common, and those that appear to have declined as a result of site disturbance. The following table lists examples of these species.

Because annual exotic species fluctuate in their cover and diversity between seasons and years, they are not used in the evaluation of botanical significance rating, although generally there is a greater cover of annual exotic species in the more disturbed sites. However, grasslands almost invariably now contain perennial and annual plant species.

Within a site there may be multiple polygons, which may differ in terms of their botanical significance. This may be due to differing disturbance levels or differences in natural site conditions such as drainage, soil depth or nutrient levels. Where the BSR varies in a site, the botanical significance of the minor areas is indicated in brackets.

Botanical significance rating does not include other assessments of conservation value, including the occurrence of threatened species, the occurrence of particular floristic associations, site size, threats from surrounding land uses and assessments of viability. These assessments, together with the botanical significance, are used to determine appropriate protection and management requirements (see s. 3.4).

The attributes of each botanical significance rating are expressed in tabular form in Table 3.1 (Chapter 3).

Botanical Significance Rating 1 (Very High)

Sites with this rating contain a very high diversity and cover of native plant species, especially native forbs and including uncommon species and several to many disturbance sensitive species, and a low cover of exotic species. These sites contain species indicative of minimal disturbance and generally include the most natural examples of the ecological community. They are amongst the best available sites of their type, and are often one of only a small number of sites with similar conservation values remaining in Australia. These sites are categorised as **partially modified natural temperate grassland**.

Botanical Significance Rating 2 (High)

Sites with this rating have a high to very high diversity of native plants. They generally have fewer species indicative of minimal disturbance than areas classed as BSR 1, but contain uncommon species and several disturbance sensitive species. They have a low cover of perennial exotic species. These sites are categorised as **partially modified natural temperate grassland**.

Botanical Significance Rating 3 (Moderate)

Sites with this rating have usually been moderately altered by disturbance or land uses. They have moderate to high native species diversity, but only those species that are tolerant of disturbance. There is low to moderate exotic species cover. These sites are categorised as **moderately modified natural temperate grassland**.

Botanical Significance Rating 4 (Low)

Sites with this rating contain a very low diversity of native species, particularly native forbs, but contain a high cover of native grasses. They contain a low to moderate cover, but may have a high diversity of perennial exotic plants. They include no species that are indicative of low levels of disturbance. They are unlikely to have a diverse native seed bank, and therefore may not be able to naturally regenerate to increase diversity. The maintenance of these sites as natural temperate grassland generally requires considerable management input. However, they may be valuable for fauna habitat, for wildlife corridors or buffers to areas of higher conservation value, and as potential sites for rehabilitation. These sites are categorised as **highly modified natural temperate grassland**.

Botanical Significance Rating 5 (Very Low)

Sites with this rating have a high cover of native grasses, but native forb cover and diversity is very low to zero. They contain only native species tolerant of high levels of disturbance (such as previous cropping, regular fertiliser input or continuous intensive grazing). Exotic species cover is moderate to low but diversity may be high. However, they may be valuable for fauna habitat, for wildlife corridors or buffers to areas of higher conservation value, and as potential sites for rehabilitation. These sites are categorised as **substantially modified native grassland (native pasture)** and are not regarded as the natural temperate grassland endangered ecological community.

Botanical Significance Rating E (Exotic)

These sites are dominated by perennial exotic species. They may contain low to very low cover of disturbance tolerant native species, mainly grasses or may be entirely exotic (such as sown pasture).

SPECIES TYPICAL OF DIFFERENT LEVELS OF DISTURBANCE

Species typical of different levels of disturbance in lowland grassy ecosystems are shown in the following table.

Degree of Disturbance	Ground Layer Species	Examples of Characteristic Species	Typical Flora of the Ground Layer	BSR Rating
Very low	Disturbance sensitive species	*Diuris* spp., *Caladenia* spp., *Thelymitra* spp.	Native species include orchids, lilies and other highly sensitive species, as well as more tolerant species.	**1**
Low	Moderately disturbance tolerant species	*Dichopogon* spp., *Bulbine bulbosa*, *Craspedia variabilis*, *Cryptandra amara*, *Themeda triandra*, *Pimelia* spp., *Wurmbea dioica*	Species present include those moderately tolerant of disturbance, as well as disturbance tolerant species.	**2**
Moderate	Disturbance tolerant species	*Chrysocephalum apiculatum*, *Convolvulus erubescens*, *Plantago varia*, *Asperula conferta*, *Glycine* spp., *Hibbertia obtusifolia*	Native species include those commonly found in a range of sites that have been subject to moderate disturbance; sensitive species are rarely present.	**3,4**
High	Disturbance tolerant native grasses	*Poa* spp., *Austrodanthonia* spp., *Austrostipa* spp., *Bothriochloa macra*, *Microlaena stipoides*	Site may contain a variety of native grass species but few or no native forbs are present.	**5**
Very high	Exotic species	Perennial and annual* weeds, introduced or adventitious species.	Either dominated by perennial exotic species species or a low cover and diversity of native species, of which most are native grasses.	**E**

* Because annual exotic species fluctuate in cover and diversity between seasons and years, they are not used in the evaluation of the degree of disturbance although generally there is a greater cover of annual exotic species in the more disturbed sites.

APPENDIX 2 Changes in Areas of Lowland Native Grassland and Threatened Species Habitat in the ACT Since 1997

1. Increase in Area of Natural Temperate Grassland since 1997

(a) New Sites Identified as Containing Natural Temperate Grassland

Area/Site Name	Floristic Association—2005	BSR—2005	Area (ha)
Canberra Central			
St Johns Church, Reid, CC03	*Austrodanthonia* grassland	BSR 4	0.9
Kintore St, Yarralumla, CC09	Dry *Themeda* grassland	BSR 3	0.8
Jerrabomberra Valley			
Tennant St, Fyshwick, JE10	Dry *Themeda* grassland	BSR 3	0.3
Gungahlin			
Nicholls, GU08	*Austrostipa* grassland	BSR 4	0.3
Wells Station Road, GU07	*Austrostipa* grassland	BSR 4	0.2
TOTAL (additional area of Natural Temperate Grassland)			**2.5**

(b) Sites Described as Being Natural Temperate Grassland Due to Improvements in Survey and Condition Assessment Techniques

Area/Site Name	Floristic Association—1997	BSR—2005	Area (ha)
Belconnen			
Dunlop Nature Reserve, BE02	*Austrostipa grassland*, native pasture	BSR 3, 4	51.1
Umbagong Park, BE04	*Austrodanthonia*, dry *Themeda* grassland, native pasture, exotic vegetation	BSR 4, 5	4.0
Glenloch Interchange, BE11	Dry *Themeda* grassland, native pasture	BSR 2	0.7
Gungahlin			
Gungaderra Grassland Reserve, GU02	*Austrostipa* grassland, native pasture	BSR 4	12.3
Crace Grassland Reserve, GU03	*Themeda* grassland, native pasture	BSR 3	8.2
Jerrabomberra Valley			
Mugga Mugga, JE01	*Austrostipa* grassland, native pasture	BSR 4	12.0
Woods Lane (Tharwa Road), JE04	Dry *Themeda* grassland, exotic, native pasture	BSR 3	8.3
Canberra Central			
Dudley St, Yarralumla, CC08	*Austrodanthonia* grassland, exotic vegetation	BSR 3	0.6
TOTAL (area reassessed as Natural Temperate Grassland)			**97.2**

2. Reduction in Area of Natural Temperate Grassland Since 1997

(a) Sites Developed in Whole or Part Since 1997

Area/Site Name	Floristic Association—1997	Status 2005	Decrease in Area (ha)
Gungahlin			
'Stray Leaf' Property, GAP 4	*Austrostipa* grassland, BSR 4	Loss of all of site	4.8
Majura Valley			
Canberra International Airport, MA03	*Austrodanthonia* grassland, BSR 3, 4	Loss of part of site	2.0
Canberra Central			
ACCC, Barton, CC04	Dry *Themeda* grassland, BSR 1	Loss of part of site	1.2
TOTAL (decrease in area of Natural Temperate Grassland)			**8.0**

(b) Sites that Have Deteriorated Since 1997

Area/Site Name	Floristic Association, Change in BSR	Cause of Reduction in Area	Decrease in Area (ha)
Canberra Central			
Yarramundi Reach, CC06	Dry *Themeda*, Wet *Themeda*, *Poa* grasslands, BSR 3 to 4	Weed invasion	10.8
Lady Denman Drive, CC07	*Austrodanthonia* grassland, BSR 3 to exotic	Weed invasion	2.1
Belconnen			
Evatt Powerlines, BE05	*Austrodanthonia* grassland, BSR 4 to exotic	Weed invasion	1.1
Gungahlin			
Mitchell, GU05	Dry *Themeda* grassland, BSR 3 to 5 (native pasture)	Site disturbance	0.3
Total area (decreased BSR)			**14.3**

(c) Sites Described in 2005 as Native Pasture or Exotic Grassland and not Natural Temperate Grassland, Based on Improvements in Survey and Condition Assessment Techniques

Area/Site Name	Floristic Association—1997	2005 Classification	Decrease in Area (ha)
Belconnen			
Lawson Territory, BE07	*Austrostipa* grassland, BSR 3	Native pasture, BSR 5	46.9
Kaleen East, BE09	*Austrodanthonia* grassland, BSR 3	Native pasture, BSR 5	24.6
Lake Ginninderra, BE06	*Austrodanthonia* grassland, BSR 4	Exotic	0.4
Majura Valley			
Canberra International Airport, MA03	*Austrodanthonia* grassland, BSR 2, 3	Native pasture, BSR 5	44.2
Jerrabomberra Valley			
Amtech, JE09	*Austrodanthonia* grassland, BSR 4	Exotic	6.2
Canberra Central			
Constitution Avenue, Reid, CC02	Dry *Themeda* grassland, BSR 3	Exotic	2.3
Lady Denman Drive, CC07	*Austrodanthonia* grassland, BSR 3	Exotic	2.1

(Continued) ▶

2. (c) *(Continued)*

Area/Site Name	Floristic Association—1997	2005 Classification	Decrease in Area (ha)
Gungahlin			
Belconnen Pony Club, GU06	*Austrodanthonia* grassland, BSR 3	Exotic	1.2
Kenny North, GAP 11	*Austrostipa* grassland, BSR 4	Exotic	11.4
Gundaroo Road South, GAP 8	*Austrostipa* grassland, BSR 4	Exotic	4.2
Kenny, GAP 12	*Austrostipa* grassland, BSR 4	Exotic	1.7
TOTAL (reduction in area of Natural Temperate Grassland)			**145.2**

Note that all these sites retain some native grassland.

3. Sites Formerly Described as Natural Temperate Grassland, but Re-assessed as Secondary Grassland or Woodland and Now Included in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004a)

Area/Site Name	Floristic Association—1997	Area (ha)
Gungahlin		
Horse Park Entrance, GAP 1	Wet *Themeda*, *Austrodanthonia* grassland, BSR 3, 4	32.1
Mulanggari Grassland Reserve, GU01	*Austrodanthonia* grassland, BSR 3	23.5
Kosciusko Ave., Palmerston, GAP 7	Dry *Themeda* and *Austrostipa* grassland, BSR 3, 4 (developed)	14.2
Harrison, GAP 5	*Austrostipa* grassland, BSR 4	4.7
Majura Valley		
Majura Training Area, MA01	*Austrodanthonia* grassland, BSR 2	15.6
Jerrabomberra Valley		
'Woden Station', JE03	*Austrodanthonia* grassland, BSR 2	10.9
Belconnen		
Caswell Drive, BE10	Dry *Themeda* grassland, BSR 3	1.0
TOTAL (included in Lowland Woodland Conservation Strategy)		**102.0**

Note:

1. **GAP** (Grassland Action Plan) location numbers are from Action Plan 1 (ACT Government 1997a).
2. **BSR**: Botanical Significance Rating (see Appendix 1).
3. **Site numbers (e.g. MA01)**: A complete list is contained in Table 3.2

APPENDIX

3 Specific and Common Names of Species in this Strategy

NATIVE GRASSES

Bothriochloa macra	Red Grass
Chloris truncata	Windmill Grass
Danthonia spp.	Wallaby Grasses
D. caespitosa	Ringed Wallaby Grass
D. carphoides	Short Wallaby Grass
D. laevis	Wallaby Grass
Elymus scaber	Common Wheat Grass
Enneapogon nigricans	Niggerheads
Poa spp.	Tussock Grasses
Poa labillardieri	Tussock Grass
P. sieberiana ssp. *sieberiana*	Tussock Grass
Panicum effusum	Hairy Panic
Stipa spp.	Spear grasses
S. scabra ssp. *falcata*	Spear grass
S. bigeniculata	Spear grass
Themeda triandra	Kangaroo Grass

NATIVE FORBS

Asperula conferta	Common Woodruff
Bulbine bulbosa	Golden Lily
Carex appressa	Sedge
C. inversa	Common Sedge
Chrysocephalum apiculatum	Common Everlasting
Goodenia pinnatifida	Scrambled Eggs
Haloragis heterophylla	Perennial Raspweed
Hydrocotyle laxiflora	Stinking Pennywort
Juncus spp.	Rushes
Leptorhynchos squamatus	Scaly Buttons
Microseris lanceolata	Yam Daisy
Oxalis perennans	Wood Sorrel
Plantago varia sens. lat.	Variable Plantain
Psoralea tenax	Emu Foot
Rutidosis leptorrhynchoides	Button Wrinklewort
Solenogyne dominii	Solenogyne
Stackhousia monogyna	Creamy Candles
Swainsona monticola	Purple Pea
S. sericea	Purple Pea
S. recta	Purple Pea
Thesium australe	Toadflax
Triptilodiscus pygmaeus	Common Sunray
Vittadinia muelleri	Narrow-leaf New Holland Daisy
Wahlenbergia spp.	Native bluebells
Wurmbia dioica	Early Nancy

EXOTIC GRASSES

Aira caryophyllea	Silvery Hairgrass
Aira elegantissima	Delicate Hairgrass
Avena spp.	Wild Oats
Bromus hordaceous	Brome
Dactylis glomerata	Cocksfoot
Holcus lanatus	Yorkshire Fog
Phalaris aquatica	Phalaris
Poa pratensis	Kentucky Bluegrass
Vulpia myuros	Rat's Tail Fescue

EXOTIC FORBS

Arctotheca calendula	Cape Weed
Carthamus lanatus	Saffron Thistle
Centaurium erythraea	Common Centaury
Cerastium glomeratum	Chick weed
Cirsium vulgare	Spear Thistle
Hypochaeris glabra	Smooth Catsear
Hypochaeris radicata	Flatweed
Paronchyia brasiliana	Chilean Whitlow
Rumex crispus	Curled Dock
Tolpis umbellata	Tolpis
Tragopogon porrifolius	Salsify
Tragopogon dubius	Salsify
Trifolium spp.	Clovers
T. arvense	Haresfoot Clover
T. campestre	Hop Clover
T. dubium	Yellow Suckling Clover
T. glomeratum	Clover
T. repens	White Clover

INVERTEBRATES

Cooraboorama canberrae	Canberra Raspy Cricket
Keyacris scurra	Key's Matchstick
Perunga ochracea	Perunga Grasshopper
Synemon plana	Golden Sun Moth

REPTILES

Aprasia parapulchella	Pink-tailed Worm Lizard
Delma impar	Striped Legless Lizard
Lampropholis delicata	Delicate Skink
Tympanocryptis pinguicolla	Grassland Earless Dragon

AMPHIBIANS

Lymnodynastes dumerilii	Eastern Banjo Frog
Neobatrachus sudelli	Spotted Burrowing Frog
Uperoleia laevigata	Orange-groined Toadlet

BIRDS

Ardeotis australis	Australian Bustard
Coturnix australis	Brown Quail
Coturnix novaezeelandiae	Stubble Quail
Ephthianura albifrons	White-fronted Chat
Gallinago hardwickii	Latham's Snipe
Gymnorhina tibicen	Australian Magpie
Pedionomus torquatus	Plains Wanderer
Rhipidura leucophrys	Willy Wagtail

APPENDIX 4 | Threatened Plant Species in Natural Temperate Grassland in the ACT (declared under the *Nature Conservation Act 1980* (ACT))

Appendix 4.1

Button Wrinklewort (*Rutidosis leptorrhynchoides*)

(Illustration: John Pratt)

In accordance with section 21 of the *Nature Conservation Act 1980*, the **Button Wrinklewort (*Rutidosis leptorrhynchoides*)** was declared an **endangere**d species on 15 April 1996 (formerly Determination No. 29 of 1996 and currently Determination No. 7 of 1998). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

Conservation Status (ACT) Endangered

Criteria satisfied (ACT Flora and Fauna Committee 1995)

The species is known or suspected to occur in the ACT region and is already recognised as endangered in an authoritative international or national listing.

The species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the near future, as demonstrated by the following:

- Current severe decline in population or distribution, from evidence based on:
  —direct observation, including comparison of historical and current records; and
  —severe decline in quality or quantity of habitat.
- Imminent risk of severe decline in population or distribution from evidence based on severe decline in quality or quantity of habitat.
- Severely fragmented distribution for a species currently occurring over a small range or having a small area of occupancy within its range.

DESCRIPTION

The Button Wrinklewort (*Rutidosis leptorrhynchoides*) is a slender perennial forb, 25–35 cm tall with up to 30 leafy stems, branching mainly at the base. The leaves are narrow, dark green, ageing to yellow–green and up to 3.5 cm long and 1.5 mm wide, with rolled edges concealing the undersides. The stems usually die back in late summer or autumn, and the new basal leaves appear by early winter. The species has bright yellow button flowers (2 cm wide) from December to April.

DISTRIBUTION AND ABUNDANCE

R. leptorrhynchoides appears to have been formerly widespread in south-eastern New South Wales and across the western plains of Victoria. The species has a disjunct distribution and is known from 17 populations in the ACT region (ten within the ACT, six near

Queanbeyan and one near Goulburn (NSW)) and nine in Victoria. Current populations range in size from five to approximately 95,000 plants. These are often restricted to small, scattered refugia that have escaped grazing, ploughing and the application of fertilisers, for example, road margins, railway easements and cemeteries (Young 1997).

Of the nine sites occurring within the ACT, two have large populations. The larger is within Stirling Park, Yarralumla, where up to 70 000 plants have been recorded (A. Young and F. Zich unpublished data). The other, comprising about 30 000 plants, occurs on the Majura Training Area, although this is confined to a small area and is therefore vulnerable to damage (Crawford and Rowell 1996). Smaller populations occur on Red Hill, at Barton, on the edge of Capital Hill, near West Block, the Campbell Park Offices and near HMAS Harman, in the Jerrabomberra Valley.

In NSW, the species is known to occur naturally at six sites within the Queanbeyan area, with the largest population (10 000 plants in February 1995) being found within the Queanbeyan Nature Reserve (A. Young and F. Zich unpubl. data). Other sites occur at 'The Poplars' near Jerrabomberra, Letchworth, along the slopes of Mt. Jerrabomberra, and along a roadside by the Queanbeyan–Captains Flat Road.

The largest known NSW population is at Gundary Reserve, a Travelling Stock Reserve and Arboretum, 5 km SSE of Goulburn, NSW and contains 95 000 plants (A. Young unpubl. data).

HABITAT

In the ACT, *R. leptorrhynchoides* occurs on the margins of open stands of Yellow Box–Red Gum Grassy Woodland with a ground layer of various native grasses and other forbs, and extends into Natural Temperate Grassland. Soils are usually shallow stony red–brown clay loams. Occasionally, Apple Box (*Eucalyptus bridgesiana*) is also present.

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

BIOLOGY

The population density of the species affects seed production, with sparsely distributed individuals producing fewer seeds per inflorescence than plants from denser colonies. This suggests that the species is dependent on the maintenance of the standing population for recruitment (Morgan 1995a).

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).

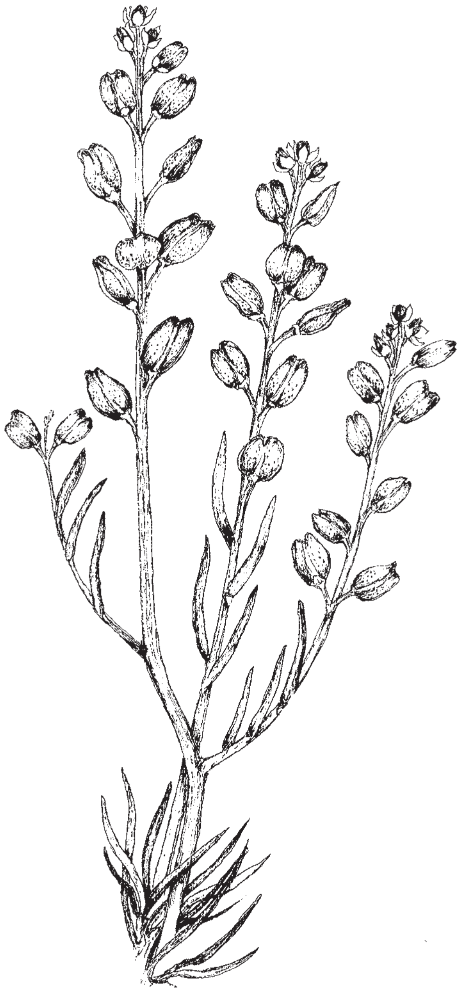
The reproductive potential and viability of small remnant populations may also be limited by inbreeding and related reductions in fitness (inbreeding depression). Research using genetic markers to characterise the mating patterns of *R. leptorrhynchoides* shows evidence of increased potential for mating among relatives in populations of less than 200 plants, especially when these are isolated by more than 5 km from other populations. The demographic consequences of this are as yet unknown, but could be significant.

Reproductive capability of populations also depends on their chromosome number. Chromosome counts of *R. leptorrhynchoides* show the species to be cytologically complex. Northern populations in the ACT and NSW are diploid (2n=26), while in the south of the range, Victorian populations are either wholly diploid, or primarily tetraploid (2n=44), with a mix of anueploids and even some hexaploids. Diploids produce more seed per head than tetraploids and any mating between the two ploidy levels produces few seed, all of which are triploids with low pollen fertility (Young 1997).

R. leptorrhynchoides has been the subject of considerable ecological and genetic research aimed at understanding the factors that limit population viability. Most of this is reviewed in Young *et al.* (2000). Issues and options for the genetic conservation of the species are contained in Young (2001).

Appendix 4.2

Ginninderra Peppercress (*Lepidium ginninderrense*)



(Illustration: Kim Neubauer)

In accordance with section 21 of the *Nature Conservation Act 1980*, the **Ginninderra Peppercress (*Lepidium ginninderrense*)** was declared an **endangered** species on 4 September 2001 (Instrument No. 192 of 2001). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

Conservation Status (ACT) Endangered

Criteria satisfied (ACT Flora and Fauna Committee 1995)

The species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the medium-term future, as demonstrated by:

- Severely fragmented distribution for a species currently occurring over a small range or having a small area of occupancy within its range.

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 to 2.0 mm wide) and 15–55 mm long. The inflorescence is an elongating raceme with a maximum length of 15 cm. Flowers are small, 2 mm wide and 1.5 mm long. Sepals are less than 1 mm long and about 0.5 mm wide, green and with scarious margins. Petals are absent (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 AND ABUNDANCE

The only known population of *Lepidium ginninderrense* occurs in the north-west corner of Belconnen Naval Transmission Station in the suburb of Lawson in the Australian Capital Territory (which is the type locality). The population is currently about 2000 plants, occupying an area of 90 x 30 metres (Avis 2000).

A second record of *L. ginninderrense* is from 1952 in the ACT suburb of Reid, however, a recent search failed to locate the species in this area (M. Gray pers. comm. cited in Scarlett 2001).

L. ginninderrense has been recorded only from these two cited localities in the ACT and is not known from outside the ACT. The species is remarkably disjunct from all other members of the allied *Lepidium* section *Papillosa* in south-eastern Australia, which are mainly confined to the inland plains west and north of the Eastern Highlands (Scarlett 2001).

HABITAT

At the type locality *Lepidium ginninderrense* grows on the flood plain of Ginninderra Creek, in Natural Temperate Grassland dominated by *Austrodanthonia* spp. and *Bothriochloa macra*. Associated herbaceous species include *Plantago gaudichaudii*, *Juncus filicaulis*, *Triptilodiscus pygmaeus*, *Parentucellia latifolia* and *Calocephalus citreus* (Scarlett 2001).

Avis (2000) has shown that *L. ginninderrense* grows in areas with relatively low perennial grass cover, often with indications of past soil disturbance.

The soil type over most of the site is a shallow red earth, with patches of colluvium on the footslopes (Crawford and Rowell 1995a cited in Lowe 1996, p. 41). The population occurs at an altitude of approximately 580 metres.

BIOLOGY

Almost nothing is known about the general biology of the species but fecundity (seed set) appears to be good. The species may still contain significant genetic variation that could form the basis for a conservation strategy (Young 2001).

APPENDIX 5 Threatened Animal Species in Natural Temperate Grassland in the ACT (declared under the *Nature Conservation Act 1980* (ACT))

Appendix 5.1

Striped Legless Lizard (*Delma impar*)

In accordance with section 21 of the *Nature Conservation Act 1980*, the **Striped Legless Lizard (*Delma impar*)** was declared a **vulnerable** species on 15 April 1996 (formerly Determination No. 29 of 1996 and currently Determination No. 89 of 1997). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

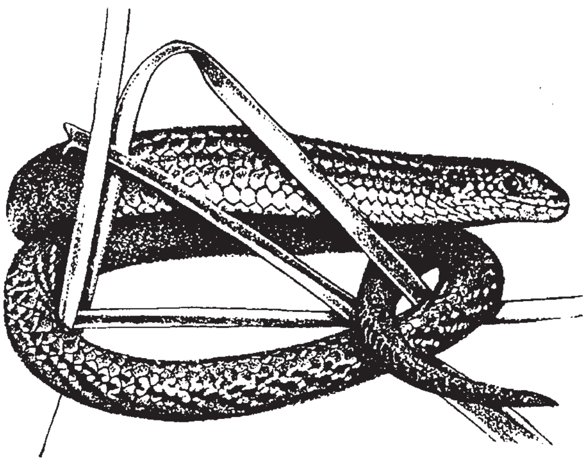


Figure 1: Striped Legless Lizard (*Delma impar*)

(Illustration: Marjorie Crosby-Fairall)

Conservation Status (ACT) Vulnerable

Criteria satisfied (ACT Flora and Fauna Committee 1995)

The species is known to occur in the ACT region and is already recognised as vulnerable in an authoritative international or national listing.

Species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the medium-term future, as demonstrated by the following:

- Current serious decline in population or distribution from evidence based on:
  - —serious decline in quality and quantity of habitat;
  - —high actual or potential levels of exploitation or persecution; and
  - —serious threats from herbivores, predators, parasites, pathogens or competitors.
- Imminent risk of serious decline in population or distribution from evidence based on the above.
- Seriously fragmented distribution for a species currently occurring over a moderately small range or having a moderately small area of occupancy within its range.

DESCRIPTION

The Striped Legless Lizard *Delma impar* (Fischer 1882) (Figure 1) is a reptile of the family Pygopodidae. The average snout-vent length of adults is 90 mm (Cogger 2000), with a maximum total length of about 300 mm and an average body weight of 4.1 grams (Coulson 1990). Sexes are externally similar.

The species is variable in colour but is most commonly pale grey-brown above, with a series of dark brown or blackish longitudinal stripes along the length of the body and tail, commencing at the neck (Cogger 2000). A large amount of variation exists between individuals in colour and intensity of the striping, and in some animals (particularly in the young), striping is indistinct or absent. The colour of the head is darker than that of the body, being dark brown to dark slate grey in adults and black in young individuals. The ventral surface has been described as whitish (Cogger 2000), however some individuals have salmon-pink coloration on the flanks that may extend to the undersurface. Most individuals have yellow coloration on the infralabial and adjacent gular scales, extending back to the tympanum (Coulson 1990). The Striped Legless Lizard can usually be distinguished from the Inornate Legless Lizard *Delma inornata*, a closely related species that also occurs in the ACT region, by the presence of stripes.

Legless lizards superficially resemble small snakes, however, they can be readily distinguished from snakes by having a visible ear opening, fleshy broad tongue, the presence of remnant hindlimbs (which are reduced to two scaly flaps near the vent) and a tail that is longer than the body, which can be voluntarily shed.

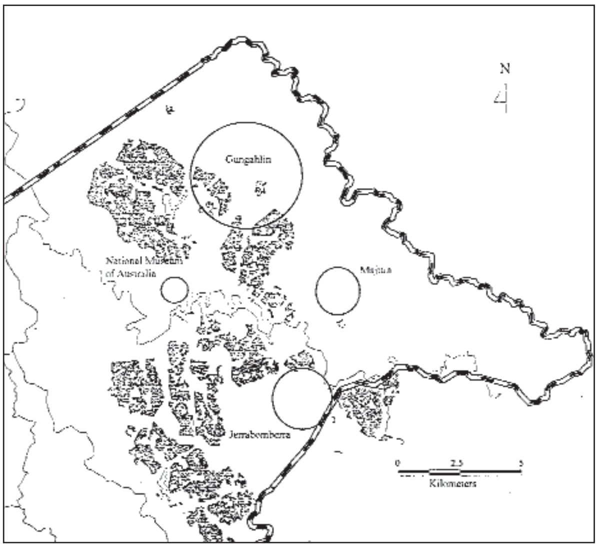


Figure 2: Four Areas Known to Support *Delma impar* in the ACT

DISTRIBUTION AND ABUNDANCE

ACT Distribution

In the ACT, the potential range of the species prior to European settlement is likely to have been within the more or less continuous area of treeless plains covering over 20 000 hectares. However, most of this area has been developed for urban and related purposes and the current distribution of the Striped Legless Lizard in the ACT is a fragmented one, with four disjunct populations recognised (Figure 2): Gungahlin, Yarramundi Reach, Majura Valley and the Jerrabomberra Valley (Rauhala *et al.* 1995). Unsuitable habitat, roads and urban development separate these sites.

Gungahlin

Three grassland reserves (Mulanggari, Gungaderra and Crace) have been established in the Gungahlin area to protect the species. It has also been found in the Kenny area and in some relatively small and isolated patches of habitat (ACT Government 1997b).

Yarramundi Reach

This small area of grassland was surveyed in 1993 and low numbers recorded (Kukolic 1994). The *Delma impar* population on the site appears to be in decline and may have become extinct.

Majura Valley

This is a large area of habitat with surveys showing the species to be present in moderate densities. To the east of the Majura Road, the habitat comprises part of the Majura Training Area and the Airservices Australia navigational beacon enclosure. To the west of Majura Road, the species has been found in the Campbell Park area but has not been fully surveyed.

Jerrabomberra Valley

The species is currently known only in the grassland to the east of Jerrabomberra Avenue on the Woden, Bonshaw and Wendover properties, as well as on HMAS Harman. In the Jerrabomberra Valley, *Delma impar* has been found in relatively low densities and is more scattered in distribution compared with the Gungahlin area.

Distribution in South-eastern Australia

The geographic range of *Delma impar* is confined to south-eastern Australia. Throughout its range, the species is considered to have suffered a substantial contraction in its distribution since European settlement.

It has been recorded from south-eastern South Australia but the area now appears unlikely to support a population (Coulson 1990; Hadden 1995). It is currently known from scattered locations in Victoria, mainly on the basalt plains to the north and west of Melbourne and in the western district of the state (Department of Conservation and Environment 1992). Surveys by the NSW National Parks and Wildlife Service in 1998–9 identified populations near Yass and Goulburn. Other records are for Cooma (1995) (Biosis Research Pty Ltd 1995) and Batlow (1977) (Cogger *et al.* 1993

HABITAT

The Striped Legless Lizard is found primarily in lowland native grasslands (Coulson 1990; Osborne, Kukolic and Williams 1993). This habitat type occurs on flat or gently undulating plains (Coulson 1990; Hadden 1995), and is dominated by perennial, tussock-forming grasses such as Kangaroo Grass *Themeda triandra*, spear grasses *Austrostipa* spp. and wallaby grasses *Austrodanthonia* spp. (Coulson 1990; Hadden 1995). The species is also found in some areas dominated by exotic grasses (Coulson 1990; Williams and Kukolic 1991; Kukolic *et. al.* 1994; Rauhala *et. al.* 1995; Hadden 1995). A tussock structure in grassland appears to be an important habitat characteristic (Wildlife Research Unit 1994; Hadden 1995), although little is known about the way in which the vegetation is utilised. There is evidence that lizards over-winter at the base of grass tussocks or just below the soil surface (Wildlife Research Unit 1994). Soils that have a moderate to high clay content and often produce cracks in summer are another habitat feature. In Victoria, most sites supporting the species have a cover of lightly embedded rocks, although this is not a feature of its habitat in the ACT (Hadden 1995).

Although the Striped Legless Lizard is found in both primary and secondary grasslands, Dorrough (1995) found that it inhabited secondary grasslands only within two kilometres of primary grasslands.

Most areas where the species persists, are thought to have had low to moderate levels of agricultural disturbance in the past (Coulson 1990; Hadden 1995; Dorrough 1995). It has been suggested (Coulson 1990; Dorrough 1995) that ploughing in particular may be incompatible with the survival of the species.

BEHAVIOUR AND BIOLOGY

The Striped Legless Lizard is known to feed on a variety of insects and arthropods including spiders, crickets, cockroaches and caterpillars (Coulson 1990; Wainer 1992; Nunan 1995). The species may display some selectivity in its diet, with *Lepidoptera* larvae (caterpillars) being implicated as a particularly important food resource (Nunan 1995).

The species is diurnal and active on the ground surface from late spring to early autumn, with a peak in activity in November and December (Kukolic 1994). Gravid individuals are commonly caught in these months, with two eggs being laid in December. There is some evidence for communal oviposition and that sometimes; eggs may be laid under rocks or other substrate (Mills 1992; Rauhala 1996). Incubation periods of between 35 and 60 days have been observed in captivity under ideal conditions; however, the incubation period is likely to be longer in the field.

The longevity of the species is not known but a maximum of ten years has been estimated (Webster *et al.* 1991; Dorrough 1995).

Appendix 5.2

Grassland Earless Dragon (*Tympanocryptis pinguicolla*)

In accordance with section 21 of the *Nature Conservation Act 1980*, the Grassland Earless Dragon (Tympanocryptis pinguicolla) was declared an endangered species on 15 April 1996 (formerly Determination No. 29 of 1996 and currently Determination No. 89 of 1997). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

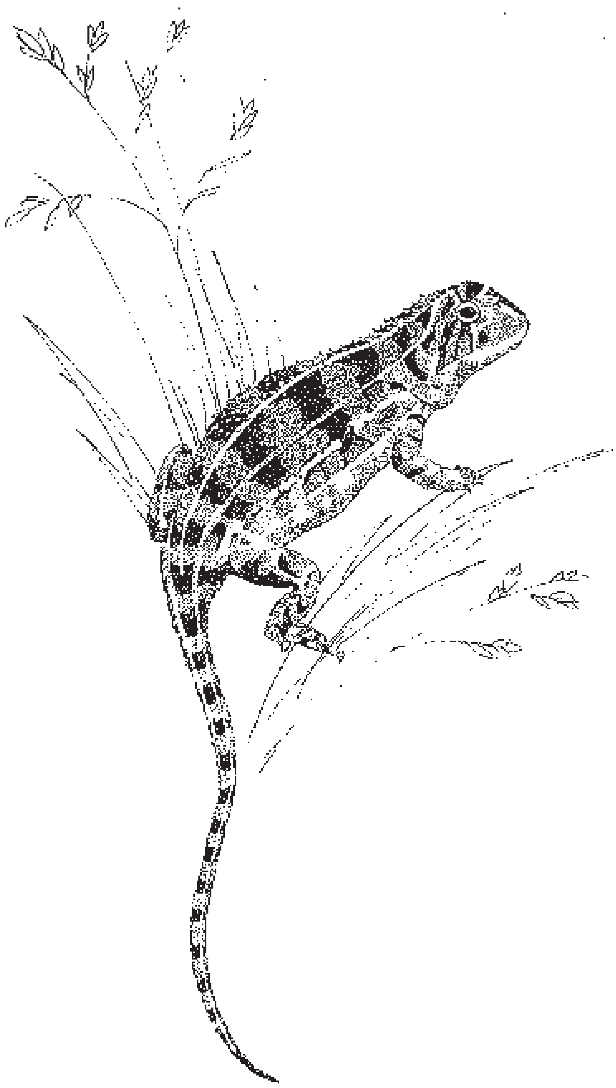


Figure 1: Grassland Earless Dragon (*Tympanocryptis pinguicolla*)

(Illustration: Liz Faull)

Conservation Status (ACT) Endangered

Criteria satisfied (ACT Flora and Fauna Committee 1995)

Species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the near future, as demonstrated by:

- Current severe decline in population or distribution from evidence based on:
  —severe decline in quality or quantity of habitat; and
  —severe threats from herbivores, predators, parasites, pathogens or competitors.
- Severely fragmented distribution for a species currently occurring over a small range or having a small area of occupancy within its range.
- Extremely small population.

DESCRIPTION

This species was originally considered to be a sub-species of *Tympanocryptis lineata* and named *Tympanocryptis lineata pinguicolla* (Mitchell 1948). Smith *et al.* (1999) reviewed the systematic status of *Tympanocryptis* in south-eastern Australia and determined that *T. l. pinguicolla* should be raised to specific status and thus be renamed *Tympanocryptis pinguicolla*. The common name has been changed from Eastern Lined Earless Dragon to Grassland Earless Dragon.

The Grassland Earless Dragon (*Tympanocryptis pinguicolla*) is a member of the family Agamidae, the dragon lizards. Most members of the genus *Tympanocryptis*, including *T. pinguicolla*, lack an external ear opening (Greer 1989) and a functional tympanum (ear drum) (Witten 1993).

T. pinguicolla is a small lizard with a stout body and short robust limbs (Figure 1). Total adult body length is between 180 and 210 mm (Smith 1994). These lizards have three longitudinal light stripes on the dorsal surface and the ventral surface is either intricately patterned with dark brown or grey markings or immaculate white or cream. They are diurnal and are cryptic in their grassland habitat. When captured, individuals can be identified from distinct grey and dark brown dorsal surface markings (Nelson *et al.* 1996) that usually form thick irregular transverse bars across the body and down the tail. Many individuals exhibit yellow or orange flushing of the throat that sometimes extends to the sides of the head and down the dorsal stripes and flanks (Smith 1994). Differentiation of these markings occurs between sexes and age classes (Langston 1996). Specimens usually have a narrow pale bar on their head between the anterior corners of the eyes (Cogger 2000).

T. pinguicolla is distinguished from other *Tympanocryptis* in south-eastern Australia by its greater number of mid-body dorsal scales and greater number of scattered dorsal spinous scales which are also higher than their basal width (Mitchell 1948; Smith 1994; Smith *et al.* 1999).

DISTRIBUTION AND ABUNDANCE

Former Distribution

In 1938 Pryor described the species as more common than the Brown Snake (*Pseudonaja textilis*) in the ACT, and animals were captured adjacent to Northbourne Avenue in the 1950s (Pryor 1938; Young 1992).

NSW records show that the species occurred near Cooma in the Southern Tablelands (Mitchell 1948) and at Bathurst (Osborne, Kukolic *et al.* 1993).

Most former records of *T. pinguicolla* in Victoria are from the basalt plains in the south of the state (Brereton and Backhouse 1993). There are also records from Maryborough and Rutherglen in central Victoria (Lucas and Frost 1894).

Present Distribution

T. pinguicolla has shown a dramatic decrease in its geographical range. The species is found in small and seasonally variable numbers in seven sites with suitable native grassland habitat in the Majura and Jerrabomberra valleys in the ACT and at 'Letchworth' near Queanbeyan in NSW (Figure 2). The lizards have also been recorded at several sites near Cooma (Osborne, Kukolic and Williams 1993; Biosis Research Pty Ltd 1995).

From the early 1990s considerable survey and research effort has been directed towards the species. The Action Plan for the species (ACT Government 1997c) identified survey and monitoring as important components of the conservation management of the species. Surveys have been undertaken of areas of potential habitat and a monitoring program of known populations is in place (e.g. Dunford et al. 2001; Evans and Ormay 2002).

Surveys of potentially suitable habitat at the Belconnen Naval Station, in areas outside of Public Land Nature Reserve, and in the Crace and Mulanggari grassland reserves at Gungahlin have failed to locate the species (Kukolic 1992; Nelson et al. 1996; Dunford et al. 2001; Evans and Ormay 2002). Similarly, Langston (1996) surveyed for the species in the Gundaroo, Bungendore and Hoskingtown areas without success. In 2000, the NSW National Parks and Wildlife Service conducted surveys for the species in the Bungendore and Goulburn areas but none were found.

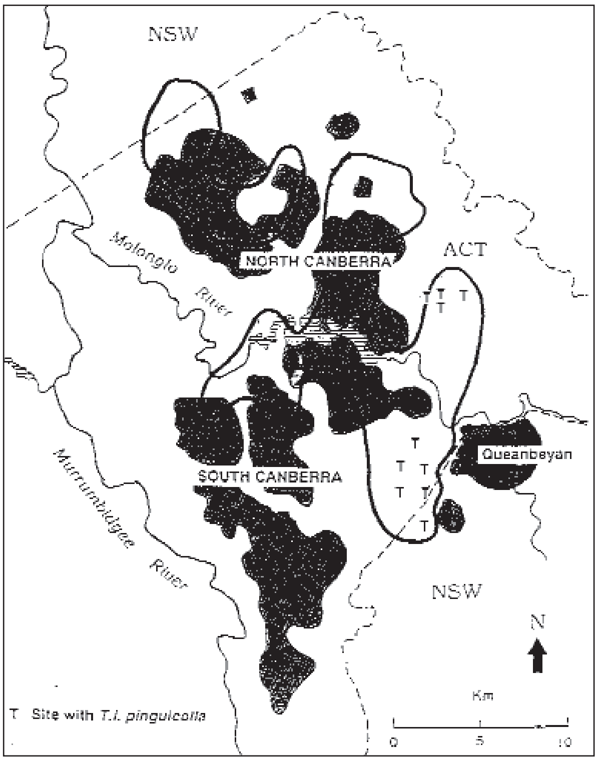


Figure 2: Distribution (T) of *Tympanocryptis pinguicolla* in the ACT and adjacent region. Former extent of natural temperate grassland outlined.

HABITAT

Observations in the ACT and region indicate that *T. pinguicolla* is found in Natural Temperate Grassland dominated by wallaby grasses (*Austrodanthonia* spp.), spear grasses (*Austrostipa* spp.), Kangaroo Grass (*Themeda triandra*) and tussock grasses (*Poa* spp.) (ACT Government 1997c; Robertson and Cooper 2000). Capture locations in the ACT suggest that the animals prefer well-drained Natural Temperate Grasslands that are relatively undisturbed and minimally pasture-improved. Nelson *et al.* (1998) also recorded the species in *Austrostipa* dominated grassland with low diversity, which had been modified by pasture improvement and weed invasion. There appears to be a preference for shorter grassland with an open structure or with open areas, however, the patchy occurrence of *T. pinguicolla* within such areas may indicate a more subtle relationship of the species to its grassland habitat (Robertson and Cooper 2000).

T. pinguicolla makes use of arthropod burrows and may retreat into these when alarmed. It also shelters beneath rocks (Victoria, Monaro region NSW) and within *Austrostipa* tussocks (ACT) (Robertson and Cooper 2000).

BEHAVIOUR AND BIOLOGY

Most of what is known about the biology and ecology of *T. pinguicolla* is derived from university research and project work in the last decade (Smith 1994; Langston 1996; Nelson 2004) and survey and monitoring by Environment ACT. Field observation is difficult because *T. pinguicolla* avoids detection by remaining still and uses its cryptic coloration to blend in with its grassland environment (Smith 1994).

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) indicating a predominantly annual turnover of adults. This turnover suggests that females breed once and gravid females have been recorded in the field from September to January (Langston 1996). However, some females survive to their second year and may produce a second clutch (Langston 1996).

T. pinguicolla is oviparous (Witten 1993). The only two known records of egg laying are for late November and early December (Langston 1996). Both records comprised a clutch of five eggs, one in a shallow scrape that was covered with soil and small stones to disguise its presence, and the other was unintentionally disturbed with the eggs successfully incubated in the laboratory. Field incubation time has been recorded at 11 weeks and two days (Langston 1996).

Hatching occurs from January to March and hatchlings show rapid growth (mean 0.3 mm/day) approaching adult size by the end of March (Smith 1994). Adult growth rates are much slower with a mean of 0.08 mm/day (Langston 1996). The young may disperse soon after hatching as small lizards have been caught in pitfall traps.

Fat storage in the neck, body and tail is thought to be an adaptation to a cooler climate (Mitchell 1948). Animals in the *T. lineata* group have been found during winter in a torpid state under rocks (Jenkins and Bartell 1980) and in arthropod burrows (Langston 1996). However, active individuals have been observed above-ground in June and trapped in August, suggesting that individuals can be active anytime weather conditions are suitable (Robertson and Cooper 2000).

Although the sizes of home ranges of *T. pinguicolla* are unknown, individuals are highly mobile. Individual adult animals have been shown to move 40 m in a day (Langston 1996) with some movements of more than 230 m between yearly trapping seasons.

Population density may be influenced by social interactions, as aggressive encounters between individuals, involving vocalisation (using a soft hiss) and displays, have been observed in captive animals and in the field (Robertson and Cooper 2000). There appears to be a dominance hierarchy based on the size of individuals (Smith 1994).

T. pinguicolla feeds on a variety of insects, banana and apple in captivity (Robson 1968; Smith 1994). In the field, animals have been observed consuming spiders and insects, however precise field dietary requirements are yet to be determined.

Appendix 5.3

Golden Sun Moth (*Synemon plana*)

In accordance with section 21 of the *Nature Conservation Act 1980*, the **Golden Sun Moth (*Synemon plana*)** was declared an **endangered** species on 15 April 1996 (formerly Determination No. 29 of 1996 and currently Determination No. 7 of 1998). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

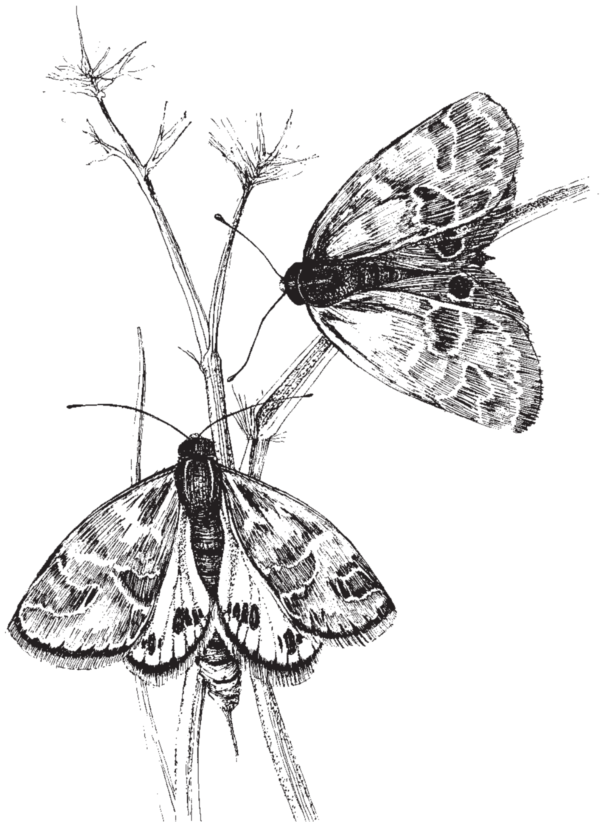


Figure 1: Golden Sun Moth (*Synemon plana*) (female—bottom left; male—top right)

(Illustration: Sarah Reglar)

Conservation Status (ACT) Endangered

Criteria satisfied (ACT Flora and Fauna Committee 1995)

The species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the near future, as demonstrated by:

- Current severe decline in population or distribution, from evidence based on:
  - —direct observation, including comparison of historical and current records; and
  - —severe decline in quality or quantity of habitat.
- Continuing decline or severe fragmentation in population, for species with a small current population.

DESCRIPTION

The Golden Sun Moth (*Synemon plana*) is a medium sized moth belonging to the family Castniidae, which is thought to be of Gondwanan origin (Edwards, 1990). The male has a wingspan of about 34 mm, the female about 31 mm. This larger male wingspan is unique in the Australian Castniidae. The upperside of the forewing of the male is dark brown with patterns of pale grey scales and the hind wing is dark bronzy brown with dark brown patches. The underside of both wings of the male is mostly pale grey with dark brown spots. The upperside forewing of the female is very dark grey with patterns of pale grey scales and the hind wing is bright orange with black submarginal spots. The underside of both wings of the female is silky white with small black submarginal spots. The adults have no functional mouthparts. They have strongly clubbed antennae and the female has a long extensible ovipositor. Coloured illustrations may be found in Common (1990) and Fraser and McJannett (1996).

DISTRIBUTION AND ABUNDANCE

At the time of European settlement, *S. plana* was widespread in south-eastern Australia and relatively continuous throughout its range, showing a close correlation with the distribution of native grasslands dominated by *Austrodanthonia* spp. (O'Dwyer and Attiwill 1999a). Museum records show that *S. plana* was still common and widespread prior to 1950, before the advent of extensive pasture improvement and other land use changes that have reduced native grasslands to scattered fragments.

The known distribution of the species from museum specimens extended from Bathurst, NSW, through the

Southern Tablelands of NSW and central Victoria to the South Australian border (Edwards 1993). There are about 30 localities in Victoria represented by museum specimens.

Currently, the species is known from 27 sites in the ACT of various sizes, 42 sites in NSW, and nine sites in Victoria. In the ACT, the species occurs in lowland areas adjacent to the city of Canberra and within the city. There are extensive populations within the Majura Training Area, 'Malcolm Vale', Canberra International Airport and the Belconnen Naval Station. Less extensive populations occur within large grassland sites at 'Woden' property in the Jerrabomberra Valley and in the Mulanggari and Crace Grassland Reserves in Gungahlin. Together, these make up the eight sites of high conservation value. Smaller sites at Campbell Park, York Park in Barton, Mulligans Flat (North and South), North Mitchell, Black Street and Stirling Ridge in Yarralumla and the Dunlop Hills Grassland Reserve in Belconnen contain populations of high to moderate density (Edwards 1994). A further eleven sites contain very small populations, which may not be viable in the short to medium term.

The 42 NSW sites are found within grassland and grassy woodlands near Yass, Boorowa, Binalong, Rye Park, Sutton, Gundaroo, areas immediately north of the ACT, and at Queanbeyan and Tumut (Clarke and Dear 1998). All sites are below 700 m (with the exception of one site south of Queanbeyan recorded at 790 m), suggesting that *S. plana* is a western species at the limit of its range. The survey by Clarke and Dear (1998) did not locate any populations in the Goulburn, Tarago and Bungendore areas, or on the Monaro (Bredbo, Cooma, Adaminaby and Dalgety).

Population estimates for *S. plana* at ACT and NSW sites vary from a few hundred to more than 100 000 individuals (Ginninderra Road and Letchworth, NSW)(Clarke and Dear 1998; ACT Government 1998a). One population estimate based on monitoring is from the small (0.4 ha) site at York Park, Barton, ACT. Population size estimates of males at York Park were 520 (1992–3), 456 (1993–4) and 736 (1994–5) or a mean for the three years of 571 (Harwood *et al.* 1995). This gives a crude population of 1700 males per hectare. There is no information about the sex ratio in adult S. plana, and the females are much more inconspicuous than the males, therefore no female population estimates were attempted at York Park. A 1:1 sex ratio would give a population density of 3500 per hectare. A two-year life cycle would mean that double the number of adults observed is potentially present, but the genetic interchange between the odd and even cohorts may be low.

Population estimates are crude and refer to the number of adults in the population (census size) not the actual number of individuals contributing to the next generation (effective size). Based on census data from a single ACT site, it is estimated that up to 99% of female fecundity is unrealised, through either adult or immature immortality (Clarke and O'Dwyer 2000). Small sites may be less viable than the observed population size would indicate. It is the effective population size that is critical in assessing the extinction risk of a population.

HABITAT

The habitat of *S. plana* is native grassland dominated by wallaby grasses *Austrodanthonia* spp., in particular, *A. carphoides*, *A. auriculata*, *A. setacea* and *A. eriantha*. In a study of eight ACT sites and six Victorian sites (four current, two historical), O'Dwyer and Attiwill (1999a) found that the percentage cover of *Austrodanthonia* at currently inhabited sites was 40% and soils were low in available phosphorus. Weed invasion is a major threat to *Austrodanthonia* on these sites (O'Dwyer and Attiwill 1999b).

In the ACT, *S. plana* usually occurs in Natural Temperate Grassland dominated by *Austrodanthonia carphoides*. Some populations of the moth at Mulligans Flat occur in grassy areas within open woodland, but all other sites are believed to have been treeless grassland prior to European settlement. In the ACT, these grasslands are not found at an altitude above 630 m. Areas dominated by *A. carphoides* occur in grasslands containing *Austrodanthonia* or *Austrostipa* associations, and may occur in patches in Dry *Themeda* grasslands. Wallaby grass is very low growing with tussocks usually separated by bare ground. These grasslands normally contain several species of *Austrodanthonia* and the species actually fed on by the moth larvae are uncertain.

In NSW, *S. plana* is also found in grasslands dominated by *Austrodanthonia setacea* and *A. auriculata* as well as *D. carphoides* (Clarke and Dear 1998)

In Victoria, *S. plana* may be found in grassland dominated by *Austrodanthonia setacea* (Douglas 1993), *A. pilosa* (Britten *et al.* 1995) and *A. eriantha* (O'Dwyer and Attiwill 1999a, 1999b). Field studies at Mt Piper, where a large *S. plana* population remains, indicate that the habitat of *S. plana* is native grassland dominated by *Austrodanthonia eriantha*, with a smaller cover of *A. auriculata*, *A. carphoides* and *A. racemosa* (O'Dwyer and Attiwill 1999b). A 40% cover of

Austrodanthonia has been shown to be the minimum density required to sustain a *S. plana* in Victoria (Dear 1997; O'Dwyer and Attiwill 1999a).

BEHAVIOUR AND BIOLOGY

The life history of *S. plana* is not fully understood. Common and Edwards (1981) described the life history of *S. magnifica* and the life history of *S. plana* is probably similar (E.D. Edwards, pers. comm. 1996 in O'Dwyer and Attiwill 1999a). The following summary of the life history of the species is drawn mainly from ACT Government (1998a) and Clarke and O'Dwyer (2000).

Most of the life cycle of *S. plana* is in the pre-adult stage. Adults are short lived (1–4 days) and do not feed, having no functional mouthparts. Five days is the longest recorded life span for the male but 1–2 days is normal (Cook and Edwards 1993). Males spend their entire adult life patrolling grassland for females, and females, once mated, spend their time laying eggs within clumps of *Austrodanthonia*. Females are reluctant to fly, even when disturbed, and walk between grass tussocks. Males are capable of active and prolonged flight, usually about one metre above the ground, but will not fly long distances (more than 100 m) from areas of suitable habitat. Thus populations separated by more than 200 m can be considered effectively isolated, and sites from which the moth has gone extinct, or vacant patches of suitable habitat are highly unlikely to be (re)colonised.

S. plana is a day flying moth, active in the warmest part of the day (1000–1400 h) and only under sunny conditions. The flying season is relatively short (6–8 weeks) mainly in November and December, but to early January in the ACT. Warm dry spring weather may result in earlier emergence while cool moist conditions may delay emergence until late November (Cook and Edwards 1993). Adult emergence continues throughout the flying season.

Females are estimated to lay 100–150 eggs (Edwards 1994). It is not known if they are laid singly or in clusters on grass clumps. Eggs are laid between the tillers of an *Austrodanthonia* tussock or between the tillers and the soil. They are inserted into the crevices by the long ovipositor of the female. The larvae feed on the underground parts of the *Austrodanthonia*. Whether the larva needs a single tussock for development or must move between tussocks to complete its development is unknown. The length of the life cycle is unknown, but may vary between one and three years. As noted above, up to 99% of total potential fecundity is unrealised, through either adult or immature mortality but levels of these are not known. Predation of adults has been observed at York Park, Barton, by several species of birds including the Willie Wagtail (*Rhipidura leucophrys*), the Magpie Lark (*Grallina cyanoleuca*), the Starling (*Sturnus vulgaris*) as well as robber flies (*Colepia abludo* and *Brachypogon* sp.) (Cook and Edwards 1993, 1994). Some reptiles may also be predators. No parasites or predators of the early stages have been recorded.

Clarke and O'Dwyer (1998, 2000) assessed the levels of genetic variation and diversity, and investigated patterns of population structure, in a sample of 20 populations of *S. plana* throughout its geographic range (Victoria, ACT, NSW). Genetically, the populations clustered into five distinct groupings corresponding to geographic locations of the populations. The Victorian group (two populations) is significantly different genetically from the other four groupings, and the two Victorian populations, 220 km apart, are significantly different from one another. These results conform to an isolation by distance model, in which genetic distance is correlated with geographical distance.

The level of genetic differentiation among groups may be sufficient for each group to be subject to separate conservation management in an effort to conserve as much genetic diversity as possible for the species. The average genetic differences between the Victorian group and the other four groups can be considered quite high and typical of values that distinguish sub-species or races. Given the limited mobility of the species, the lack of differentiation between closely located populations may indicate that these were all historically connected and have only recently undergone fragmentation.

Appendix 5.4

Perguna Grasshopper (*Perunga ochracea*)

In accordance with section 21 of the *Nature Conservation Act 1980*, the **Perunga Grasshopper (*Perunga ochracea*)** was declared a **vulnerable** species on 19 May 1997 (formerly Instrument No. 89 of 1997 and currently Instrument No. 192 of 1998). Section 23 of the Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration. The Action Plan requirements are incorporated into this *Lowland Native Grassland Conservation Strategy*.

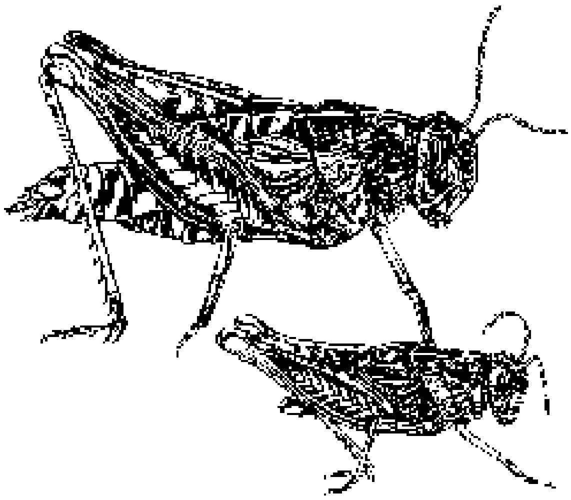


Figure 1: Perunga Grasshopper (*Perunga ochracea*) (Female (above) and male (below))

(Illustration: Fiona Sivyer)

Conservation Status (ACT) Vulnerable

Criteria satisfied (ACT Flora and Fauna Committee 1995)

The species is observed, estimated, inferred or suspected to be at risk of premature extinction in the ACT region in the medium-term future, as demonstrated by:

- Current serious decline in population or distribution, from evidence based on:
  - —direct observation, including comparison of historical and current records; and
  - —serious decline in quality or quantity of habitat.
- Seriously fragmented distribution for a species currently occurring over a moderately small area of occupancy within its range.

DESCRIPTION

The Perunga Grasshopper, *Perunga ochracea* is the only described species in the genus (Orthoptera: Acrididae: Catantopinae). The Australian National Insect Collection (ANIC), Canberra, has specimens also of an undescribed species (designated as *Perunga* sp. 1), known only from South Australia. *Perunga* belongs to the sub-tribe Apotropina of the tribe Catantopini (Rentz 1996). Members of the sub-tribe 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 (Figure 1).

The species is distinctive in having the pronotum (the dorsal surface of the first thoracic segment) wrinkled and slightly extended caudally. In the Canberra region, the species is distinguished further by the appearance on the pronotum of a pale 'X' (D. Rentz pers. comm.), which is the most useful field identification characteristic. The wings are shorter than the length of the pronotum and possess many raised longitudinal veins. Adult females range in length from 26–35 mm and adult males from 15–20 mm. Males possess short, rounded furculae and simple, elongate cerci (the pair of appendages at the apex of the abdomen), each with a blunt, rounded tip which is slightly deflexed. Females bear very short, stout cerci and the dorsal ovipositor valves are strongly recurved. Adults are variable in colour, ranging from brown to grey and often with green. Colour 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.). A colour photograph is found in Rentz (1996).

DISTRIBUTION AND ABUNDANCE

Perunga ochracea has been collected mainly as individuals or in low numbers, though population densities may vary among years and sites (ACT Government 1999).

The species was first described from Wagga Wagga in NSW. Until the collection of individuals in surveys in 1997–1998, and one individual taken at Mt Majura in 1992, all specimens in the ANIC were collected prior to 1970. They came from near Wagga Wagga (at Uranquinty), Boorowa or nearby Galong, or from the ACT and adjacent areas of NSW, including Jeir, Murrumbateman and Queanbeyan. Localities in the ACT where ANIC specimens of *P. ochracea* had been collected include Black Mountain, Gungahlin, 1.6 km SW of Hall, 3.2 km NE of Kambah Pool, at the foot of Mt Stromlo, at Reid and near Weetangera.

In 1975–76 *P. ochracea* was recorded from specific localities in Tuggeranong (now the suburbs of Calwell and Gordon) and the lower slopes of Mt Jerrabomberra (in areas that are now housing estates). There are also records from sites on the edge of Naas Road north of the junction of the Gudgenby and Naas rivers and near the cork oak plantation adjacent to William Hovell Drive (R.C. Lewis pers. comm.).

In 1997–8 *P. ochracea* was found in Natural Temperate Grassland in the Mulanggari, Gungaderra and Crace Nature Reserves at Gungahlin, in the Majura Valley (Majura Training Area, Air Services Australia Beacon site and the Campbell Park paddocks), in the Jerrabomberra Valley ('Woden' property) and in Belconnen Naval Station (Stephens 1998, Dunford pers. comm.). In addition, a female specimen was collected in the grassland at Letchworth Housing Estate near Queanbeyan in December 1997 (Stephens 1998). More recently, new sites have been found in Natural Temperate Grassland in the Jerrabomberra Valley (2001–2) and a single specimen at East O'Malley (2002). A new population has also been located in NSW.

On the basis of ANIC and other records, it is suggested that the species has a small range stretching 180 km east-west and 150 km north-south. However, the area of occupancy within this range is likely to be low because of the reduction in size or extinction of populations through habitat alteration and fragmentation. The ANIC records and recent collections suggest that the species was once quite widespread across the ACT.

No population studies have been undertaken, therefore it is impossible to estimate population sizes.

HABITAT

In the ACT, *P. ochracea* has been found in both Natural Temperate Grassland dominated by *Danthonia* spp., *Stipa* spp. or *Themeda triandra*, and in native pasture (Stephens 1998, M. Dunford pers. comm.). The species may also occur 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. Field observations suggest that the species uses grass tussocks as shelter spaces. Stephens (1998) recorded several individuals in heavily grazed habitats, where the availability of dense grass tussocks was low. Despite this, these individuals were found in or near grass tussocks, suggesting they are an essential habitat requirement.

BEHAVIOUR AND BIOLOGY

P. ochracea is a cryptic grasshopper which is difficult to see unless first disturbed. When disturbed, the species 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). This is unusual compared with most other ACT grasshopper species that overwinter as eggs rather than nymphs. Adults of *P. ochracea* have been collected from late October to mid February (ANIC specimens). The life cycle is a single year.

It has been suggested that *P. ochracea* has a dietary relationship with *Chrysocephalum* spp. (Rentz 1996), largely due to collection of the species at sites containing these forb species, particularly Common Everlasting (*Chrysocephalum apiculatum*). Dietary analysis undertaken by Stephens (1998) found that all six individuals of *P. ochracea* examined had consumed forb species. *Perunga* sp. 1, from South Australia, has been recorded eating several species of forbs, both flowerheads and leaves. In feeding trials, *Perunga* sp. 1 readily fed on the petals and flowers of Capeweed (*Arctotheca calendula*) and less so on wild geranium (*Erodium* spp.) and *C. apiculatum* (P. Birks pers. comm.). Although Stephens (1998) ultimately made no attempt to determine the exact forb species that *P. ochracea* was eating, there was no evidence from crop contents that the individuals collected had consumed *C. apiculatum*, despite this forb species being present where the individuals were collected.

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 other studies of grasshopper assemblages (e.g. Belovsky and Slade 1993).

FIGURE 2.2

Estimated pre-1750 and current distribution of lowland native grassland in the Australian Capital Territory

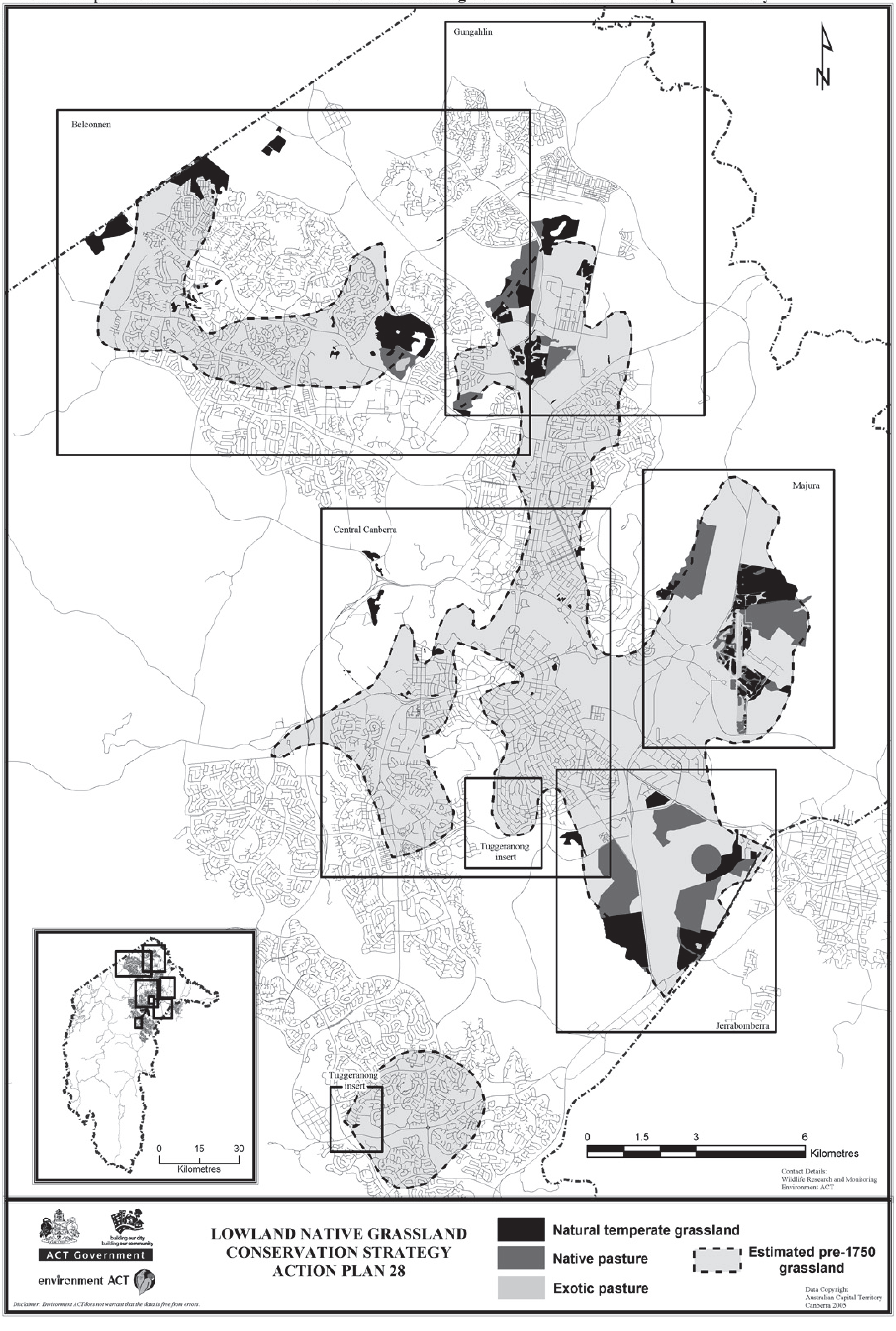


FIGURE 2.3

Majura Valley: Lowland Native Grassland and Threatened Species

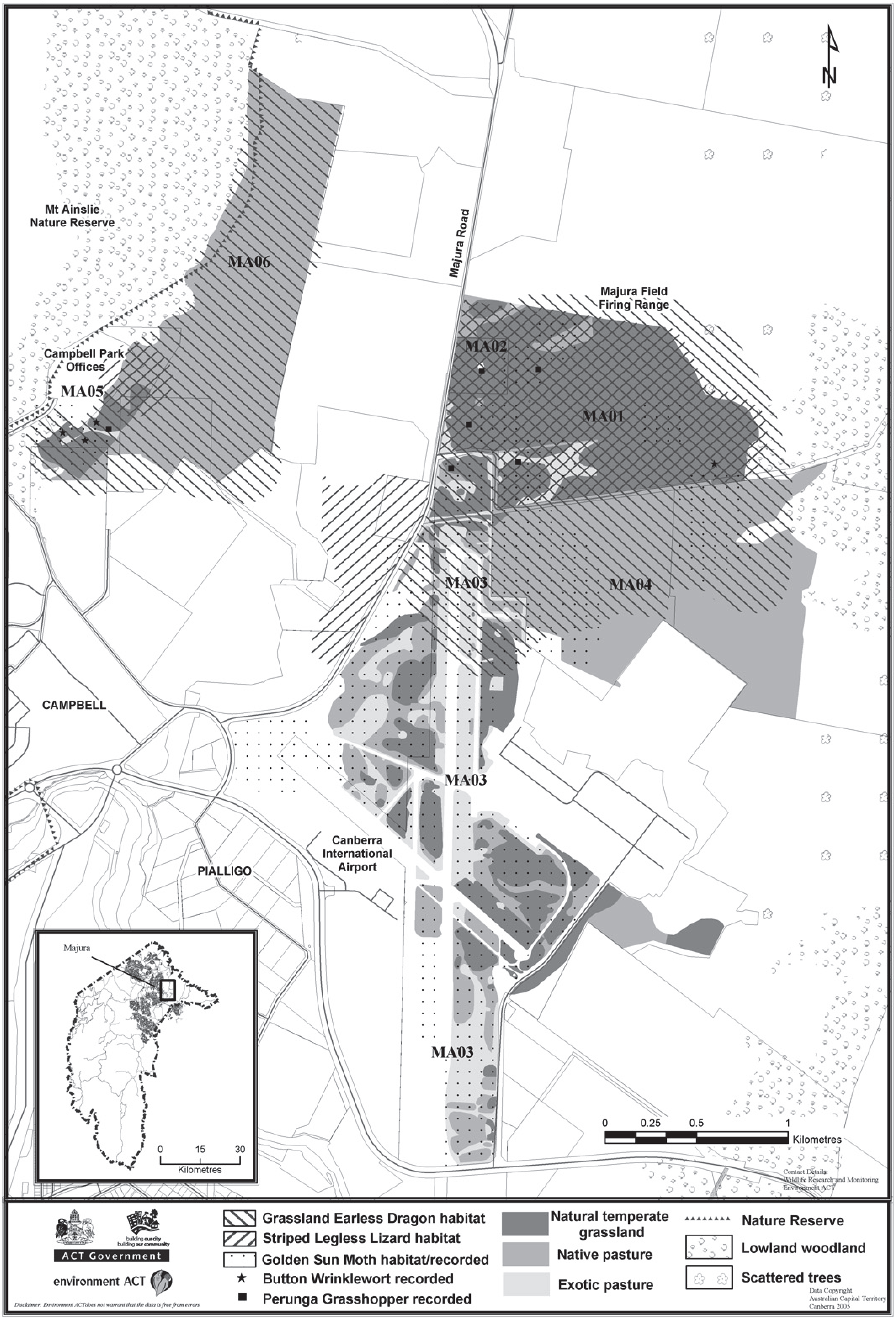


FIGURE 2.4

Jerrabombera Valley: Lowland Native Grassland and Threatened Species

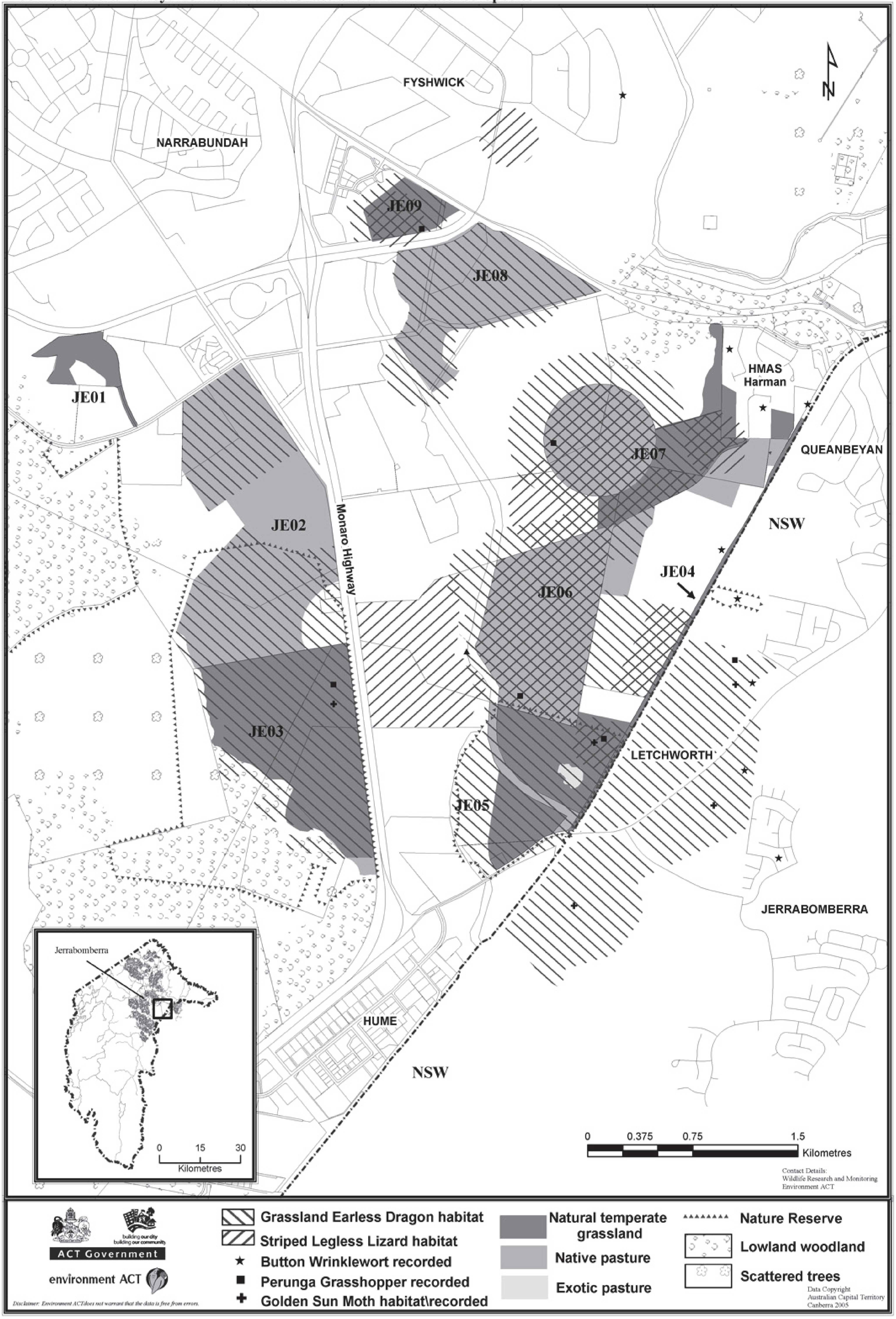


FIGURE 2.5

Gungahlin: Lowland Native Grassland and Threatened Species

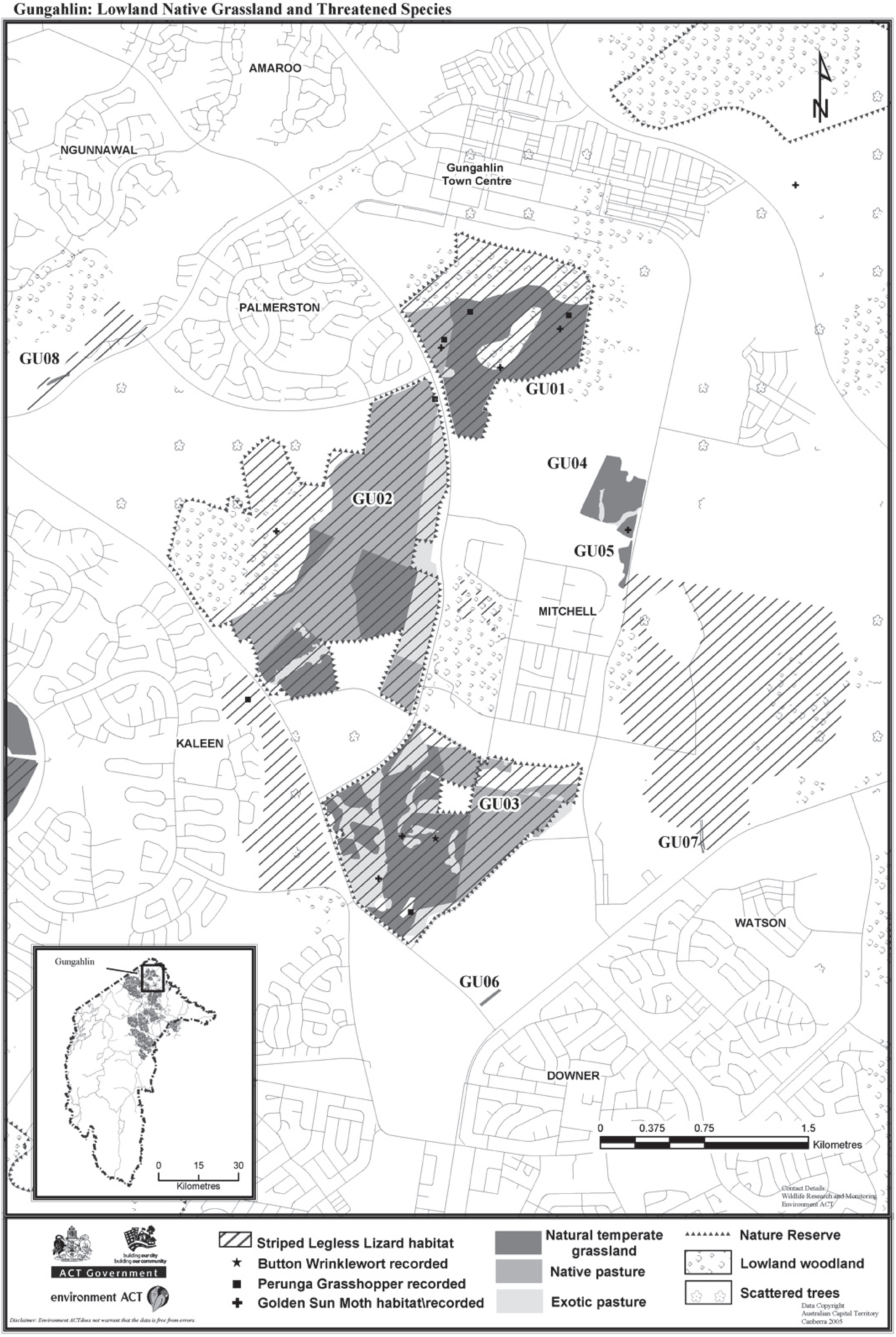


FIGURE 2.6

Belconnen: Lowland Native Grassland and Threatened Species

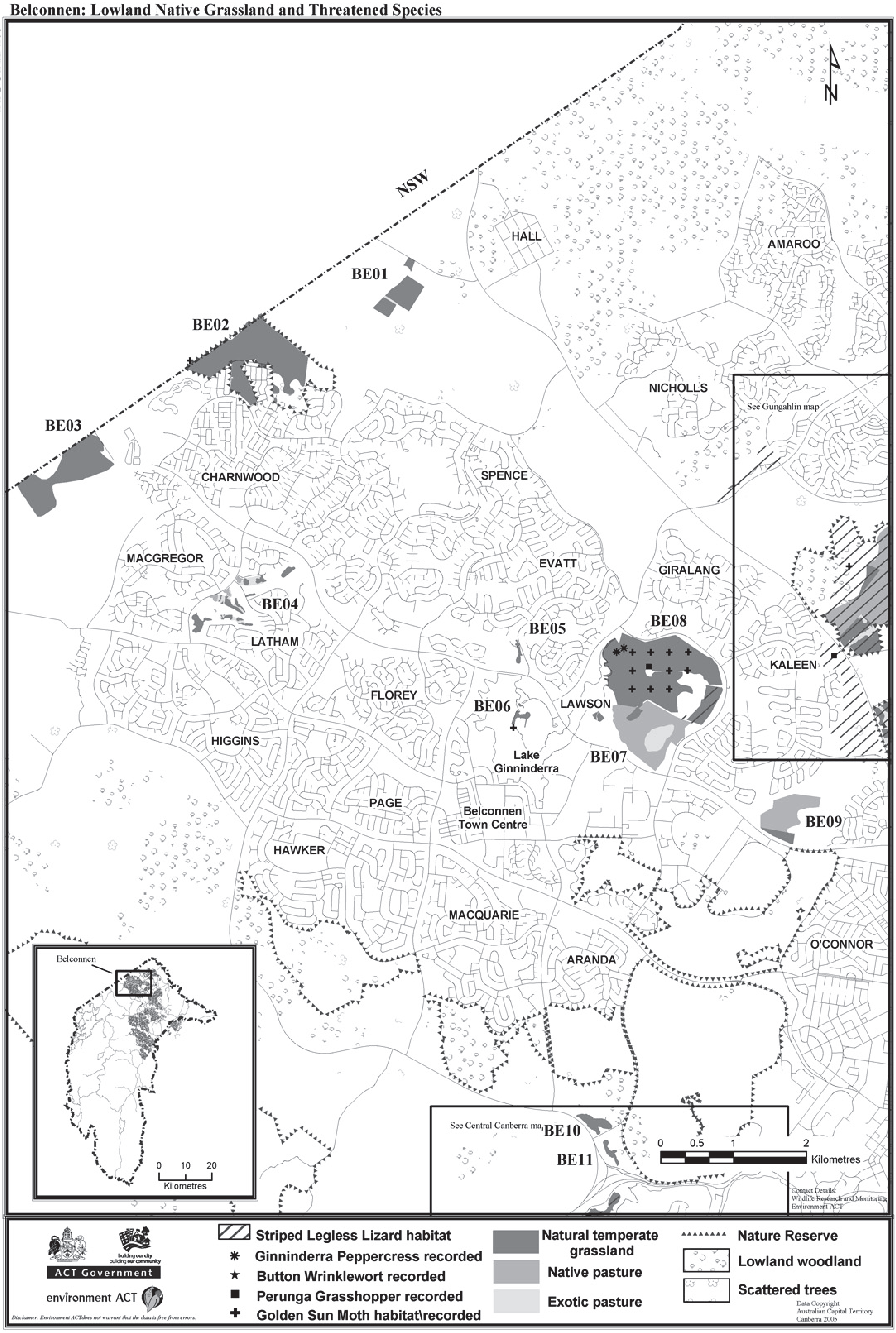
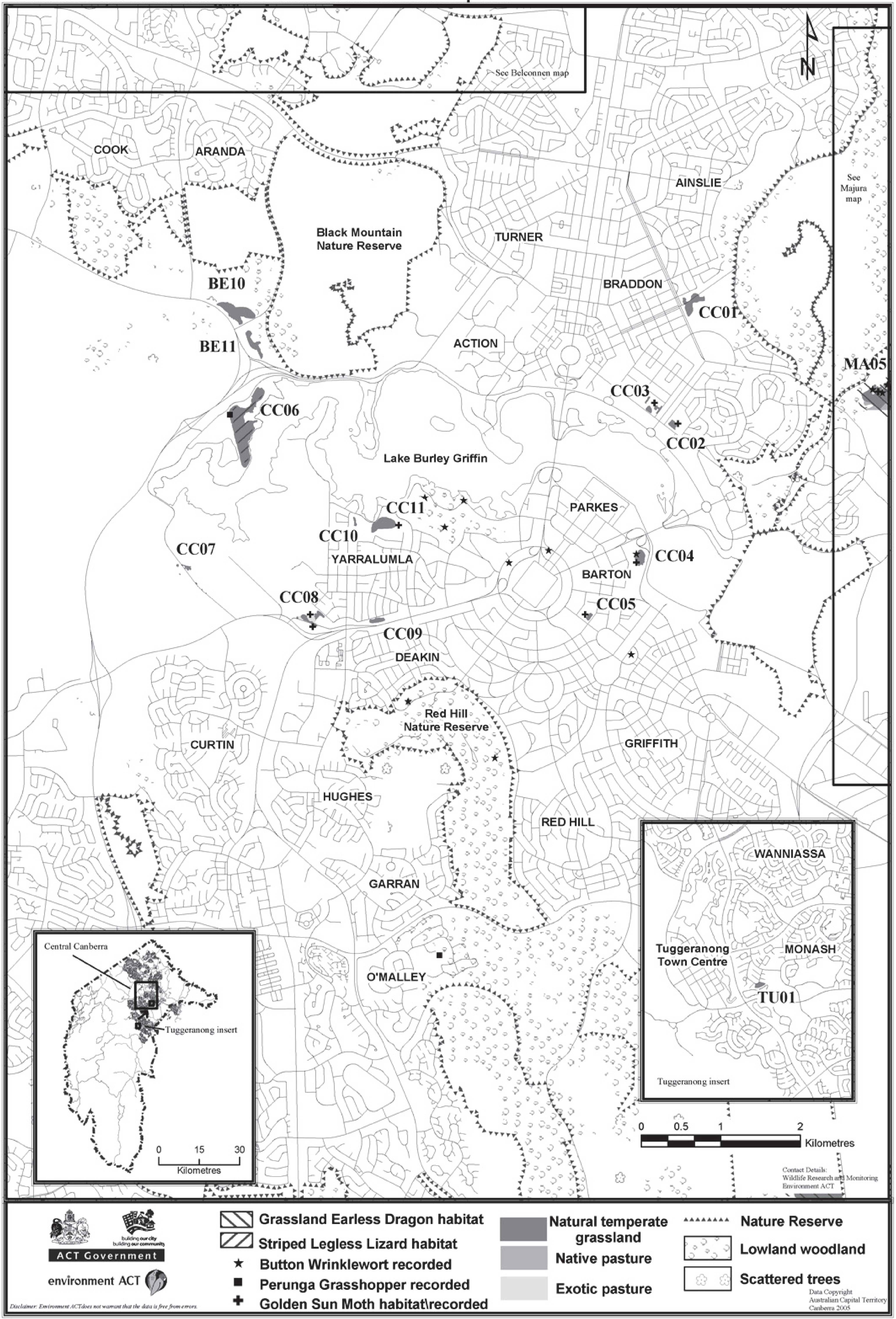


FIGURE 2.7

Canberra Central: Lowland Native Grassland and Threatened Species



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ACT Government

ACT NATIVE GRASSLAND
CONSERVATION STRATEGY AND ACTION PLANS

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CONTENTS

PART A CONSERVATION STRATEGY

FIGURES

TABLES

CONTENTS

PART B ACTION PLANS

VISION

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

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

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

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

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

Native grasslands are a unique ecosystem that warrants care and attention. Grasslands are distinctive in that they require active management (Williams and Marshall 2015) to conserve them. Without active management these grasslands will continue to degrade. By working together we can conserve these areas for now and the future.

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

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

1. INTRODUCTION

1.1 OVERVIEW

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

1.2 CONSERVATION GOALS OF THE STRATEGY

This ACT Native Grassland Conservation Strategy provides the strategic context for the protection, management and restoration of native grasslands in the ACT. As outlined in the previous section, the Vision Statement for strategy is:

> *"Healthy native grasslands supporting a diverse flora and fauna for now and the future"*

To achive this vision, the strategy is organised around the following conservation goals:

1.2.1 Protection goals (Chapter 2)

- Conserve all remaining areas of native 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 linkages, or contribute significantly to threatened species conservation, or are a priority for rehabilitation.
- Conserve viable wild populations of native grassland flora and fauna species in the ACT, and support local, regional and national efforts towards conservation of these species.

1.2.2 Threat management goal (Chapter 3)

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

1.2.3 Management goal (Chapter 4)

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

1.2.4 Ecosystem function and connectivity goal (Chapter 5)

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

1.2.5 Monitoring and research goal (Chapter 6)

- Sound research, monitoring and adaptive management underpin the conservation of native grasslands and component species.

1.2.6 Community engagement goals (Chapter 7)

- Community groups, landholders and others are actively involved in native grassland conservation.
- An informed community supports the use of native grassland areas for conservation.

1.3 OBJECTIVES OF THE STRATEGY

Underpinning the conservation goals (previous section) of the strategy are these more specific objectives:

- Identify criteria for protection and conservation management of sites.
- Provide management principles and guidelines for the conservation and restoration/enhancement of native grasslands aligned with the strategies outlined in the ACT Nature Conservation Strategy (ACT Government 2013a).
- Provide monitoring and research priorities for the native grassland associations found in the ACT.
- Provide overaching goals and objectives for conservation of the native grasslands and component species, and provide strategic context for action plans for threatened species and the Natural Temperate Grassland ecological community.
- Describe the remaining areas of native grassland in the ACT, including a broadening of the scope since the previous strategy to include native grasslands across the full elevation range of the ACT, and grasslands (native or exotic) that may provide habitat or connectivity for grassland flora and fauna.
- Describe the floristic associations found in native grassland areas in the ACT based on current classification methods.
- Enourage and support community participation in the conservation of native grasslands and component species.

Achieving the vision, goals and objectives of the strategy will depend on undertaking the actions in the action plans. This strategy outlines principles and guidelines on which to base conservation actions.

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

1.4 SCOPE OF THE STRATEGY

The strategy considers all native grassland ecosystems of the ACT across the full elevation range from lowland grasslands in and around Canberra to the grasslands of the montane and

Ecological burn at Jerrabomberra West Nature Reserve (J. Seddon)

subalpine zones, regardless of tenure and land use. It considers the ecological value and management of native grassland, and exotic grassland (which is dominated by invasive weeds), some of which provides habitat for threatened grassland fauna.

Derived (or 'secondary') grasslands are included in the ACT Lowland Woodland Conservation Strategy (ACT Government 2004) as they are derived from cleared woodland. However, the principles for managing derived grasslands will largely be consistent with the principles in this strategy.

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

Unlike the previous strategy, this revised strategy covers all grasslands in the ACT, including rocky grasslands and grasslands that occur above 625 metres above sea level (see Chapter 8).

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

1.5 STRUCTURE OF THE STRATEGY

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

Chapter 1:

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

Chapter 2:

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

Chapter 3:

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

Chapter 4:

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

Chapter 5:

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

Chapter 6:

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

Chapter 7:

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

Chapter 8:

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

1.6 RELEVANT POLICY AND LEGISLATION

1.6.1 International and national context

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

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

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

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

1.6.2 ACT legislation

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

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

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

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

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

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

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

1.6.3 ACT policy on nature conservation and climate adaptation

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

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

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

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

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

1.6.4 ACT policy on environmental offsets

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

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

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

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

1.7 ACTION PLANS

1.7.1 Overview

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

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

The action plans associated with this strategy include:

- Natural Temperate Grassland
- Baeuerlen's Gentian (*Gentiana baeuerlenii*)
- Button Wrinklewort (*Rutidosis leptorhynchoides*)
- Ginninderra Peppercress (*Lepidium ginninderrense*)
- Golden Sun Moth (*Synemon plana*)
- Grassland Earless Dragon (*Tympanocryptis pinguicolla*)
- Perunga Grasshopper (*Perunga orachea*)
- Striped Legless Lizard (*Delma impar*)

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

1.7.2 Links between this strategy and action plans

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

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

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

1.7.3 Development and review of action plans

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

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

1.8 IMPLEMENTATION

This strategy is a thematic document, i.e. it is not site-specific, and instead deals with native grassland conservation across all sites and land tenures in the ACT. The goals of the strategy will be achieved through a variety of means, relevant to the different tenures.

Achieving the vision and goals of the strategy will depend on allocation of adequate resources to undertake the actions outlined in the action plans. Primary responsibility for implementation and coordination of this strategy on ACT public land lies with the ACT Government.

Achievement of the goals of the strategy will also require the participation of managers of Commonwealth land (Department of Defence and other Commonwealth Government departments) and private land (rural lessees, Canberra International Airport). Liaison and cooperation with NSW agencies, particularly the Office of Environment and Heritage, is an important element in implementing this strategy.

Community groups in the ACT have been instrumental in advocating for native grassland conservation, raising public awareness, and undertaking a range of on-ground grassland management and restoration activities. Ongoing (and increasing) community support and participation in native grassland conservation will be essential to achieving the goals of the strategy.

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

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

2. STRATEGY: PROTECT NATIVE GRASSLAND AND COMPONENT SPECIES

Button wrinklewort and natural temperate grasslands at Majura training area

2.1 OVERVIEW

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

The ACT contains significant remnants of the current extent of Natural Temperate Grassland in the region. These grassland remnants occur on lands that are under a range of tenures and levels of protection, including nature reserve, urban open space (generally public land under the Territory Plan), Territory land under rural leasehold, unleased Territory land, Commonwealth-owned and managed 'National Land', privately-leased Commonwealth land, and 'Designated' land (land owned by either the Territory or the Commonwealth that is under the planning control of the Commonwealth National Capital Authority) (Table 2).

Substantial areas of the remaining native grasslands are now contained within nature reserve or other areas where land management goals focus on conservation. Montane and su-alpine grasslands (see Chapter 8), which were not included in the previous (2005) strategy, but are included in this strategy, are protected in Namadgi National Park. The small size and fragmented nature of the many remaining grassland areas, and the significant development pressures on land in and around existing urban areas due to Canberra's growth, pose particular difficulties for protection and management of grassland sites. A number of high conservation-value grassland sites outside of nature reserves (including on Commonwealth land) are subject to infrastructure development proposals, and other grassland sites (including those within nature reserves), are subject to urban edge effects (weed invasion, recreation pressures, increased predation of grassland fauna by foxes and cats, requirement for fire fuel reduction though burning and slashing).

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

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

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

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

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

The Conservation Significance Categories outlined in this chapter provide a guide for protection and management priorities of individual grassland sites. Achieving the protection goals in this strategy will depend upon encouraging protection of grassland sites on land owned by other jurisdictions.

2.2 PROTECTION GOAL

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

Retain areas of native grassland in lower ecological condition that serve as ecological buffers or landscape linkages, or contribute significantly to threatened species conservation, or are a priority for rehabilitation.

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

2.3 KEY PRINCIPLES

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

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

2.4 CONSERVATION SIGNIFICANCE CATEGORIES

2.4.1 Floristic Value Score

For the purposes of protecting and managing the remaining native grasslands in the ACT, each known site has been assessed and identified as falling into a Conservation Significance Category (CSC) (Table 2, Figure 1 and Figure 2). Since the previous strategy, the ACT Government has adopted the use of the Floristic Value Score (FVS) to quantify native grassland ecological condition (or 'quality') (Rehwinkel 2015; Commonwealth of Australia 2016a). Grasslands in higher condition have higher native plant diversity and lower levels of disturbance or modification and fewer weeds. This relatively recently developed measure is widely-used for assessing grassland condition.

Definitions of major grassland classifications, including 'Grassland', 'Native Grassland' and 'Natural Temperate Grassland' are provided in Table 5 (Section 8.1). A grassland is part of the Natural Temperate Grassland of the South Eastern Highlands Critically Endangered Ecological Community under the EPBC Act (Rehwinkel 2015; Commonwealth of Australia 2016a) if it:

- is dominated by native vascular plants, and
- meets the required non-grass and indicator species composition, and
- has a FVS of 5 or more.

The FVS plays a key role in allowing an area of native grassland to be assigned to the most appropriate CSC. In addition to the ecological condition of grassland, the measures that determine the CSC of the patch are its size (area) and value as habitat for threatened species. Note that the minimum patch size considered to contain the threatened Natural

Temperate Grassland ecological community under the EPBC Act is 0.1 ha (Commonwealth of Australia 2016b). A grassland that does not meet the EPBC Act criteria for Natural Temperate Grassland is still classed as native grassland if it is dominated (> 50% cover) by perennial native species (refer to section 8.1).

In the ACT, the FVS has been assessed for grasslands known to be in high ecological condition (from previous grassland surveys and assessments using other methods). Grasslands in high condition meet the criteria for CSC 1 grasslands. The Floristic Value Score has not been undertaken for all grassland sites in the ACT that are in moderate or low condition. These moderate or low condition grasslands have not yet been assigned to either CSC 2 or 3 in this strategy (these grasslands are shown as 'other' sites in Figure 1). Determining whether a grassland site is CSC 2 or 3 will depend on detailed site inspections to assess the Floristic Value Score. Some CSC 2 or 3 sites may have development potential and so may be subject to future statutory environmental and planning approval processes.

2.4.2 Key threatened species habitat

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

2.5 CONSERVATION SIGNIFICANCE CATEGORY 1 SITES

Sites in this category meet the following criteria:

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

Sites in the ACT assessed as meeting these criteria total approximately 4500 hectares (ha) and include:

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

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

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

CSC 1 sites that have a FVS ≥ 5 and area ≥ 0.1 ha meet the criteria for EPBC listing as Natural Temperate Grassland. Some CSC 1 sites may not meet Natural Temperate Grassland criteria but are considered to be CSC 1 sites because they contain key threatened species habitat. Refer to the Natural Temperate Grassland action plan (in this document) and the ACTmapi website for locations of grasslands assessed as CSC 1, other native grasslands (CSC 2 and CSC 3) and distributions of threatened grassland fauna ACTmapi website.

2.5.1 Protection guidelines for CSC 1 grassland sites

For Territory-owned land, the appropriate level of protection for CSC 1 sites is nature reserve under the *Planning and Development Act 2007* or similar formal protection. Some CSC 1 sites are already protected in reserves, and others are protected as urban open space and are managed for conservation. For Territory leasehold land, formal protection may include ecological land management agreement or Conservator's Directions. For land that is not owned by the Territory (such as National Land) the ACT Government will encourage other landowners/agencies to conserve CSC 1 sites on their lands. Sites on Commonwealth Land (including Department of Defence land and privately leased Commonwealth land such as Canberra International Airport) are, depending on the specific site, currently given a level of protection through the EPBC Act, Commonwealth Heritage listing, management plans, access restriction and (for defence lands) formal recognition in site Range Standing Orders.

2.6 CONSERVATION SIGNIFICANCE CATEGORY 2 SITES

Sites in this category meet the following criteria:

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

CSC 2 grassland sites are those with a history of greater modification (e.g. exhibiting reduced plant species diversity, loss of disturbance-sensitive species and an increase in disturbance tolerant species, and greater weediness). These sites are generally in moderate condition and are likely to be viable in the medium term but their long-term viability may be limited by virtue of their size, low area to perimeter ratio and/or impacts from surrounding land uses. These sites may provide habitat for threatened species and may complement CSC 1 grassland sites by providing connectivity to adjacent habitat or act as a buffer to adjacent incompatible land uses.

For some of these sites, management and restoration actions might result in significant improvement in the ecological condition and therefore each site should be assessed for management priority based on expected benefit (improvement in ecological condition, improvement in habitat quality etc.) for the resources expended.

CSC 2 sites that have a FVS ≥ 5 and area ≥ 0.1 ha meet the criteria for EPBC listing as Natural Temperate Grassland. Some CSC 2 sites may not meet Natural Temperate Grassland criteria but are considered to be CSC 2 sites because they contain habitat for threatened species. Refer to the Natural Temperate Grassland action plan (in this document) and the ACTmapi website for locations of grasslands assessed as CSC 1, other native grasslands (CSC 2 and CSC 3) and distributions of threatened grassland fauna ACTmapi website.

2.6.1 Protection guidelines for CSC 2 grassland sites

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

Wallaby Grass, Common Everlasting Daisy, Natural Temperate Grassland

2.7 CONSERVATION SIGNIFICANCE CATEGORY 3 SITES

Sites in this category meet the following criteria:

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

CSC 3 grassland sites have a lower conservation value, and may or may not meet the condition thresholds to be classified as Natural Temperate Grassland (see Commonwealth of Australia 2016a). However, these sites may still contribute to conservation of grassland biodiversity. Typically, these sites include small patches (<10 ha) of native grassland (which may include Natural Temperate Grassland) in poor to moderate condition, or include threatened species habitat that is dominated by exotic grasses, such as Phalaris (*Phalaris aquatica*) and Chilean Needlegrass (*Nasella neesiana*). Many of these sites occur on small and very small urban sites and on rural leases, and/or are severely fragmented and have reduced viability as a grassland community. CSC 3 sites also include grasslands that are important as buffers between higher quality grasslands and adjacent incompatible land uses, or are important connections between higher conservation value sites. CSC 3 sites may also include grasslands that are landscape features within the urban fabric, or that provide opportunities for education or research. CSC 3 grasslands also have intrinsic value for potential restoration, and for some of these sites, management and restoration actions might result in significant improvement in the ecological condition

CSC 3 sites that have a FVS ≥ 5 and area ≥ 0.1 ha meet the criteria for EPBC listing as Natural Temperate Grassland. Some CSC 3 sites may not meet Natural Temperate Grassland criteria but are habitat for threatened species or form important ecological bufferes or landscape habitat connections. Refer to the Natural Temperate Grassland action plan (in this document) and the ACTmapi website for locations of grasslands assessed as CSC 1, other native grasslands (CSC 2 and CSC 3) and distributions of threatened grassland fauna ACTmapi website.

2.7.1 Protection guidelines for CSC 3 grassland sites

CSC 3 sites should be retained for their value as threatened species habitat or for their buffer/connectivity function. CSC 3 sites that are Natural Temperate Grassland should be retained for their potential to be restored to higher ecological condition, particularly where they serve as ecological buffers or habitat connections. Each site should be assessed as part of the outline planning, environmental assessment and development approval process. Planning and management arrangements may include agreements with non-government landholders, property management agreements with rural lessees and protection of sites within the urban fabric. These arrangements provide a means to continue the primary land use while accommodating the conservation values of these sites. Sites identified as having potential for restoration should be managed to maintain their current ecological condition until their condition can be improved.

2.8 LOCAL, REGIONAL AND NATIONAL COOPERATION

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

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

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

Table 2. List of native grassland sites in the ACT grouped by geographic location, showing land tenure, land use, size class, presence of threatened species and Conservation Significance Category (CSC). NR = Nature Reserve, BG = Baeuerlan's Gentian, BW = Button Wrinklewort, GP = Ginninderra Peppercress, GSM = Golden Sun Moth, GED = Grassland Earless Dragon, PG = Perunga Grasshopper, SLL = Striped Legless Lizard, PTWL = Pink-tailed Worm-lizard, (?) = uncertain occurance.

Name of each site by geographic area	Land tenure	Land use	Size class	Threatened species	CSC
GUNGAHLIN					
Mulanggari Grasslands NR	Territory	Reserve	50-100 ha	GSM, PG, SLL	1
Gungaderra Grasslands NR	Territory	Reserve	>100 ha	GSM, PG, SLL	1
Crace Grasslands NR	Territory	Reserve	>100 ha	BW, GSM, PG, SLL	1
Franklin Grassland	Territory	Vacant	10-50 ha	GP, GSM, SLL	1
Mitchell Grassland	Territory	Rural (agisted)	<1 ha	SLL	2/3
Kenny	Territory	Rural (agisted), proposed NR	>100 ha	SLL	1
Percival Hill NR	Territory	Reserve	<1 ha	SLL	2/3
MAJURA VALLEY					
Majura Training Area	Commonwealth	Defence	>100 ha	BW, GSM, GED, PG, SLL	1

Name of each site by geographic area	Land tenure	Land use	Size class	Threatened species	CSC
Airport Services (Beacon)	Leased Commonwealth	Airport Services	1-10 ha	GSM, GED, PG, SLL	1
Canberra International Airport	Leased Commonwealth	Airport	>100 ha	GSM, GED, PG	1
'Malcolm Vale'	Leased Commonwealth	Rural	>100 ha	GSM, GED(?)	2/3
'Campbell Park'	Commonwealth	Defence	10-50 ha	BW, GSM, GED, PG, SLL	1
Majura West	Territory	Rural	>100 ha	GSM, GED, PG, SLL	1
JERRABOMBERRA VALLEY					
'Mugga Mugga'	Territory	Reserve	10-50 ha		2/3
'Callum Brae'	Rural Leasehold	Rural	>100 ha	GED	1
Jerrabomberra West Grassland NR	Territory	Reserve	>100 ha	GSM, GED , PG	1
Woods Lane	Territory	Roadside	10-50 ha	BW	2/3
Jerrabomberra East Grasslands	Territory	Reserve	50-100 ha	GSM, GED, PG, SLL	1
Bonshaw Grasslands	Territory	Rural, proposed NR	>100 ha	BW GSM, GED, PG, SLL	1
'Cookanalla'	Rural Leasehold	Rural	50-100 ha	GED	1
Amtech East	Territory	Vacant	10-50 ha	GSM, PG, SLL	2/3
Tennant St, Fyshwick	Territory	Rural (agisted)	<1 ha	BW	1
BELCONNEN					
Ginninderra Experimental Station (CSIRO)	Commonwealth	Rural (research)	10-50 ha		2/3
Dunlop Nature Reserve	Territory	Reserve	50-100 ha	GSM	1
Jarramlee Nature Reserve	Territory	Reserve	50-100 ha	GSM	2/3
Umbagong Park, Florey	Territory	Urban Open Space	10-50 ha		2/3
Evatt Powerlines, Evatt	Territory	Urban Open Space	1-10 ha		2/3
Lake Ginninderra	Territory	Urban Open Space	1-10 ha	GSM	2/3
Lawson Hill	Territory	Urban Open Space	1-10 ha	GSM	2/3
Lawson Grasslands	Commonwealth	Defence	>100 ha	BW, GP, GSM, PG, SLL	1
Kaleen East paddocks	Territory	Hills, ridges and buffers (agisted)	10-50 ha	PG, SLL	2/3
Caswell Drive	Territory	Reserve	1-10 ha		2/3
Glenloch Interchange	Territory	Road Reserve	1-10 ha		1
Kama Nature Reserve	Territory	Reserve	10-50 ha	PTWL	1
Molonglo and Murrumbidgee River Corridors	Territory	Reserve, Rural	>100 ha	PTWL	1

Name of each site by geographic area	Land tenure	Land use	Size class	Threatened species	CSC
University of Canberra	Territory	Private Lease	1-10 ha	GSM	2/3
CANBERRA CENTRAL and TUGGERANONG					
CSIRO Headquarters, Campbell	Commonwealth	Urban Open Space	1-10 ha	GSM	2/3
St Johns Church, Reid	Territory	Urban Lease	<1 ha	GSM	2/3
St Marks, Barton	Territory	Urban Lease	1-10 ha	BW, GSM	1
York Park, Barton	Commonwealth	Urban Open Space	<1 ha	GSM	2/3
Yarramundi Grasslands, Canberra Central	Commonwealth	Urban Open Space	10-50 ha	PG, SLL(?)	2/3
Lady Denman Drive, Yarralumla	Commonwealth	Road Reserve	<1 ha		2/3
Dudley St, Yarralumla	Territory	Urban Open Space	1-10 ha	GSM	2/3
Kintore St, Yarralumla	Commonwealth	Vacant	<1 ha	BW	2/3
Novar St, Yarralumla	Territory	Urban Open Space	<1 ha		2/3
Black St, Yarralumla	Territory	Urban Open Space	1-10 ha	GSM	2/3
Isabella Pond, Monash	Territory	Urban Open Space	1-10 ha		1
Stirling Ridge	Commonwealth	Urban Open Space	1-10 ha		2/3
Tuggeranong Grassland, Tuggeranong	Territory	Urban Open Space	1-10 ha		1
SOUTHERN ACT					
Namadgi National Park	Territory	Reserve	>100 ha	BG	1

Table 2 includes grassland sites that have been identified since the previous (2005) grassland strategy. These sites include rocky grasslands in Molonglo and Murrumbidgee River Corridors and in Kama Nature Reserve, montane and subalpine grasslands in Namadgi National Park (above 625 m elevation), and small patches of native grassland at the University of Canberra, Stirling Ridge and in Tuggeranong. Grassland areas added to the ACT reserve system since 2005 are shown in Table 11 in Chapter 8.

Figure 1. Map of native grasslands in the north of the ACT showing Conservation Significance Category 1 grasslands, and 'Other grasslands' (which include Conservation Significance Category 2 and 3 grasslands, and exotic grasslands). The Conservation Significance Category is based several criteria, including grassland condition and habitat for threatened species.

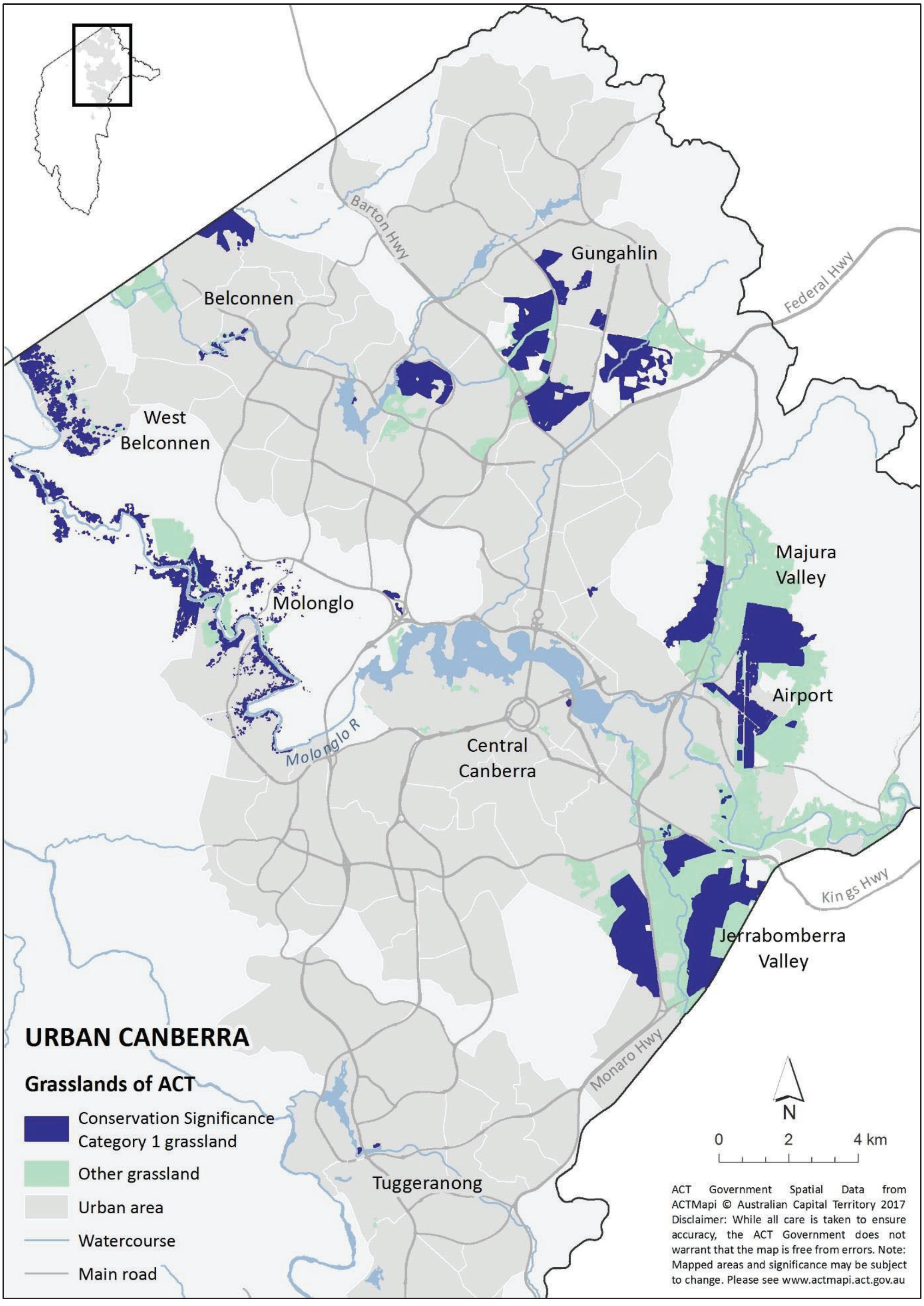
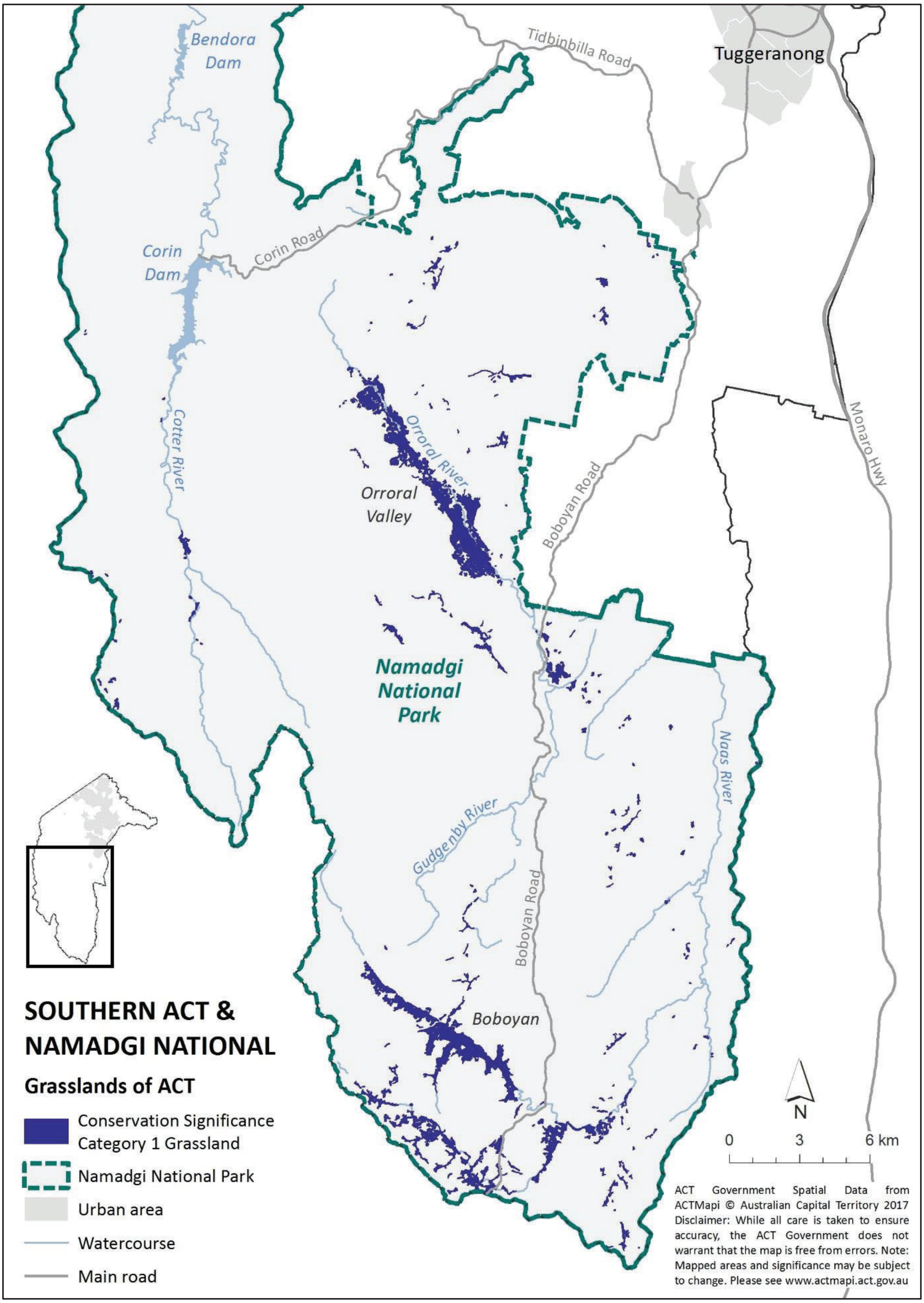


Figure 2. Map of native grasslands in the south of the ACT. All of these grasslands are Conservation Significance Category 1.



3. STRATEGY: REDUCE THREATS TO NATIVE GRASSLAND BIODIVERSITY

3.1 OVERVIEW

Native grasslands in south-eastern Australia are recognised as one of the continent's most threatened ecological communities (Gilfedder *et al.* 2008). Many of the key drivers of grassland loss in south-eastern Australia are historic in nature. By far the greatest cause of grassland loss has been agriculture, particularly the sowing of improved pasture, cropping and superphosphate application (Williams and Morgan 2015). Whilst these threats continue, grasslands are also being lost to new threats that are likely to intensify over the coming decades. Grasslands now face five major threats: (1) the long-lasting effects of historic habitat loss, (2) ongoing destruction of grasslands, (3) exotic species invasions, (4) inappropriate disturbance regimes, and (5) climate change (Williams and Morgan 2015). The consequences of climate change are likely to result in exacerbation of current threats and new threats. Managing threats is a key strategy in conserving and restoring grasslands in the ACT.

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

3.2 THREAT MANAGEMENT GOAL

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

3.3 KEY PRINCIPLES

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

- An adaptive management approach is required to achieve continuous improvement.
- Impact of the urban edge on grasslands (and ongoing conservation management costs) can be reduced at the planning stage (e.g. by allowing adequate buffers and not permitting housing on the outer edge of perimeter roads).

3.4 MANAGE WEEDS

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

Many weeds are so widespread in native grassland communities of the ACT that it is now largely impossible to control them. These include species such as Catsear (*Hypochaeris radicata*), Sorrel (*Acetosella vulgaris*) and Dandelion (*Taraxacum officinale*) and many annual grasses such as Brome Grass (*Bromus* spp.), Quaking Grass (*Briza* spp.), Hairgrass (*Aira* spp.) and Fescue (*Vulpia* spp.). Significant weeds of montaine and subalpine grasslands include Mouse-ear Hawkweed (*Hieracium pilosella*), Sweet Vernal Grass (*Anthoxanthum odoratum*), and Ox-eye Daisy (*Leucanthemum vulgare*).

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

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

3.4.1 Guidelines to manage weeds

- Follow current best practice strategies for weed management as provided in the ACT Weeds Strategy (ACT Government 2009).
- The four most serious weeds that should receive priority for control are the perennial grass species African Lovegrass (*Eragrostis curvula*), Chilean Needlegrass (*Nassella neesiana*), Serrated Tussock (*Nassella trichotoma*), and the perennial forb St John's Wort (*Hypericum perforatum*).
- Species that have been highlighted as potentially becoming major weeds in high elevation grasslands are Mouse-ear Hawkweed (*Hieracium pilosella*), Orange Hawkweed (*Leucanthemum vulgare*) and Oxeye Daisy (*Hieracium aurantiacum*) (Rowland 2012; Doherty, Wright and McDougall 2015). It is particularly important to report any sightings of these species to enable immediate action.
- Other weeds that require attention for control and eradication include Sweet Vernal Grass (*Anthoxanthum odoratum*), the annual grass Wild Oats (*Avena* spp.) (depending on rainfall), the forbs Saffron Thistle (*Carthamus lanatus*) and Paterson's Curse (*Echium plantagineum*), and woody weeds such as African Boxthorn (*Lycium ferocissimum*), Sweet Briar (*Rosa rubiginosa*), Hawthorn (*Crataegus monogyna*) and Firethorns (*Pyracantha* sp.).
- Mowing/slashing is a major cause of weed spread. It is essential that best practice

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

- To minimise weed spread during mowing/slashing, a protocol such as the 'Stop, Inspect, Protect' (NSW DPI) should be made standard for all slashing, both within and outside reserves:
  - **Stop**: do not slash invasive grass in seed and do not mow infested areas before clean areas.
  - **Inspect** and thoroughly wash down slashers between sites.
  - **Protect** native vegetation by reporting new invasive grass infestations as they are found.
- When applying control methods for a particular weed, care should be taken to prevent a 'weed-shaped hole' that allows the invasion of a second weed (Firn, House and Buckley 2010).
- Drifting of herbicides from spraying weeds onto surrounding native vegetation should be avoided.

- Appropriate action should be taken for weeds that are declared as pest plants under the *Pest Plants and Animals Act 2005* (View the Act (PDF, 167Kb)). For example, if a pest plant has been declared as notifiable, the chief executive of the relevant government agency should be notified of any sightings. Many of these pest plants are found in ACT native grasslands.
- Any sightings of weeds on the list of New Weeds, Alert Weeds and Sleeper Weeds should be reported to the Parks and Conservation Service Senior Weed Management Officer.
- If stock are used to manage grass biomass, where practical stock should be quarantined before being moved between sites to allow time for viable seed to be passed, in order to reduce weed incursion risk.

3.5 MANAGE INTRODUCED PEST ANIMALS

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

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

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

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

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

Feral horses are widespread in many Australian ecosystems, including subalpine environments. Feral horses are abundant in areas near the ACT, including Kosciusko National Park and on occasion have crossed the border into Namadgi National Park, where they are controlled. There are many documented impacts of feral horses, including soil compaction, erosion, trampling, track formation, loss of vegetation cover, weed dispersal, and species composition change in grassy areas due to grazing (ACT Government 2007; Nimmo and Miller 2007).

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

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

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

Wild dogs (mostly dingoes that have hybridised with domestic dogs) are present in remote areas of the ACT including Namadgi National Park

Serrated Tussock

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

3.5.1 Guidelines to manage introduced pest animals

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

3.6 ECOLOGICALLY INAPPROPRIATE DISTURBANCE REGIMES

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

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

In other Natural Temperate Grassland communities, overgrazing has occurred as a result of inappropriate stocking densities (sheep and cattle), high numbers introduced grazers such as rabbits, and in some instances by relatively high densities of kangaroos (see section 3.7). A review of grassland condition in the ACT (Hodgkinsn 2014) for the Commissioner for the Environment and Sustainability concluded that overgrazing by kangaroos, animal pests and domestic herbivores was a threat to some grassland sites, particularly during drought. Over-grazing can result in the simplification of grassland structural complexity, and changes in plant species composition through grazing selectivity (Morgan 2015). Unlike fire, which may be less discriminate (depending on herbage moisture and density) in herbage mass removal, grazers have preferences for grazing some species over others. For example, *Themeda triandra* is palatable to stock, and in south-eastern Australia, *T. triandra* dominated grasslands can be converted to dominance by other species under persistent livestock grazing (Lunt *et al.* 2007).

Native forbs can also be reduced or lost from the plant community if they are more palatable and are grazed preferentially, or if they are generally intolerant to disturbance (Tremont and McIntyre 1994; McIntyre and Lavorel 1994). Stock and other introduced grazers can cause physical degradation by trampling, increased nutrient inputs from animal droppings, increased weed invasion through the creation of bare ground and weed seed dispersal, soil erosion, and compaction. These impacts can be exacerbated during times of drought, leading to increased risk of drought-induced mortality for plants and soil erosion (Hodgkinson 1995).

See section 4.7 for guidelines to implement ecologically appropriate disturbance regimes.

3.7 MANAGE GRAZING BY KANGAROOS

Grazing by native herbivores is an integral ecological process in native grasslands. Eastern Grey Kangaroos are the most abundant native mammalian herbivore in grasslands and are considered to be an 'ecosystem engineer' in the ACT and region due to their dominant influence on grassland structure and resource availability for other species (ACT Government, 2010; Howland *et al.* 2014; ACT Government 2017a). Kangaroo densities can fluctuate depending on influences such as food availability (grass growth determined by weather), creation of artificial watering points (in arid areas), predator removal, fencing and habitat fragmentation.

In the ACT, high kangaroo densities in urban grassland and woodlands have resulted in overgrazing in some areas, increasing the proportion of short (<10 cm) vegetation, particularly during drought years (ACT Government 2010; Vivian and Godfree 2014). The resulting lack of variation in grass tussock structure and consequent loss of plant cover reduces the diversity of fauna species that depend on tussocks for habitat (; Antos and Williams, 2015; Howland *et al.* 2014; ACT Government 2017a).

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

3.7.1 Guidelines to avoid overgrazing by kangaroos

- Kangaroos are the preferred grazers for managing grass biomass and structure in native grasslands in the ACT (Chapter 4).
- Populations of kangaroos in the ACT should be maintained as a significant part of the

Eastern Grey Kangaroos

fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory. To avoid overgrazing by kangaroos, Eastern Grey Kangaroo populations should be managed according to the Controlled Native Species Management Plan for Eastern Grey Kangaroos (ACT Government 2017a).

3.8 MANAGE IMPACTS OF URBANISATION

Urban grasslands face a different suite of pressures compared to those in montane, rural or semi-rural areas. For example, in urban areas, pressures on grasslands commonly include dumping (of rubbish, building rubble and garden waste), high nutrient inputs, microclimate modification, trampling, trail bike riding, rock removal, frequent mowing/slashing, and roaming domestic cats, while natural disturbance regimes such as the occurrence of wildfire, are often severely modified. Weeds in urban grasslands are often garden escapees and species from waste areas (Cilliers, Williams and Barnard 2008).

Grasslands in urban areas tend to lose populations of native plant species more than those in other areas. The risk of a plant species being lost from a grassland patch increases with factors such as fragmentation (e.g. due to higher road density and urbanisation) and reduction in natural disturbances (e.g. longer intervals between fires) (Williams *et al.* 2005a, 2005b).

A thorough discussion of design and planning principles for native grasslands in urban areas can be read in Marshall (2015).

3.8.1 Guidelines to minimise impacts of urbanisation

- During the planning stages of new developments, urban edges should be designed to minimise impacts of urban areas on adjacent native grasslands (including provision of adequate buffer areas and creation of hard urban edges such as roads to minimise incursions of garden weeds and domestic animals).
- Fire fuel reduction zones that are intensively managed to protect urban assets from fire (i.e. Inner Asset Protection Zones) should be incorporated into the development area and not adjacent protected areas. For example, planning to have a sealed road between a suburb and the adjacent nature reserve provides a desirable hard edge and also serves as part of the Inner Asset Protection Zone (which may also include a mown area between the road and the nature reserve fence which can be used for cycle paths and recreational activities such as walking dogs).
- Sites adjacent to grassland remnants in urban areas should be managed to avoid adverse effects on grasslands, such as reducing run-off, weed invasion, trampling and pest animals.
- In small urban grassland remnants, avoid shading from nearby planted trees or buildings (Marshall 2015).
- Plants (including trees) that are not native to grasslands should not be planted in native grasslands set aside for conservation. Consideration should be given to removing any existing inappropriate plantings in grassland conservation areas, unless the planting is of heritage value.
- Avoid impacts from infrastructure developments in high conservation urban grassland remnants, such as laying of pipelines and hard-surface paths. Where services (e.g. cables, pipelines) are necessary they should be installed by tunnelling under the surface, not trenching, wherever possible.
- Measures should be implemented that aim to prevent activities that cause disturbance to grassland remnants, such as rock removal, topsoil removal, stockpiling or dumping of materials such as gravel and soil, fertiliser use, vehicle parking and driving though grassland sites for access, and activities that result in soil compaction and soil erosion. If disturbance is necessary, follow-up rehabilitation should be undertaken including levelling, weed removal and encouraging the establishment of native plant species from the adjacent vegetation (Eddy 2002).
- Any new residential areas developed in the vicinity of a Natural Temperate Grassland Reserve, or threatened grassland fauna habitat, should be declared cat containment areas.

- Ongoing protection and management of grassland reserves in urban areas can be enhanced by including the local community in grassland conservation and educational activities, such as through urban Landcare and ParkCare groups.

3.9 MANAGE THE CONSEQUENCES OF CLIMATE CHANGE

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

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

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

- Minimising human induced non-climate stressors, and encouraging landuse change that benefits biodiversity.
- Protecting large areas of habitat and maintaining large populations, promoting species-level genetic diversity, and enhancing connectivity to support migration and range shifts (see Chapters 2 and 5).
- Monitoring and accepting that ecosystems will adapt and change (see Chapters 5 and 6).

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

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

3.9.1 Guidelines to manage the consequences of climate change

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

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

4.1 OVERVIEW

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

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

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

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

Managing grasslands for a range of species will also rely on retaining habitat features such as burrows made by invertebrates (spiders, crickets) and where appropriate, moist areas, rocks, and scattered trees.

A key aim of this strategy is to provide a strong focus on conservation management of the remaining grassland sites in the ACT. This chapter provides goals, principles and guidelines for the management of native grasslands and threatened species habitat. The specific nature and detail of some management guidelines in this chapter (such as management of herbage mass and grassland structure) are more typical of guidelines in a management plan, and have been included in this strategy because of their crucial role in maintaining the condition of grasslands and biodiversity. Their inclusion in this strategy aims to:

- provide land managers with a convenient reference for grassland management guidelines (where relevant, management guidelines have been compiled from the individual action plans), and
- assist the development of detailed site-specific management and/or operational plans

4.2 MANAGEMENT GOAL

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

4.3 KEY PRINCIPLES

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

4.4 APPLY BEST PRACTICE WITHIN AN ADAPTIVE MANAGEMENT FRAMEWORK

There have been substantial advances in knowledge of native grassland in south-eastern Australia over the last three decades (for example, see Williams *et al.* 2015), though many aspects remain uncertain. Within an overall objective of maintaining and improving grassland biodiversity, an appropriate response to this uncertainty is to apply 'adaptive management' (Nichols and Williams 2006).

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

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

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

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

The ACT Conservator of Flora and Fauna will encourage best practice conservation management actions for native grasslands to be

Dry tussock grassland at Cotter Flats

undertaken in an adaptive framework and facilitate the incorporation of monitoring and research results into management of grasslands and component species.

4.5 MANAGEMENT PLANS

Each area of native grassland managed for conservation will have a set of specific management requirements, and so each area will require a management plan. Management plans are already in place for many grasslands managed for uses that include conservation, such as Nature Reserves, land managed by the Commonwealth Government (Department of Defence and the National Capital Authority), and land on the Canberra International Airport. Existing plans should be periodically reviewed and updated to take account of new information (such as the guidelines in this strategy and the action plans), and other relevant information.

Management plans should be developed for grassland areas managed for conservation, where these plans do not exist. Management plans should state the management (conservation) goals for the grassland area and the management actions to be undertaken to achieve the goals. The ACT Conservator of Flora and Fauna will continue to encourage rural lessees to manage native grassland on their lands to maintain and improve their condition, by providing advice, educational materials, and though Land Management Agreements that may include preparation and implementation of a management plan for native grasslands.

4.6 MANAGE HERBAGE MASS AND STRUCTURE

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

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

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

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

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

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

Pink-tailed Worm-lizards occur in rocky grasslands, with shallowly embedded surface rocks comprising a key structural component of their habitat. Further details of the habitat requirements of Pink-tailed Worm-lizards can be found in the Pink-tailed Worm-lizard Action Plan (ACT Government 2017b).

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

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

4.6.1 Definition of grass height

Grass height (or length) is defined in this document as the height of the grass leaves, not the longer culms that bear seedheads, which are often taller than the grass leaves. The grass leaf height is defined as the height of the denser part of the tussock or grass sward, and does not include the few longer grass leaves that often extend higher than the 'bulk' of the grass leaves in the tussock or sward. Therefore, the height of a tussock is measured from the ground up to where the denser (or leafier) part of the tussock thins out to become relatively few grass leaves (these relatively few grass leaves and seedhead culms may extend much higher).

4.6.2 Guidelines for managing herbage mass and structure

General guidelines for herbage mass and structure

- As a general rule, aim to maintain a grassland that has intermediate levels of herbage mass, which will promote a grass structure suitable for many grassland species, including threatened species. Such grassland will usually have well-defined tussocks mostly ranging in height between 5 cm and 20 cm, and inter-tussock spaces composed of shorter grasses and forbs with perhaps some bare ground. Avoid removing most of the herbage mass as this creates a very short grassland. Short grassland has grass mostly <5 cm high and usually a high proportion of bare ground but may also have dead thatch or short forbs. Also avoid maintaining grasslands that have high herbage mass. High herbage mass 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. See Section 4.6.1 for definition of grass height.
- In addition to maintaining mostly intermediate levels of herbage mass, aim to maintain a heterogeneous, patchy grassland sward. A patchy grassland of mostly intermediate levels of herbage mass has a grass sward of mostly intermediate height and density that is interspersed with patches of shorter, sparser grass and patches of longer, denser grass. Such a patchy grassland structure is often naturally created under grazing (by native or introduced herbivores) where mostly intermediate levels of herbage mass are maintained, but could possibly be created using burning. The uniform height created by slashing or mowing is unlikely to promote patchy grassland structure. However, slashing/mowing may still be useful for managing herbage mass and maintaining inter-tussock spaces.
- Aim to maintain herbage mass at intermediate levels even during productive (high grass growth) years, as this will help maintain inter-tussock gaps to allow for the

Striped Legless Lizard in Kangaroo Grass (M. Evans)

regeneration of native forb species (Wong and Morgan 2007).

- The three main tools for managing herbage mass are the manipulation of grazing regimes (including both native and introduced grazers), the manipulation of fire regimes, and mowing/slashing. Each of these techniques has a different effect on plant biomass, as well as on native and introduced plant species (Morgan 2015).
- Where grazing is used to manage grass biomass, the preferred method is to use native herbivores (kangaroos), with grazing by stock used in circumstances where kangaroo grazing is unable to maintain the desired grass herbage mass and structure at a site.
- If fire is used as a management tool in grasslands with threatened fauna, aim to create a patchy mosaic of burnt and unburnt areas at a fine-scale (burnt and unburnt patches that are tens of metres across rather than hundreds of metres across). In low quality habitat (where abundance of threatened lizards is expected to be low), burns may be required on a broader scale to improve overall habitat quality. Seasonal conditions, expected rainfall and topography need to be taken into account when planning burns to minimise impacts on threatened species, promote establishment of native perennial grasses and minimise the risk of weed establishment and erosion (see section 3.4). Slashing/mowing may be required in circumstances where it is not practical to use grazing and/or burning to manage herbage mass. Slashed material may need to be removed to avoid accumulating dead thatch.
- Different grassland community types require different frequencies of herbage mass removal because rates of herbage mass accumulation depend on grass and forb growth rates, which in turn will vary according to plant species, soil fertility, and climate, as well as seasonal moisture availability (Morgan 2015; Lunt and Morgan 2002; Schultz, Morgan and Lunt 2011). The grassland associations mentioned below are described in section 8.9.
    - ➢ At sites with high moisture and nutrient availability, such as some high productivity Kangaroo Grass (*Themeda triandra*) dominated grasslands, grass growth is relatively fast and will require more frequent biomass removal (e.g. grassland associations r3 – if dominated by *Themeda*, and r7 (see section 8.9)).
    - ➢ In lower productivity sites, grass growth is more likely to be limited by lower resource availability and poorer growing conditions, requiring less grass removed, or less frequent removal. This is likely to be the case in grasslands dominated by Wallaby Grasses (*Rytidosperma* spp.) and Speargrasses (*Austrostipa* spp.) (e.g. grassland associations r3 – if dominated by *Rytidosperma*, r5, r6), and grasslands at higher elevations (e.g. grassland associations a14, a30, r1 and r2) and on rocky sites (e.g. grassland association r8) (see section 8.9).
- The history of past management practices at a site can influence the outcome of different herbage mass management techniques. For example, implementation of fire in long-unburned grassland may have different outcomes to fire used in regularly-burned grassland due to changes in the dominant grass species over time (Sinclair, Duncan and Bruce 2014). The past management practices at a site should be adopted as an initial guide to the herbage mass management method (Morgan 2015).
- Herbage mass and inter-tussock space can vary seasonally according to moisture availability. The prevailing or expected climatic conditions (e.g. drought or La Niña) should be considered when planning grass structure and herbage mass management strategies.

Species priority

- If there is conflict between management of habitat for threatened grassland species and management for overall grassland floristic diversity, priority should be given to management of habitat for the threatened grassland species.
- If there is conflict between habitat management for two or more threatened grassland species, the priority for management should be determined on the basis of the threatened species listing category (vulnerable, endangered, critically

endangered), how abundant and/or restricted in distribution the remaining populations are, how important the site is to the conservation of the species and the nature of any ongoing threats.

- The management of threatened grassland plants should be given equal importance to the management of threatened grassland animals.

Guidelines for threatened flora habitat

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

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

Guidelines for Golden Sun Moth habitat

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

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

Guidelines for Grassland Earless Dragon habitat

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

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

Guidelines for Perunga Grasshopper Habitat

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

Refer to the Perunga Grasshopper Action Plan for more information.

Guidelines for Striped Legless Lizard habitat

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

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

Guidelines for Pink-tailed Worm-lizard Habitat

- Aim to maintain grassland that is composed of native grasses (particularly Kangaroo Grass (*Themeda triandra*)) with no or little weed cover (weeds are a key threat to Pink-tailed Worm-lizard habitat).
- Maintain surface rock by implementing management actions that prevent or discourage surface rock removal (shallowly embedded surface rock is a key habitat requirement for the species).
- Avoid disturbance in the species habitat, such as intense grazing, application of fertilizer, trampling, soil earthworks/movement/erosion.
- Moderately frequent fire (every 3–8 years) and light grazing (kangaroos or stock) may assist in maintaining a cover of native grasses such as *Themeda triandra*. The influence of fire regime on the abundance of the Pink-tailed Worm-lizard has not been studied.

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

4.7 IMPLEMENT ECOLOGICALLY APPROPRIATE DISTURBANCE REGIMES

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

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

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

4.7.1 Guidelines for implementing appropriate grazing regimes

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

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

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

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

In urban lowland grasslands of the ACT, kangaroo densities and their impacts on native vegetation and fauna should be managed in accordance with ACT Government policies as outlined in the Controlled Native Species Management Plan for Eastern Grey Kangaroos (ACT Government 2017a), the Kangaroo Management Plan (ACT Government 2010), and other subsidiary documents.

4.7.2 Guidelines for implementing appropriate burning, and burning regimes

- To promote native plant diversity, fires in native grasslands should be implemented in mid to late summer or autumn as this period is outside the major growing season, but before the first autumn rains that can cause resprouting and seed germination (Morgan 2015). Burning of sprouting or germinating plants can impede regeneration of these plants. However, some grassland plants species can be sensitive to summer or autumn burns (Lunt 1994), in which case a late winter or spring burn might be appropriate.
- The frequency and timing of fire at a site should consider the life cycles of grassland species present, particularly if the aim is to minimise the immediate impact of prescribed burns on these species. For example, for species such as the Striped Legless Lizard, burning when the animals are most active (i.e. afternoons in September–October or March–April) allows them to move away from fire, whereas burning in Golden Sun Moth habitat in the breeding season or in the month following (October–January) is likely to kill all the eggs laid at the bases of grass tussocks and it is possible the burnt tussocks may not be suitable oviposition sites for females. Where burning is used to maintain or improve habitat quality, the risk of immediate impact to target species from fire needs to be weighed against longer-term habitat benefit.
- Grasslands should not be burnt uniformly, but in a heterogeneous (or mosaic) pattern of burnt and unburnt patches to allow a range of refugia and grass structures for species to persist (Wong and Morgan 2007). If threatened grassland animals are present at a site, aim to create burnt and unburnt patches that are tens of metres across rather than hundreds of metres across, and avoid burning more than a total of 50% of the habitat for these species at the site in any year.
- Steps should be taken to reduce the risk of weed invasion after a planned fire. This may involve close monitoring of burnt areas in grasslands at high risk (i.e. close to weed sources, history of weed invasion and a soil seed bank of exotic species) and weed control.
- In higher productivity *Themeda triandra* dominated grasslands, frequent burning (every 1 to 5 years) is considered to be an important ecological process for maintaining floristic diversity and fauna habitat (Morgan 2015). Fire can improve tussock grass health and habitat heterogeneity for fauna and benefit native plant biodiversity by maintaining inter-tussock space (Morgan 2015; Lunt, Prober and Morgan 2012). If fires occur less frequently, the grass canopy has more time to re-establish, and significant reductions in gap size and number can occur after just three years without fire (Morgan 1998). As well as the competitive exclusion of other species, including other vascular plants and the biological soil crust (Morgan 1999; O'Bryan *et al.* 2009), longer fire-free periods (even after six years) can lead to declines in the health and vigour of *Themeda triandra* tussocks (Morgan and Lunt 1999). However, these fire frequencies may not be optimal for maintaining plant diversity during periods of drought or La Niña (higher rainfall) or for conserving a priority plant or animal that has a different requirement for fire frequency.
- There is currently insufficient evidence to support the frequent use of fire in low productivity grasslands; that is, those grasslands dominated by species other than

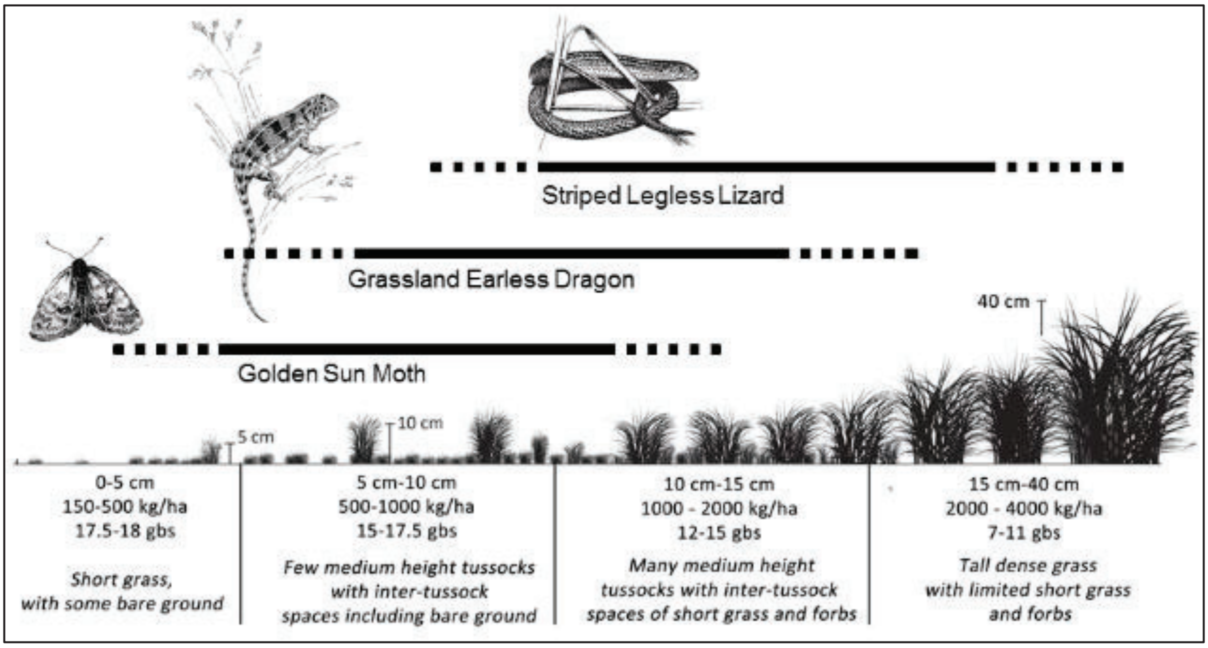
Themeda triandra, and T. triandra grasslands in low productivity sites or at higher elevations where the growing season is shorter. There is some evidence to suggest that fire in drier or colder native grasslands does not promote plant diversity (Wong and Morgan 2007) and can even cause grass mortality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

- For sites that are lower in productivity or in steep topography the benefit of ecological burning should be considered in light of the erosion potential of the proposed burn area. Software tools are available that estimate erosion potential by taking into account fire fuel loads, topography and weather. Fire frequency is naturally lower in higher elevation (montane and sub-alpine) grasslands, with landscape-level fires being a relatively rare event, and the introduction of planned fire is unlikely to be required. After fire, the in-filling of inter-tussock space and production of a litter layer in montane and sub-alpine grasslands can take years to occur due to slower plant growth, potentially increasing the risk of soil erosion (Wahren, Papst and Williams 2001).
- Implementing an appropriate fire regime can be logistically challenging due to the often narrow window of opportunity (prevailing weather and moisture conditions) and the requirement for fire-fighting resources to undertake burns safely. Ecological burns are often undertaken at the same time of year as hazard reduction burns, when demand for fire-fighting resources is high. For an ecological burn program to be successful, land managers need to be adequately resourced, including during periods of high resource demand.

4.7.3 Guidelines for implementing appropriate mowing/slashing regimes

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

Figure 3. Grass structure and habitat suitability for some threatened grassland fauna. Relationships are based data collected during field surveys by the ACT Government and Howland et al. (2016a, 2016b). Solid lines are preferred habitat, dashed lines are less suitable habitat.



- Winter is generally the best time for mowing/slashing to avoid negative impacts to grassland plants, as at other times of the year it can potentially reduce grass reproduction due to its effect on active grass growth and tiller production, flowering and seed production (Morgan 2015).
- The height at which grass is slashed is likely to affect fauna habitat, and so the minimum slash height should be regularly reviewed in the light of new information.
- Where possible, slashed material should be removed due to the potential for smothering grass tussocks, and creating moist conditions that favour exotic grass growth (Eddy 2002; Morgan 2015).
- It is essential that best practice slashing/mowing hygiene is followed (such as detailed in the Parks and Conservation Service Weeds Operation Plan). See Section 3.4.1 for more information on mowing/slashing.

4.8 MANAGE FIRE RISK

Managing native grasslands, particularly those within the urban fabric of Canberra, involves recognising the dual goals of conservation and of minimising fire risk.

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

Grasslands in the urban area, however, can pose a fire risk to residences and urban infrastructure. To reduce fire risk, management of urban grasslands involves maintaining low to moderate levels of grass herbage mass (fuel load) within 'Asset Protection Zones' that are located adjacent to urban development. Low herbage mass is maintained through regular burning, grazing or slashing/mowing. 'Fire-wise' planning of the interface between reserves and urban development areas is also important in minimising fire risk, such as using hard surfaces (sealed road) between nature reserves and adjacent urban areas (refer to section 3.8).

Reducing fire risk also involves maintaining adquate infrastructure to support fire suppression, both for wildfires and to contain ecological burns. Fire suppression infrastructure includes access for emergency vehicles to strategic locations within reserves and along reserve boundaries, and maintenance of fire trails within reserves.

4.9 MANAGE HABITATS THAT INCLUDE A HIGH COMPONENT OF EXOTIC GRASSES

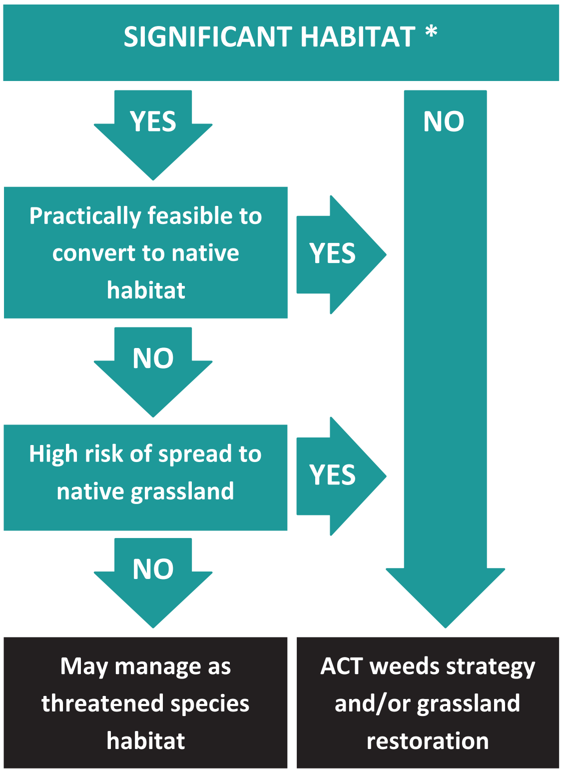
Native grasslands, including high quality Natural Temperate Grassland, typically contain a component of exotic grass and other weeds. Some exotic grasses, such as Serrated Tussock (*Nassella trichotoma*), tend to occur as individuals or small clumps of plants dispersed amongst native grasses whereas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

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

Phalaris as habitat for Striped Legless Lizards might be the best option.

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

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



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

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

Figure 4 provides a flow diagram to assist with decisions on managing habitat that includes exotic grass.

4.9.1 Guidelines for managing habitats that include exotic grasses

- Where exotic grasses do not comprise significant habitat for threatened grassland species, management should be according to the ACT Weeds Strategy 2009 - 2019 (ACT Government 2009).
- Where a patch of exotic grass (whether or not it is habitat for threatened species) poses a high risk of spread into high quality native grassland because it cannot be practically contained, management should be according to the ACT Weeds Strategy.
- Where exotic grasses comprise significant habitat for threatened grassland species and it is also practically feasible to convert the exotic habitat back to native grassland habitat, the exotic grasses should be managed according to the ACT Weeds Strategy with the aim of restoring native grassland habitat (which is likely to require additional actions to those in the Weeds Strategy, such as restoring native grasses).
- Where exotic grasses comprise significant habitat for threatened grassland species and it is not practical to convert the exotic habitat to native habitat, but it is practically feasible to contain the spread or there is a low or acceptable risk of spread into native grassland, management options may include controlling the spread and managing the exotic grass as part of the broader habitat for the threatened species.

4.10 IMPLEMENT MEASURES TO SAFEGUARD POPULATIONS

For some threatened species, preventing extinction in the wild requires significant ex-situ actions such as establishing programs for captive breeding, propagation, seed banks and translocation of individuals. Captive populations have also been used for undertaking essential conservation research that is impractical on wild populations.

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

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

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

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

4.10.1 Guidelines to safeguard populations

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

4.11 LOCAL AND REGIONAL COOPERATION

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

- Liaising with Commonwealth agencies responsible for managing National Land containing native grassland and habitat for threatened species, and seeking cooperative agreements (such as MOUs) with those agencies.

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

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

5.1 OVERVIEW

Native grasslands in the ACT and surrounding region were extensive at the time of European settlement (Groves and Williams 1981; Costin 1954). Almost all of the region's lowland grasslands are now lost due to development in valleys and low-lying areas, with the remainder being highly fragmented. Many native grasslands now have a significant exotic plant species component because of their small size, the surrounding land use and their land use history (Williams and Morgan 2015). Whilst protection and active management can arrest the decline of grasslands, restoration is required to reverse the decline. Restoration of degraded grasslands provides opportunities to enhance the extent, connectivity and condition of grasslands. Knowledge of how to restore grasslands is currently limited, though there is an increasing number of small-scale experimental projects, often undertaken by community groups, that aim to trial new ideas and methods to restore the structure, composition and function of native grasslands.

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

Evidence over the last decade has shown that ecological change in response to climate change is unavoidable, widespread and substantial (Williams *et al.* 2014). An important strategy for grassland conservation is to improve ecosystem function and connectivity between fragmented grassland habitats (ACT Government 2013a), with the aim of improving the long-term viability of the grassland ecological community and its resilience to climate change and other pressures. Whilst enhancing connectivity can increase some risks (e.g. conduit for fire and pests), the benefits are generally considered to outweigh the risks.

5.2 ECOSYSTEM FUNCTION AND CONNECTIVITY GOAL

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

5.3 KEY PRINCIPLES

- Rather than aim to restore fragmented native grasslands to a pre-European state, a more realistic goal is to enhance ecosystem function and connectivity by improving the ecological condition of grassland remnants and their value as habitat though appropriate management, threat mitigation, rehabilitation, and maintaining and creating habitat connections between remnants.
- Under a changing climate, characteristics of ecological communities (including native grasslands) will change as the communities seek a new equilibrium with the changing environmental conditions.
- Ecosystems should be viewed and managed as changing entities, with management aiming to facilitate the natural response under a changing climate though enhanced ecosystem resilience and adaptability.

- Areas that are larger, in better ecological condition and more connected in the landscape are generally more resilient and viable in the longer term, and better able to provide conditions for species and ecosystems to adapt to climate change.
- Degraded grasslands, and grasslands that are overgrazed, are more likely to experience reduction or disruption of healthy ecosystem functions.
- Small, fragmented grasslands are more susceptible to disturbance, such as from edge effects. However, such grasslands may be suitable for small-scale restoration actions.
- Small isolated populations are more susceptible to local extinction and to genetic problems.

5.4 IMPROVE RESILIENCE AND ADAPTABILITY UNDER A CHANGING CLIMATE

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

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

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

5.4.1 Guidelines to improve resilience and adaptability to climate change

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

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

Natural Temperate Grassland monitoring site at Cookanalla property

  - creating reserves with hard boundaries (e.g. roads) then intensively managing within them

- Promote community re-assembly with native species by:
  - managing exotic species
  - continuing to manage for 'local species' and
  - considering introduction of non-local regional species that are adapted to new local conditions

- Identify, manage and protect refugia.

- Manage ecosystems for ecological diversity to promote resilience and monitor what works to inform adaptive management.

- Encourage land use changes that favour native grassland biodiversity.

- Maintain adequate herbage mass/cover to help buffer grassland fauna from predicted climatic temperature and rainfall extremes. Grass cover provides shade, reduces evaporation, reduces erosion and moderates hot/cold extremes in soil temperature.

5.5 ENHANCE ECOSYSTEM FUNCTION (RESTORATION)

Restoration is the practice of renewing and repairing degraded, damaged or altered ecosystems and habitats (Gibson-Roy and Delpratt 2015). The aim of restoration is to improve native biodiversity and ecosystem function.

The native grasslands of south-eastern Australia, particularly lowland temperate grasslands, have typically experienced severe disruption to their natural processes and loss of species diversity. As such, rather than complete restoration of ecological condition and ecosystem function to approximate the pre-European state, more realistic and achievable restoration goals commonly include improving the vegetation structure and plant composition of grasslands, improving habitat for fauna, controlling exotic species, and enhancing native biodiversity (Prober and Thiele 2005).

There is a growing body of knowledge related to grassland restoration, though methods are currently more suited to small-scale projects. There is an urgent need to develop practical methods for larger-scale restoration of grasslands. Detailed techniques to enhance/restore the ecological condition and ecosystem function of native grasslands are outside the scope of this document (see Gibson-Roy and Delpratt 2015 for more details), though some key considerations and guidelines are given below.

A key step in native grassland restoration is the establishment of a healthy and moderately dense native grassy sward (Prober and Thiele 2005). Restoration of a native grassy sward on degraded grassland sites that lack native grasses will require sufficient seed to be available and adequate soil nutrient content (Gibson-Roy and Delpratt 2015). Currently, techniques for the restoration of *Themeda triandra* swards are better understood compared to other dominant native grass species (Prober and Thiele 2005; Cole and Lunt 2005). In many cases, it may be preferable to re-introduce native forbs at the same time, even prior to, the native grassy sward (Gibson-Roy and Delpratt 2015).

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

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

Sourcing adequate quantities of native seed has been an impediment to large-scale native grassland restoration. However, developments in commercial production of native seed are likely to result in larger quantities of native seed becoming available.

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

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

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

Table 3 summarises the typical attributes for grasslands in various states of condition, and options for enhancement/restoration to promote shifts from one condition state to another.

5.5.1 Guidelines to enhance ecosystem function though restoration

- Give priority for restoration to sites that are already in moderate condition, as these sites will require fewer resources to improve them to a higher quality state, and to sites in locations where enhancing ecosystem function would add the most ecological value to the surrounding landscape. For example, priorities might include sites that are critical habitat for threatened species, areas that connect high quality remnants (to improve habitat and facilitate movement of fauna), areas that would increase the size of habitat for threatened species, degraded patches within high quality grassland, buffer areas or sites adjacent to high quality grassland that increase the size of the patch.

- Use the goal and scale of grassland enhancement/restoration to determine the approaches and techniques used. Smaller-scale enhancement/restoration techniques that move a grassland from one state to another (e.g. Table 3) could involve steps such as weed control, improving fauna habitat elements and managing herbage mass and grazing levels. Larger-scale native grassland restoration is more resource-intensive, particularly for highly degraded sites, and requires adequate long-term project resourcing. Consider undertaking actions to promote natural regeneration before planting to restore native grasslands.
- Maintain the physical structure of grasslands, and enhance where needed, to provide a diversity of habitat for the fauna community. These include soil cracks and holes, rocks where they naturally occur, wet areas and watercourses (e.g. for grassland frogs), specific micro-habitats for particular species (e.g. basking sites for reptiles) and plant litter.

5.6 ENHANCE HABITAT CONNECTIVITY

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

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

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

Fragmentation of Natural Temperate Grassland can also increase the risk of extinction of populations of grassland flora and fauna,

Perunga Grasshopper, Gungaderra Nature Reserve

particularly in urban areas (Williams *et al.* 2005, 2006; Hoehn *et al.* 2013). Fragmentation results in the restriction of the movement of animals and plant propagules due to the reduced connectivity between habitats. For fauna, movement between fragments depends on mobility and movement patterns. For example, the female Golden Sun Moth (*Synemon plana*) has poor flying ability and populations that are separated by more than 200 m are considered to be isolated (Mulvaney 2012). Movement of fauna between patches can be further impeded by unsuitable habitat between patches, such as urban development, or by barriers such as major roads (Antos and Williams 2015). In the absence of dispersal, small populations of plants and animals in grassland remnants are more vulnerable to extinction after unpredictable events, such as fire and drought, as there are few opportunities for re-colonisation from other populations (Keller 2002; Dimond *et al.* 2012). Small and isolated remnant populations can also be at greater risk of inbreeding, reducing genetic diversity and population fitness and viability, and ultimately increasing extinction risk (Dudash and Fenster 2000; Keller 2002).

5.6.1 Guidelines to maintain and enhance habitat connectivity

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

Table 3. Grassland states, typical attributes, and options for enhancement/restoration. Modified from McIntyre and Lavorel 2007.

	Grassland states, typical characteristics and transition steps from highest quality to lowest quality					
	Highest quality					Lowest quality
Attributes	Reference (historical) grassland	High quality native grassland	Low quality native grassland	Degraded grassland	Fertilised pasture	Sown pasture
Native marsupial grazing	Present at moderate levels	Present at moderate levels	Present but potentially at levels that are too high or too low	Absent or at levels that are too high or too low	Absent or at levels that are too high or too low	Absent
Native grassy sward	Present and maintained at	Present and maintained at moderate levels	Present but either too high (not managed) or	Absent	Absent	Absent

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

Lemon Beauty Heads (J. Lidner)

6. STRATEGY: MONITORING AND RESEARCH

6.1 OVERVIEW

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

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

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

6.2 MONITORING AND RESEARCH GOAL

Sound research, monitoring and adaptive management underpin the conservation of native grasslands and component species.

6.3 MONITOR GRASSLAND COMMUNITY CONDITION

Regular monitoring of native grassland communities over time provides important information on trends in grassland community condition, potentially triggering management actions when grassland condition declines. The ACT Conservator of Flora and Fauna will continue to develop the Conservation Effectiveness Monitoring Program (CEMP) which uses current best-practice monitoring actions outlined in the Lowland Native Grassland Ecosystem Monitoring Plan (Brawata *et al.* 2017). These monitoring actions were developed for key ACT ecological communities, including native grasslands.

The CEMP gathers information from monitoring projects and qualitative sources across government and non-government groups to make structured assessments of reserve condition and effectiveness of management programs. The program uses indicators of reserve condition and ecological stress levels imposed by threatening processes in ACT reserves. The indicators used for grassland monitoring by the CEMP are listed in Table 4.

Since the previous strategy, the ACT Government has adopted the Floristic Value Score (FVS) to quantify native grassland condition. This relatively recently developed method of measuring the quality of a grassland site, based on Rehwinkel (2015), is widely-used for assessing grassland condition, with sites measuring 5 or more being considered to have a floristic value sufficient to be considered part of the Natural Temperate Grassland Critically Endangered Ecological Community under the Commonwealth EPBC Act (Rehwinkel 2015; Commonwealth of Australia 2016a).

In addition to ACT Government programs, survey and monitoring of native grasslands and component species is also undertaken by private ecological consultants (often contracted by the ACT Government), researchers, and community groups. Liaison and collaboration between the ACT Government and these stakeholders in the development of survey and monitoring guidelines will help ensure these activities are undertaken using consistent methods and according to best practice, and data collected is suitable for informing planning and management decisions.

Table 4. Monitoring indicators for the CEMP Lowland Native Grassland Ecosystem Condition Monitoring Plan (Brawata *et al.* 2017) (this monitoring is used for reserves). NTG = Natural Temperate Grassland.

Element	Indicators	Metrics
Natural Temperate Grassland ecological community	C1. Natural Temperate Grassland	C1.1 Extent of native vs. exotic grasslands within reserves C1.2 Extent of NTG within reserves
Grassland Flora	C2. Native Flora general	C2.1 Native plant species richness C2.2 Ground cover C2.3 Indicator 2 species richness
	C3. Threatened Flora	C3.1 Button Wrinklewort C3.2 Ginninderra Peppercress
Grassland Fauna	C4. Native Fauna general	C4.1 Reptiles, general C4.2 Invertebrates, general
	C5. Threatened Fauna	C5.1 Grassland Earless Dragon C5.2 Striped Legless Lizard C5.3 Golden Sun Moth C5.3 Pink-tailed Worm-lizard
Inappropriate grazing regime	S1: Herbivore pressure	S1.1 Eastern Grey Kangaroo S1.2 Rabbit S1.3 Domestic stock
Inappropriate fire regime	S2. Fire regimes	S2.1 Fire frequency within ecological thresholds S2.2 Fire season as recommended in ecological guidelines
Invasive weeds	S3. Invasive weeds	S3.1 Changes in distribution and abundance of priority weeds S3.2 Invasive weeds - New incursions
Introduced predators	S4. Introduced predators	S4.1 European Fox S4.2 Feral Cat

6.3.1 Priorities for current and future monitoring

- Use the Conservation Effectiveness Monitoring Program as a framework for monitoring the condition and long-term changes in grassland ecosystems, and other targeted, adaptive management (see Chapter 4) monitoring programs to investigate the effectiveness of different grassland management strategies.
- Increase replication of monitoring sites to adequately represent all grassland associations in the ACT, including higher elevation grasslands, which may be particularly important for detecting woody species encroachment under climate change (i.e. community associations r1, r2, a14 and a30, see section 8.1.6).
- Finalise mapping of native grassland community boundaries and canopy cover of trees and shrubs, to provide a baseline to detect woody species encroachment under climate change.
- Use action plans to guide monitoring for individual threatened species.
- Use information from citizen science projects (e.g. Canberra Nature Map, Vegwatch), where relevant to grassland monitoring.
- Collate data collected by stakeholders (community, consultants and researchers) for floristic diversity at native grassland sites to undertake FVS analysis and other condition measures.

6.4 COLLECT BASELINE INFORMATION

The effective management of grassland connectivity and ecosystem function requires baseline information on the distribution and characteristics of the ecosystem. Such information is essential for assessing future changes, for example the effect of climate change on the distribution and abundance of species.

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

- Mapping of the ACT's vegetation communities at the 1:25,000 scale.
- Classification of mapped grassland units to the vegetation association level defined by Armstrong *et al.* (2013).
- Soil mapping for the ACT.
- Hydro-geological profiles for the ACT.
- Mapping of the ACT's most serious weeds.
- Connectivity mapping of grassland patches at scales appropriate to plant and animal dispersal.
- Grassland Enhancement Program (section 8.5.4).
- Participation in cross border planning and sharing of data for the ACT and region's grasslands.

6.4.1 Map the extent and condition of grasslands

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

The method used to produce existing maps (based on a combination of aerial photography interpretation and fieldwork) is unable to separate native grassland units into the various temperate grasslands of Armstrong *et al.* (2013), and existing maps instead show grassland as either native grassland, exotic grassland, or Natural Temperate Grassland (if the site meets the definition of Natural Temperate Grasslands of the South Eastern Highlands Endangered Ecological Community) (Baines *et al.* 2014). Work has begun to map the higher elevation grasslands according to the classification of Armstrong *et al.* (2013) and allocated to the r1, r2, a14 or a30 association types (see section 8.1.6).

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

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

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

6.5 ADDRESS KNOWLEDGE GAPS IN GRASSLAND CONSERVATION AND RESEARCH

Knowledge through research and monitoring (and consequently management techniques) is improving steadily, though substantial knowledge gaps remain. Knowledge gaps include:

- Restoration techniques and approaches aimed at improving grassland condition.
- Effects of a changing climate.
- Aspects of the ecology of grassland species important to their conservation.
- Effects and control of biological invasions.

A recent international literature review by Richter and Osborne (2014) identified these and other knowledge gaps. Halting the ongoing decline of grassland condition will require active grassland management, whereas reversing the decline will rely on restoring degraded and damaged grasslands. A priority for research is the development of innovative and practical methods to restore grasslands, particularly for sites that are medium to large in area.

The limited taxonomic and ecological understanding of grassland invertebrates is reflected in the ACT, although there have been several recent projects investigating beetle dynamics in the ACT's lowland woodlands (Barton *et al.* 2011, 2013a, 2013b, 2014), as well as species-specific research on the Golden Sun Moth (Richter *et al.* 2013; Richter *et al.* 2009). The decline of populations of Grassland Earless Dragons during the 2002–2009 drought has highlighted the need for a better understanding of the effects of drought and/or overgrazing on this species.

Taxonomic research is still lacking for many grassland species, including plants. In particular, taxonomic refinement is still needed for some of the ACT's rare plants that can occur in grasslands, including the orchids and some forbs. Comprehensive ecological and genetic studies are also lacking for most plant species, with most of the focus so far being on the threatened plant species.

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

Native grassland conservation and management can be enhanced through the building of links and knowledge sharing among ACT Government and Commonwealth departments, grassland researchers (e.g. from local universities), community groups (e.g. ParkCare, Friends of Grasslands, Ginninderra Catchment Group) and the private sector (e.g. Greening Australia). Substantial research on native grassland restoration and conservation of threatened species is being undertaken in NSW and Victoria. Building links can be achieved through on-site discussions, workshops, conferences, and collaborative initiatives and projects.

6.5.1 Research priorities

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

- Short and long-term effects of grazing levels, fire and mowing/slashing as tools to manage grasslands and appropriate regimes for these tools.

- Ecology and management of non-*Themeda triandra* dominated grassland associations, and native grasslands that occur at higher elevations, particularly for biomass management and disturbance regimes, and the development of management guidelines in these ecosystems.
- Techniques to improve the condition of native grasslands, and restoration of degraded grasslands.
- Interaction between kangaroo density, climatic factors and grassland biomass management, and techniques to improve management of kangaroo densities (including the use of fertility control).
- Taxonomy and ecology of grassland invertebrates (including burrow-making species) and grassland plant species.
- Monitoring and assessing the effect of climate change on the abundance and distribution of species.

A priority is also information exchange, which is enhanced by building links between reserchers, conservation agencies and community groups in the ACT and other jurisdictions.

Eastern Grey Kangaroos

7. STRATEGY: ENGAGE THE COMMUNITY

7.1 OVERVIEW

Community engagement in nature conservation has a long and active history in the ACT (ACT Government 2013a). However, compared to other vegetation types (forests, woodlands, riparian zones) community appreciation of native grasslands can be difficult to achieve, particularly because grassland values are not necessarily obvious (Lunt 1994). To secure a future for Australia's endangered temperate native grasslands in the face of urban expansion, agicultural intensification and the uncertain impacts of climate change, a broader cross-section of society needs to gain a greater appreciation and understanding of native grasslands and their ecology (Williams and Marshall 2015).

Current threats (Chapter 3) to native grasslands all present enormous challenges to the management of grassland biota, and commitment from all stakeholders will be necessary to address them (Williams and Morgan 2015). The lack of awareness and appreciation of native grasslands by the general public is still considered to be a major issue in grassland conservation (Williams 2015). Activities that engage the public in native grassland conservation can promote an appreciation of grassland values by fostering an emotional connection between people and native grasslands (Reid 2015).

Community groups in the ACT have been instrumental in advocating for native grassland conservation, raising public awareness, and undertaking citizen science projects and on-ground restoration activities. Section 8.5.8 provides an overview of community engagement activities undertaken since the previous strategy, including those that specifically focus on native grasslands, as well as activities that include other ecosystems.

7.2 COMMUNITY ENGAGEMENT GOAL

Community groups, landholders and others are actively involved in native grassland conservation.

An informed community supports the use of native grassland areas for conservation.

7.3 KEY PRINCIPLES

- Conservation of native grasslands is dependent upon community support for management of grasslands for biodiversity and habitat values (Reid 2015).
- Community engagement in native grassland conservation can foster an appreciation and awareness of the value of grasslands and build support for grassland conservation in the community.
- The contribution of community volunteers to native grassland management and restoration programs can be essential to their outcomes (Gibson-Roy and Delpratt 2015). Understanding the motivations and goals of volunteers is important in recruiting and retaining volunteers. Volunteers are more likely to stay motivated and engaged when they know their work is valued and respected, and are having a broader impact (Reid 2015).
- Citizen science programs can make a valuable contribution to environmental science.
- Embracing recent and emerging technologies is an effective approach to harnessing the enthusiasm and skills of citizen scientists, and has the potential to gather and process large amounts of data that can contribute significantly to research and management of grasslands.
- The benefits of increasing the level of recreation and tourism in native grasslands

needs to be balanced against potential impacts on native grasslands.

7.4 ENGENDER COMMUNITY INVOLVEMENT THROUGH AWARENESS RAISING AND VOLUNTEERING

The ACT Government aims to increase the number of volunteer groups and areas actively managed by volunteers by introducing new engagement strategies and targeting new interest groups. A focus will be on encouraging the involvement of youth in nature conservation (ACT Government 2013a). Recent market research found that around one in thirty ACT residents were currently involved as a volunteer in the ACT's reserve system, and 13% of residents expressed interest in becoming a volunteer (Market Attitude Research Services Pty Ltd 2017).

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

There are a number of active community groups that advocate for native grassland conservation, and undertake on-ground restoration actions and public awareness raising activities:

Friends of Grasslands (FoG), established in 1994, is a community, not for profit association dedicated to conservation of natural temperate grassy ecosystems in south-eastern Australia. FoG advocates, educates and advises on matters to do with the conservation of grassy ecosystems, and undertakes survey, monitoring and other on-ground work. Over its 20 year history FoG has held singnificant conferences (such as the recent 'Grass half empty or grass half full?'), workshops and field-days, and produces a regular newletter. FoG is based in Canberra and has over 200 members that include professional scientists, landowners, land managers, and interested members of the public.

'Landcare', and its various catchment goups and landcare groups, work closely with local communities to implement on-ground projects aimed at addressing land degradation, including degrdadion of grasslands. 'Parkcare' groups work closely with parks staff to undertake on-ground management and restoration projects in Canberra's nature reserves. A number of special-interest groups with substantial knowledge about specific biota of grasslands also undertake conservation projects in grasslands. Some of these groups come under the umbrella of larger conservation organisations such as the Conservation Council ACT and Canberra Ornithologists Group.

Community education campaigns can assist in building community awareness about native grasslands and their management, particularly at the urban interface, as well as encouraging community activities to reduce threats to grassland ecosystems. Effective community education can also lead to changes in behaviour, such as improved compliance with conditions of entry to reserves, participation in on-gound conservation projects and community adoption of sites.

7.4.1 Guidelines to engender community involvement and support

- Continue to support ParkCare groups with training (safety, monitoring and on-ground activities), protective clothing, access to equipment, and provide Parks and Conservation Service resources such as staff support and coordination (ACT Government 2013a). Promote formation of ParkCare or similar groups for key grassland sites.
- Lead by example (best practice conservation management of native grasslands) to inform and influence other groups.
- Support community groups (grants, incentives, advice, leadership) to enable substantial projects and activites to be undertaken, including citizen science projects, on-ground grassland restoration activites, and projects to increase public awareness.
- Facilitate information and skills exchange between stakeholders aimed at achieving best practice management of native grasslands. Effective approaches include: workshops, seminars/forums and hands-on events to demonstrate best practice methods and facilitate information exchange

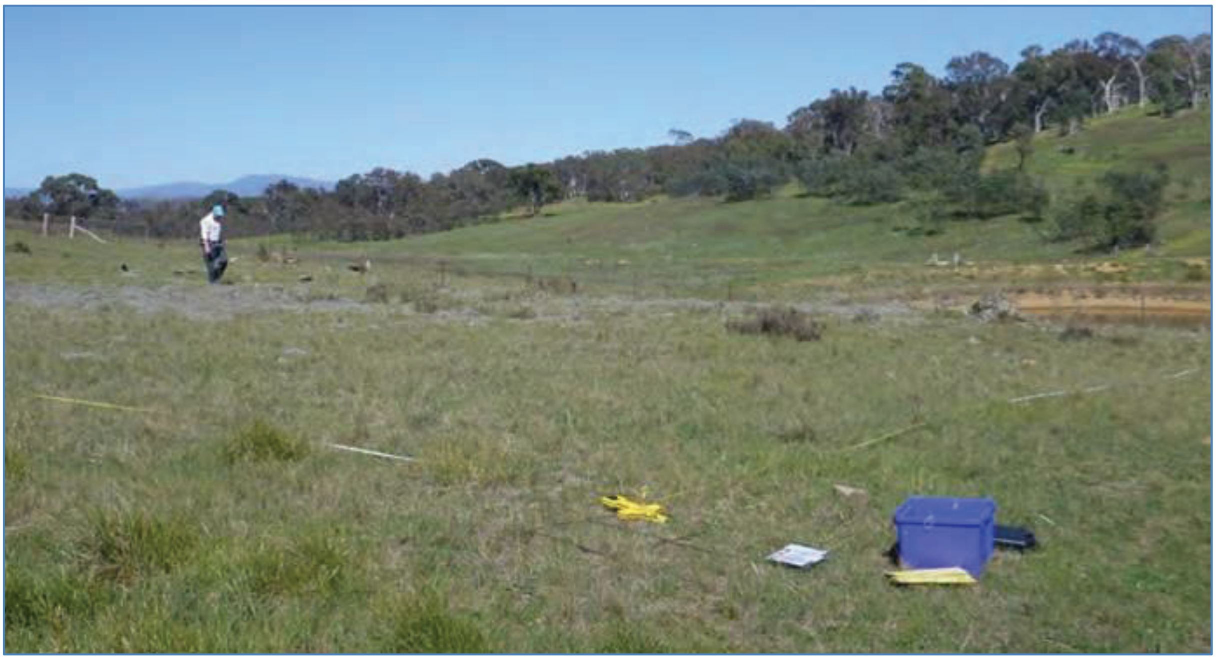
between stakeholders, production of high quality education materials.

- Build community awareness and support of native grasslands through community liaison and public education activities that create emotional connections between people and grasslands. Effective approaches include: hands-on events such as weeding or planting, raising awareness about activities that impact on grasslands (e.g. off-leash dog walking, weed spread from urban gardens), promoting understanding of grassland ecology and values (e.g. high quality education and interpretive material, on-site signage, walks and talks, and art- and photography-based projects), and informing the community about the importance and role of particular management strategies (e.g. controlled burning, weed spraying).
- Encourage best-practice urban design around urban grasslands to protect biodiversity whilst enhancing aesthetics and educational opportunities.
- Develop and improve information sharing tools (such as ACTMapi, Canberra Nature Map and other apps) that enable up-to-date information on grasslands and their management to be accessible to the public.
- Identify potential sites where restoration will enhance the conservation values of the site.
- Promote use of native grasses and forbs in home-gardens, commercial premises, roadside landscapes, roundabouts, and public spaces. Horticulture, and familiarity with native plants from seeing them in public places, fosters an understanding and appreciation of native plants.

7.5 ENHANCE AND PROMOTE USE OF CITIZEN SCIENCE

Citizen science is an increasingly popular and widely-used method in environmental science and land management, with applications in data collection, data processing, monitoring and research. Citizen science projects are emerging as an excellent engagement tool for promoting awareness of the natural environment and delivering usable data to researchers and managers (Williams et al. 2015). Enhancing and promoting the use of citizen science is an important strategy in the ACT, particularly because of the wealth of skills and knowledge in the ACT community (ACT Government 2013a). Examples of citizen science projects include Waterwatch, Frogwatch, Golden Sun Moth surveys (University of Canberra and FoG), and the Canberra Ornithologists Group, which have

Grassland condition monitoring, Gungaderra Nature Reserve



all contributed large amounts of monitoring data.

Some of the most popular and fast-growing citizen science activities involve use of the latest internet-based and smart-phone technology. Well-designed tools such as these have the capacity to collect large amounts of data and increase community interest in conservation and research, including projects that are conducted entirely online, such as data-processing projects (Bonney *et al.* 2014). An example of a recent citizen science project in the ACT that embraces the latest technology and harnesses the community's passion for photography is the Canberra Nature Map (Visit the Canberra Nature Map website). This project commenced in 2014 as an internet-based repository for geo-referenced community photographs of rare native plants. Within a year its popularity had increased the scope to all plants (including weeds) and other taxonomic groups (e.g. reptiles, mammals, butterflies and birds) in the ACT and surrounding region.

7.5.1 Guidelines to enhance and promote citizen science

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

7.6 BUILD INDIGENOUS ENGAGEMENT IN THE MANAGEMENT OF NATURAL RESOURCES

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

Ecological spring burn

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

Opportunities to further engage the Aboriginal community and draw on traditional knowledge in land management will be explored, including supporting Indigenous people to rediscover and share cultural knowledge and facilitating their participation in on-ground management of grasslands.

7.7 SUPPORT APPROPRIATE RECREATIONAL AND TOURISM USE OF NATURAL AREAS

Facilitating recreation and tourism in natural areas is an important approach to engaging the community with the natural landscape and broadening understanding and support for these areas. This is particularly relevant to ACT urban grassland reserves given that research suggests the community generally does not appreciate the values of grasslands (Williams 2015). Recent surveys of ACT residents' use of Canberra Nature Parks found the grassland reserves had among the lowest visitation rates of the urban nature reserves (Market Attitude Research Services Pty Ltd 2017).

Although recreation and tourism in natural areas is an important part of developing appreciation of these areas, visitation can also result in negative impacts on flora and fauna. Programs promoting visitation of grasslands, particularly sensitive areas (such as those containing threatened species) need to take into account risks of negative impacts and manage the risks accordingly. Negative impacts can arise from trampling of vegetation, illegal collection of plants (such as threatened orchids), unofficial track creation, mountain bike riding, rubbish dumping, dog excrement and other impacts related to domestic animals, and weed invasion (Rankin 2015; Williams 2015).

In the ACT there are existing plans of management that already define appropriate use for reserves, though monitoring of impacts and additional strategic guidance will help ensure appropriate recreation and tourism is encouraged that will support conservation management across multiple tenures (ACT Government 2013a). The ACT Government intends to encourage appropriate recreational use of natural areas though development of a recreation strategy (ACT Government 2013a).

7.8 ENHANCE KEY PARTNERSHIPS ACROSS GOVERNMENT, COMMUNITY AND THE PRIVATE SECTOR

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

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

Pale Sundew (M. Beddingfield)

8. BACKGROUND

8.1 WHAT ARE NATIVE GRASSLANDS?

8.1.1 Native grassland composition

Native grasslands are vegetation communities that are dominated (> 50% cover) by native grass and forb species where the cover of shrubs and trees is less than 10% (Eddy 2002; Commonwealth of Australia 2016a). See Table 5 for definitions of major grassland classifications.

Over 110 species of native grasses are currently recognised in the ACT, with the most species-rich genera being *Rytidosperma*, *Poa*, and *Deyeuxia* (Lepschi, Mallinson and Cargill 2012). Common species of grasses in the ACT and region are presented in Table 6.

In south-eastern Australia, native grasslands can be species-rich (high number of species) at small spatial scales, and relatively undisturbed native grasslands often contain a diversity of herbaceous species (forbs), including orchids, lilies, and broad-leaved forbs such as daisies. Species that often co-dominate with grasses include *Chrysocephalum apiculatum* (Common Everlasting Daisy) and a range of *Lomandra* (Mat-Rush), *Juncus* (rushes), and *Carex* (sedges) species (Table 6).

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

Native grassland species tend to have short-lived transient seeds, with few species developing a persistent soil-stored seed bank (Lunt 1990; Morgan 1989; Morgan and Williams 2015). However, many species are long lived below ground and rely on seasonal regeneration from tubers or buds located at or close to the ground (Morgan 2014; Morgan and Williams 2015).

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

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

8.1.2 Native grassland structure

The presence of perennial native grasses imparts a characteristic structure to native grasslands. Many of the dominant grass species are tussock grasses, which can be defined as a dense, erect clump of tillers, usually tufty in appearance (Groves and Williams 1981). This upper canopy stratum of the ground layer plants generally varies in height from mid high (0.25–0.5 m) to tall (0.5–1.0 m), and in cover from open to dense (greater than 70% ground cover) (Walker and Hopkins 2009).

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

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

Table 5. Definitions of major grassland classifications.

Term	Definition
Grassland	Areas with at least 10% foliage cover where that cover is dominated by grasses and forbs and there is <10% tree and shrub cover.
Native Grassland	Grassland with more than 50% of the perennial foliage cover composed of indigenous species.
Natural Grassland	Grasslands occurring in areas considered to have <10% tree and/or shrub cover due to natural processes (e.g. cold air drainage).
Derived (or Secondary) grassland	Grasslands remaining on sites where humans have reduced the natural tree and/or shrub cover to less than 10%. Derived grasslands can be native or exotic. This community is not included in this strategy, and instead is included in the woodland strategy.
Exotic Grassland	Grasslands where more than 50% of the perennial foliage cover is comprised of non-indigenous species.
Natural Temperate Grassland	Grassland with indigenous species comprising more than 50% of the total foliage cover (excluding non-indigenous annuals). Under the EPBC Act the minimum patch size to meet the Natural Temperate Grassland Critically Endangered Ecological Community is 0.1 ha (Commonwealth 2016a). The dominant grasses are typically *Themeda triandra*, *Rytidosperma spp*., *Austrostipa spp*., *Bothrochloa macra*, *Poa sieberiana* or *Poa labillardierei*. There is a diversity of indigenous forbs which may comprise up to 70% of the species present, or if disturbed, having components of the indigenous species sufficient to re-establish the native groundcover. Occurrence is limited to the temperate zone (elevation up to approximately 1200m asl) where tree growth is inhibited by natural processes.
Montane Grassland	Grassland with indigenous species comprising more than 50% of the total foliage cover (excluding non-indigenous annuals). The dominant grasses are typically *Poa labillardierei* and *Themeda triandra*, often occurring with Juncus spp. Occurrence is on higher elevation mountain slopes and valleys in the South Eastern Highlands bioregion, generally between 900 and 1200 m asl, below the sub-alpine zone.
Sub-alpine Grassland	Grassland with indigenous species comprising more than 50% of the total foiage cover (excluding non-indigenous annuals). The dominant grasses are typically *Poa costiniana*, *Poa clivicola* and *Poa hookeri*. Occurrence is generally above 1200m asl where tree growth is inhibited by natural processes.

Table 6. Common native grasses and forbs of Natural Temperate Grasslands in the ACT (Benson 1994; Eddy *et al.* 1998; Environment ACT 2005)

Scientific name	Common Name	Notes
Grasses		
Themeda triandra	Kangaroo Grass	Important and widespread dominant or co-dominant structural component of many native grasslands in the ACT, particularly in productive and less disturbed sites.
Poa sieberiana	Poa Tussock	Important and widespread dominant or co-dominant structural component of many native grasslands in the ACT.
Austrostipa bigeniculata	Tall Speargrass	Very common and widespread. Tends to occur on deeper soils and drainage lines.

Scientific name	Common Name	Notes
Austrostipa scabra	Corkscrew Grass	Very common and widespread. Tends to occur in drier grassland sites and on shallow soils such as hill crests, upper slopes and ridges.
Rytidosperma spp.	Wallaby Grass (various species)	Very common and widespread. Can become dominant with increased grazing. Over 20 species occur in the ACT. Formerly known as *Austrodanthonia* spp.
Poa labillardierei	River Tussock	A large tussock grass mainly found in wet grassland sites such as drainage lines, river and creek flats, and seepage areas.
Bothriochloa macra	Redleg Grass	Moderately common and widespread, usually occurs as a minor component of native grasslands.
Aristida ramosa	Purple Wiregrass	Moderately common and widespread. Usually occurs as scattered plants or in small clumps.
Anthosachne scabra	Common Wheat Grass	Common and widespread. Usually occurs as a minor component of native grasslands in the inter-tussock spaces. Formerly known as *Elymus scaber*.
Panicum effusum	Hairy Panic	Common and widespread, particularly in well-drained soils where summer soil moisture is more reliable. Usually occurs as a minor component of native grasslands in the inter-tussock spaces.
Forbs		
Chrysocephalum apiculatum	Common Everlasting	Common and widespread. Can co-dominate with grasses at some sites.
Leptorhynchos squamatus	Scaly Buttons	Common and widespread.
Acaena ovina	Sheep's Burr	Common and widespread.
Lomandra spp.	Mat-Rush (various species)	Common and widespread, with the four main species being *L. multiflora* (Many-Flowered Mat-Rush), *L. longifolia* (Spiny-Headed Mat-Rush), *L. filiformis* (Wattle Mat-Rush) and *L. bracteata* (Short-Flowered Mat-Rush).
Carex spp.	Sedges (various species)	Usually found in damp to wet sites, with the main species being *C. inversa* (Knob-Sedge), *C. appressa* (Tall Sedge) and *C. breviculmis* (Short-Stem Sedge).
Juncus filicaulis	Pinrush	Found in seasonally moist grasslands, where it often co-dominates with *T. triandra*.

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

8.1.3 Floristic composition

Native plant species richness in native grassland (particularly native grasslands in higher ecological condition such as Natural Temperate Grassland) can be very high, particularly at small scales (i.e. alpha diversity) (Tremont and McIntyre 1994; Morgan and Williams 2015). This diversity is due to the wide variety of native forb species present, which can comprise up to 70% of the species at a site. Native forbs include sedges, rushes, orchids, lilies, and broad-leaved herbs such as daisies. Over 700 forb species have been identified in grasslands across south-eastern Australia (Eddy 2002), including *Chrysocephalum apiculatum* (Common Everlasting Daisy) and a range of *Lomandra* spp. (Mat-Rush), *Juncus* spp. (rushes), and *Carex* species (sedges).

A diversity of native grasses also occur in native grassland, with dominant and widespread species including *Themeda triandra* (Kangaroo Grass), *Poa sieberiana* (Poa Tussock), *Austrostipa bigeniculata* (Tall Speargrass), *Austrostipa scaber* (Corkscrew Grass) and *Rytidosperma* spp. (Wallaby Grasses). Less dominant grasses that commonly occur in the inter-tussock spaces include *Bothrichloa macra* (Redleg Grass), *Anthosachne scabra* (Common Wheat Grass) and *Panicum effusum* (Hairy Panic). In addition to vascular plants, native grasslands also contain non-vascular plants and other organisms that constitute the biological soil crust, such as mosses, liverworts, lichens, cyanobacteria, algae and fungi (Morgan 2004).

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

8.1.4 Native grassland fauna

Fauna are an intrinsic part of grassland ecosystems, and are essential for a range of functions such as pollination, seed dispersal, nutrient recycling and maintenance of soil condition. Grasslands provide habitat for animals and are a source of food for both herbivores and predators.

Common grassland fauna include mammals, birds, reptiles, frogs, and invertebrates such as spiders, ants, flies, moths, beetles, and grasshoppers (Eddy 2002; Antos and Williams 2015). A range of fauna can be found below ground, including organisms such as worms and micro-organisms. Grazing herbivores, such as kangaroos, wallabies, wombats and termites, are particularly important in native grasslands due to both their role in transferring energy and nutrients from the producers to other parts of the ecosystem and also their effect on habitat structure for a wide range of organisms.

Native grassland in the ACT is also home to two threatened species of invertebrates: the Perunga Grasshopper (*Perunga ochracea*), and the Golden Sun Moth (*Synemon plana*), as well as several species that are considered to be rare, such as the Canberra Raspy Cricket (*Cooraboorama canberrae*), Lewis's Laxabilla Grasshopper (*Laxabilla smaragdina*) and Key's Matchstick Grasshopper (*Keyacris scurra*).

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

Many birds inhabit and forage in native grassland. In the ACT, five birds are considered to be grassland specialists: the Stubble Quail (*Coturnix pectoralis*), Brown Quail (*Coturnix australis*), Singing Bushlark (*Mirafra javanica*), Brown Songlark (*Cinclorhamphus cruralis*) and the Australasian Pipit (*Anthus novaeseelandiae*). Latham's Snipe (*Gallinago hardwickii*), a species protected under migratory bird agreements with Japan and China, utilises wetlands in native grassland sites and flooded grasslands. A large number of other bird species forage in native grassland of the ACT, including the Australian Magpie (*Gymnorhina tibicen*) and Magpie-lark (*Grallina cyanoleuca*). Birds of prey commonly hover or soar over native grasslands in search of food.

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

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

8.1.5 Habitat and ecology

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

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

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

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

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

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

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

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

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

Using this hierarchy, Armstrong *et al.* (2013) classified and described the native plant communities of the upper Murrumbidgee catchment in NSW and the ACT (1.741 million ha) based on numerical analysis of full-floristic plot data, using 4106 survey plots compiled from a range of different datasets. Nine grassland communities are found in the ACT. Although these communities are well-described, their distributions have not yet been fully mapped across the ACT. These nine grassland community classifications are detailed in section 8.9, and supersede the floristic associations described in the previous native grassland strategy (ACT Government 2005).

8.1.7 Environmental determinants of ACT grassland associations

A range of environmental factors influence the occurrence and distribution of the nine grassland associations found in the ACT. These include climate (particularly moisture availability), landscape position, elevation, geology, drainage patterns and soil nutrients. Changes in these environmental factors are associated with differences in the dominant grass species and the associated grassland forbs. For example, in creek and river flats, the dominant grass is more likely to be *Poa labillardierei*, whereas *Themeda triandra* dominates on drier well-drained slopes (Armstrong *et al.* 2013; Williams and Morgan 2015).

8.1.8 Natural Temperate Grassland: Commonwealth and ACT listing as a threatened ecological community

Natural Temperate Grassland is broadly decribed as a native ecological community occurring in the temperate climatic zone that is largely treeless and is dominated by native grass and forb species. This ecological community is more fully described in the Natural Temperate Grassland action plan (Part B of this document).

Natural Temperate Grassland is listed as threatened under Commonwealth (EPBC Act 1999) and ACT legislation (NC Act 2014). The Commonwealth EPBC listing is 'Natural Temperate Grassland of the South Eastern Highlands Critically Endangered Ecological Community' (Commonwealth of Australia 2016a). The ACT listing is 'Natural Temperate Grassland Endangered Ecological Community'.

At the time of writing there are differences between the Commonwealth and ACT legislation in the definition of what is Natural Temperate Grassland. However, the ACT legislation is expected to be revised soon to align with the definition of Natural Temperate Grassland under the EPBC Act, to avoid two definitions.

In anticipation of the ACT definiton aligning with the Commonwealth EPBC Act definition, this strategy uses the Commonwealth EPBC Act definition of Natural Temperate Grassland.

The key current differences between the Commonwealth and ACT definitions relate to the altitudinal range they occur in, and the ecological condition (low condition grasslands do not meet the crieteria for the Natural Temperate Grassland ecological community).

Under the current NC Act definition Natural Temperate Grassland does not include grasslands higher than 625 metres above sea level whereas the EPBC Act listing of the Natural Temperate Grasslands of the South Eastern Highlands includes grasslands that occur at altitudes between 250 and 1200 metres on in and around the South Eastern Highlands (SEH). Currently, any grassland over 1200 metres, including those in the Alpine Complex, are not part of any threatened or endangered community listing.

Under the EPBC Act, the ecological condition of grassland is determined using the Floristic Value Score (FVS) (Rehwinkel 2015; Commonwealth of Australia 2016a), a metric based upon the presence of certain indicator plant species. The ACT also uses a floristic metric (which includes the presence of indicator plant species species), although the results of this metric are not readily comparable to those of the more recently developed FVS.

8.1.9 Native grasslands, degraded grasslands, and exotic grasslands

The condition of native grassland ranges from high quality grassland (Natural Temperate Grassland) that retains its ecological integrity, though to degraded grasslands that include native grasslands in poor ecological condition and exotic grasslands. Degraded native grasslands have lost much of their native species diversity and contain a high proportion of non-native species (weeds). Grasslands that are dominated by non-native species (weeds) do not meet the definition of native grassland (Table 5) and these degraded grasslands (from the perspective of the original native grassland) are classed as exotic grasslands.

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

Degraded grasslands are at the other end of the continuum from high quality Natural Temperate Grassland. Degraded grasslands include native grasslands in low ecological condition, and former native grasslands that have become exotic grasslands. Degraded native grasslands are still dominated by one or more native grass species, which may not have been the original dominants, but have very few or no native forbs and a high proportion of introduced perennial species such as Phalaris (*Phalaris aquatica*), African Lovegrass (*Eragrostis curvula*), Cocks-foot (*Dactylis glomerata*) and Chilean Needlegrass (*Nasella neesiana*). Exotic grasslands may still have some of the original native grasses present, but are dominated by introduced perennial species.

Degraded grasslands (both native and exotic) can still have a range of economic, social, functional, and biodiversity values. For example, they may provide important habitat for threatened animal species, provide connectivity in the landscape, or play a role in landscape function such as erosion and groundwater management. Degraded grasslands have the potential to be restored to higher condition native grassland under favourable management.

Natural Temperate Grassland, degraded native grassland and exotic grassland may occur at a

Gibraltar burn

site in a mosaic. In such circumstances the exotic grassland may be part of a continuum of habitat used by native grassland fauna, and may offer refuge during certain times, for example creek-flat exotic grassland may offer refuge during drought. Thus conservation of native grassland (including Natural Temperate Grassland) and the native fauna it contains needs to take into account the broader grassland patch in which it sits.

8.1.10 Derived grasslands

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

8.1.11 Rocky grasslands

This grassland association was not included in the prevous (2005) strategy but is included in this strategy due to a change in the description of Natural Temperate Grassland under the Commonwealth EPBC Act. This grassland association is described in detail in section 8.9 as association r8.

As the name implies, rocky grasslands occur in areas where rocks comprise a relatively high proportion of the ground cover. This grassland association comprises open to dense, mid to tall tussock grassland with the upper stratum dominated by *Themeda triandra*, *Aristida ramosa*, *Lomandra filiformis* and *Austrostipa densiflora*.

In the ACT, rocky grasslands are most commonly found on midslopes in the Molonglo and Murrumbidgee river corridors, but also occur on some hills in Canberra. Rocky grasslands comprise important habitat for the threatened Pink-tailed Worm-lizard (more details are given in the Pink-tailed Worm-lizard action plan 2017).

8.1.12 Montane and sub-alpine grasslands

These grassland associations were not included in the prevous (2005) strategy but are included in this strategy due to a change in the description of Natural Temperate Grassland under the Commonwealth EPBC Act. Montane grasslands are described in detail in section 8.9 as grassland associations r1, r2 and r7, and sub-alpine grasslands are described as associations a14 and a30. Almost all (99%) of these associations occur in Namadgi National Park.

Montane grasslands most commonly occur on the broad flats and lower slopes associated with creeks and rivers, usually in areas with severe frosts. Sub-alpine grasslands commonly occur between the edge of woodlands and the edge of poor drainage areas. In Namadgi National park these grasslands typically occur between sphagnum moss bogs and the surrounding woodland.

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

8.2.1 Historical distribution

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

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

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

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

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

8.2.2 Aboriginal use and influence

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

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

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

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

8.2.3 Early exploration and settlement

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

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

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

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

The impacts of this early settlement soon became evident. By 1840 P.E. de Strzelecki, in a report to Governor Gipps, expressed concern about the effects that drought, cropping and over-grazing were having on soil erosion. By the late 1800s in the higher mountain grasslands, fifty years of summer stock grazing and the practice of burning off had already resulted in the reduction in plant cover, soil erosion and loss of some plant species (Costin 1954).

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

8.3 CURRENT NATIVE GRASSLAND DISTRIBUTION IN THE ACT

The distribution of native grasslands (including Natural Temperate Grassland) are shown in Chapter 2 and in the Natural Temperate Grassland action plan (in Part B of this document). The most up-to-date maps for this ecological community ares publicly available on the ACT Government's mapping portal (Visit the ACTmapi website). Table 7 shows approximate areas of grassland community types based on the most recent mapping.

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

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

The largest areas of lowland native grassland are found in the eastern and southern areas of Canberra's urban area, particularly the Jerrabomberra and Majura Valleys, including native grasslands in the Majura Training Area and the Canberra International Airport. Relatively large areas of native grasslands can also be found in Gungahlin and Belconnen, including Crace Nature Reserve, Mulanggari Nature Reserve, Gungaderra Nature Reserve, Molonglo river corridor, 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.

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

Detailed mapping has been completed for Long Flat, Grassy Creek, Orroral Valley and Emu Flats. At the time of writing mapping was being completed for Sam's Creek, Grassy Creek, Nursery Creek, Rendezvous Creek and Bogong Creek. There is potential for sites to exist on leasehold land in the central Naas Valley, upper Gudgenby River area, and lower Blue Gum Creek area.

8.4 THREATENED AND UNCOMMON GRASSLAND SPECIES IN THE ACT

8.4.1 Threatened species

Native grasslands in the ACT are an important ecosystem for a range of threatened flora and fauna species. These species include three plant species and four animal species declared as threatened in the ACT under the NC Act (2014) (Table 8), and an additional two plant species listed as threatened under the EPBC Act.

Currently, the plant *Gentiana baeuerlenii* is only known from one location in higher elevation montane grasslands of the Orroral Valley, ACT, and despite annual surveys has not been recorded since 1998.The Hoary Sunray (*Leucochrysum albicans* var. *tricolor*) and the Austral Toadflax (*Thesium australe*) are found in native grasslands and grassy woodlands, and are included in the ACT Lowland Woodland Conservation Strategy (ACT Government 2004).

8.4.2 Uncommon and rare species

There are many species occurring in native grasslands of the ACT that may be of conservation concern (Table 9 and 10) even though they are not currently listed under ACT or Commonwealth legislation as threatened. These include species that are uncommon or rare because they are either at the margin of their distribution or they occur naturally at low density. Some of these species are of conservation concern because they are declining (in the ACT or elsewhere) and because small populations tend to be more vulnerable to disturbance. Minimising threats and monitoring their abundance and/or habitat is required to help prevent these species becoming threatened.

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

Table 7. Grassland community types based on most recent mapping of 73,740 hectares of the eastern ACT. These totals will change as mapping of the remainder of the ACT progresses.

Grassland Community	Area mapped	Notes
Natural Temperate Grassland < 625 m	880 ha	Approximate area, not mapped at the association level.
Natural Temperate Grassland >625 m	1900 ha	Potential Natural Temperate Grassland approximate area, grassland not mapped at the association level, includes r1, r2, a14.
Native grassland (excluding Natural Temperate Grassland)	2600 ha	Approximate area, may include areas of secondary grassland – currently unable to differentiate. Not mapped at the association level.

Table 8. Conservation Status of ACT and Commonwealth threatened flora and fauna species found in ACT native grasslands.

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

Species	Common Name	Cwlth	ACT	NSW	VIC	QLD
Perunga ochracea	Perunga Grasshopper	-	V	-	-	-

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

Table 9. Uncommon and rare grassland Fauna species in the ACT.

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

* previously Singing Bushlark

Table 10. Uncommon and rare grassland Flora species in the ACT.

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

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

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

Table 11. Grassland areas added (or in the process of being added) to the ACT's conservation estate since 2005, including Natural Temperate grassland (NTG), other native grassland areas, and exotic grassland.

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

8.5 GRASSLAND CONSERVATION ACTIVITIES IN THE ACT SINCE 2005

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

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

Community groups and universities continue to play a key role in the conservation of native grasslands. Not-for-profit community groups undertake a wide range of on-ground management activities and experimental restoration projects, in addition to advocacy and raising public awareness. Since the previous strategy, significant research projects on grasslands and their fauna have been undertaken by universities and other institutions (including the Australian Botanic Gardens), often in partnership with the ACT Government. These projects include Honours, PhD and post-doctoral research on Grassland Earless Dragons, Golden Sun Moths, grazing effects of kangaroos, and translocation of threatened plants. Supporting and partnering with community groups, universities and other organisations in the future will be essential to achieving the goals of this strategy.

8.5.1 Protection in conservation reserves

A key objective for grassland conservation arising from the previous Strategy was: "a comprehensive, adequate and representative system of Natural Temperate Grassland areas in the ACT is protected by reservation or other measures where reservation is not practical or desirable". This has been largely achieved for land owned and managed by the ACT Government by the addition of over 700 ha of grasslands, including 169 ha of Natural Temperate Grassland, as either new reserves or as additions to existing reserves (Table 11).

Since the last strategy (2005), Natural Temperate Grassland at a number of small sites on Territory land has been lost to urban development (total area lost is less than 10 ha). Natural Temperate Grassland has also been lost (total area less than 10 ha) on Commonwealth land to development on the Canberra International Airport (leased) (<10 ha)

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

8.5.2 Management of kangaroo grazing pressure

A 'conservation culling' program for kangaroos commenced in five reserves in 2009 and expanded gradually to 11 reserves containing areas of the endangered grassland or woodland communities. The program is managed in accordance with the Controlled Native Species Management Plan for eastern grey Kangaroos (ACT Government 2017a), and the ACT Kangaroo Management Plan (ACT Government 2010). Where possible it is also managed on a co-operative basis with kangaroo management undertaken by other land managers, including rural landholders (as outlined in 'Calculation of the Number to Cull', ACT Government 2016a) and the Commonwealth Government. For more information, view the Calculation document (1467Kb)

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

8.5.3 Mapping and surveys

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

- **The Native Vegetation of New South Wales and the ACT**. State-wide mapping, classification and descriptions of vegetation (Keith 2004).
- **Plant communities of the upper Murrumbidgee catchment** in New South Wales and the Australian Capital Territory. Classification and descriptions of vegetation communities (Armstrong *et al.* 2013).
- **The peat-forming mires of the Australian Capital Territory**. Mapping and descriptions of peat-forming mires of the ACT by the Australian National University. Includes mapping and description of Poa sod tussock grassland (fen), equivalent to community a14 *Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion of Armstrong *et al.* (2013) (Hope, Nanson and Flett 2009).
- **The vegetation of the Kowen, Majura and Jerrabomberra districts of the ACT**. Vegetation mapping of approximately 21,000 ha in the Kowen, Majura and Jerrabomberra districts. This ACT Government project mapped 4,906 ha of native grassland and 424 ha of Natural Temperate Grassland (Baines *et al.* 2014).
- **ACT Vegetation Community Mapping**. Territory-wide mapping of vegetation communities commenced by the ACT Government in 2013 is expected to be completed by 2017. Where possible the mapping classifies grasslands dominated by native species into the appropriate association (see section 8.1.6). Where it is not possible to classify grassland to the association level it is mapped as Native Grassland (areas dominated by native species but with unknown diversity), Natural Temperate Grassland (areas that have a diversity of native forbs and are known to meet the criteria that define this endangered ecological community) or Exotic Grassland (areas dominated by exotic species).
- **Surveys for the Pink-tailed Worm-lizard** have been undertaken in the Molonglo River valley and adjacent areas, including vegetation surveys at Molonglo and Ginninderry, to inform planning for urban development. Mapping was also undertaken for this species in the Urambi, Cooleman and Pinnacle areas.
- **Canberra Nature Map.** A website and app allowing the community to record locations of sightings of plants and animals.
- **Weed mapping projects.** Weed mapping on reserves by ACT Government and weed spraying contractors using mobile mapping technology. Weed mapping by citizens using the Weed Spotter website and app.

8.5.4 Research projects

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

Eastern Grey Kangaroo Research. A number of research projects on kangaroos and their grazing effects have been conducted or are currently underway, much of which has included grassland ecosystems:

- Doctoral Thesis by B. Howland (Howland 2016, Australian National University) on the interactions between kangaroos and grassland fauna (Howland *et al.* 2014; 2016a; 2016b)
- Doctoral Thesis by D. Fletcher (Fletcher 2006, University of Canberra) on population dynamics of Eastern Grey Kangaroos in temperate grasslands.
- Methods for estimating kangaroo densities (Howland 2008).

- Impacts of kangaroo grazing on lowland woodland and grassland communities, including vegetation structure, herbage mass, floristics, insects reptiles and birds (McIntyre *et al.* 2010; Barton *et al.* 2011; Armstrong 2013; Manning *et al.* 2013; Vivian and Godfree 2013; Howland *et al.* 2014, 2016a, 2016b; McIntyre *et al.* 2015).
- Movement behaviour of kangaroos in urban Canberra (ACT Government unpublished data).
- Fertility control (ACT Government 2013b). The ACT Government has supported research into fertility control for Eastern Grey Kangaroos since 1998, undertaken in collaboration with the Invasive Animals CRC and CSIRO using the immunocontraceptive vaccine GonaCon™.

Development of the Floristic Value Score. A method to assess the relative conservation value of grasslands in the ACT and surrounding NSW region has been researched and developed by Rehwinkel (2015). The method incorporates species richness and the abundance of significant ‘indicator’ species to calculate a Floristic Value Score (FVS). The FVS was incorporated into the condition thresholds of the Approved Conservation Advice for the updated listing of NTG-SEH under the EPBC Act in 2016 (Commonwealth of Australia 2016a). The FVS is also now used by the ACT Government and ecological consultants to assess the quality of native grassland sites in the ACT, and has been adopted by the NSW Office of Environment and Heritage.

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

- Doctoral thesis by W. Dimond (University of Canberra) “Population decline in the endangered Grassland Earless Dragon in Australia : identification, causes and management” (Dimond 2010; Dimond *et al.* 2012).
- Post-doctoral research by L. Doucette on the field ecology and reproduction in captivity of Grassland Earless Dragons.
- Genetics studies by S. Sarre and others (University of Canberra) to examine the effects of habitat fragmentation on Grassland Earless Dragons (Hoehn *et al.* 2013).
- Honours thesis by T. Stevens on home ranges of Grassland Earless Dragons (Stevens *et al.* 2010).
- Golden Sun Moth: survey methods (A. Richter et al. 2009, University of Canberra), habitat manipulation (Sea and Downey 2014a, University of Canberra) and translocation methods (Sea and Downey 2014b, SMEC Australia Pty Ltd).
- Research by the ACT Government on rock placement to improve habitat connectivity for Pink-tailed Worm-lizards in the Molonglo River corridor (ACT Government).
- Seed storage, germination trials and translocations of Ginninderra Peppercress (Australian National Botanic Gardens, Greening Australia, ACT Government).
- Experimental grassland management using small scale burns (ACT Government).

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

Croke Place Grassland Management Experiment. Long-term research on the floristic responses of a remnant patch of Natural Temperate Grassland to mowing and burning, undertaken by the North Belconnen Landcare Group in association with ACT Government and the Ginninderra Catchment Group (Hodgkinson 2016).

Ginninderra Catchment Grassland Restoration Research Project. This experimental project aims to find efconomical and effective means of restoring degraded grassland. Treatments at each of the 15 sites include mowing, 2 burning regimes and non-treatment (controls). This project is managed by the Ginninderra Catchment Group in collaboration with ACT Government, ACT Rural Fire Service, CSIRO, Greening Australia, University of Canberra, Australian National University, Friends of Grasslands, and a number of Landcare and Parkcare groups in the Catchment.

8.5.5 Monitoring

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

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

Long-term threatened species monitoring is undertaken by the ACT Government for the ACT's threatened grassland species (Table 8) and is outlined in the respective action plans for each species (Part B). These survey and monitoring programs have been undertaken for over two decades and form the basis for determining long-term trends in the distribution and abundance for threatened species. A long-term monitoring program for Grassland Earless Dragons that was established in 2003 detected the severe population decline of this species during the 2002–2009 drought, and subsequent signs of population recovery. The detection of this decline prompted a number of studies into Grassland Earless Dragon ecology, including two PhD studies.

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

Grassland condition surveys have been undertaken for 49 lowland native grassland sites in the ACT as part of an invstigation into native grasslands by the ACT Commissioner for Sustainability and the Environment (Cooper 2009). A subsequent report (Hodgkinson 2014) to the Commissioner assessed the condition of grasslands at 14 grassland sites. These surveys provide a valuable baseline against which to assess future trends in grassland condition.

8.5.6 Herbage mass management

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

8.5.7 Fire ecology

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

8.5.8 Community collaboration and engagement

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

- Golden Sun Moth survey: Community-based citizen science project tosurvey/monitor Golden Sun Moth abundance at numerous sites in the ACT. Funded by WWF, coordinated by University of Canberra, involved FoG and other interested citizens (Richter *et al.* 2009).
- Vegwatch: a robust monitoring tool developed for the Molonglo Catchment Group to enable its volunteer member groups to monitor the effectiveness of their on-ground work (Sharp and Gould 2010).
- The Grass Experiment at the Pinnacle Nature Reserve: a collaborative project between the Friends of the Pinnacle, the Australian National University, and ACT Parks and Conservation to experimentally investigate methods to reduce the dominance of exotic species in a grassy ecosystem (Friends of the Pinnacle 2011).
- Restoration and management activites at Yarramundi Grassland, a collaboration between Friends of Grasslands and the Natonal Captial Authority.
- A 2014 forum run by Friends of Grasslands: 'Grass half full or grass half empty? Valuing native grassy landscapes' (Milligan and Horton 2014) to present and demonstrate achievements in grassland conservation and management throughout south-eastern Australia.
- Seeing Grasslands: a project funded in 2010 that aimed to raise the profile of grasslands through community photographic workshops, resulting in exhibitions and a book (Reid 2015).
- Canberra Nature Map: a website and app founded by an ACT resident in 2014 allowing citizens to report sightings of plant species through photography. The tool is being expanded to include reptiles and birds.
- Weed Spotter: a website and app allowing citizens to report sightings of weeds or to map weed extent.
- Snakes Alive!: an annual exhibition by the ACT Herpetological Association and Australian National Botanic Gardens raising awareness of reptiles and amphibians, including the threatened grassland species Grassland Earless Dragon and Striped Legless Lizard (Reid 2015).
- ACT Region Catchment Groups Art Prizes 2015 'Native Grasslands' Exhibition.
- Contribution to reference/educational materials on grassland monitoring, such as monitoring chapter (Sharp et al. 2015) in *Land of Sweeping Plains* (Williams et al. 2015).
- Several ACT Government research projects have involved community volunteers, including kangaroo surveys, vegetation surveys and surveys for Striped Legless Lizards and other repiles.

8.5.9 Independent review

The ACT Commissioner for Sustainability and the Environment (CSE) conducted an investigation into the conservation of native grasslands in the ACT between 2007 and 2009 (Cooper 2008, 2009). The aim was to assess the condition of grasslands (including grazing by kangaroos) and management arrangements, to ensure the protection and long-term sustainability of native lowland grasslands. The CSE engaged additional surveys for selected reseves in 2014 (Hodgkinson 2014). The reports made numerous recommendations that were considered by the ACT Government and have subsequenty informed and influenced ACT Government management programs for native grasslands.

8.6 EVIDENCE BASE FOR THE ACT NATIVE GRASSLAND STRATEGY

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

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

Pink-tailed Worm-lizard (R. Milner)

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

8.7 CLIMATE CHANGE: POTENTIAL IMPACTS ON NATIVE GRASSLANDS

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

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

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

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

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

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

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

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

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

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

8.8 KANGAROO GRAZING OF NATIVE GRASSLANDS

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

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

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

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

Despite the practical advantages of livestock, kangaroos are preferable for long term conservation because they are distinctly different grazers to livestock, being highly selective for grasses (Jarman and Phillips 1989).

Native grasslands have also evolved under kangaroo grazing, and kangaroos cause less damage to soils of grasslands than hard-hoofed livestock.

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

8.9 DESCRIPTIONS OF GRASSLAND ASSOCIATIONS

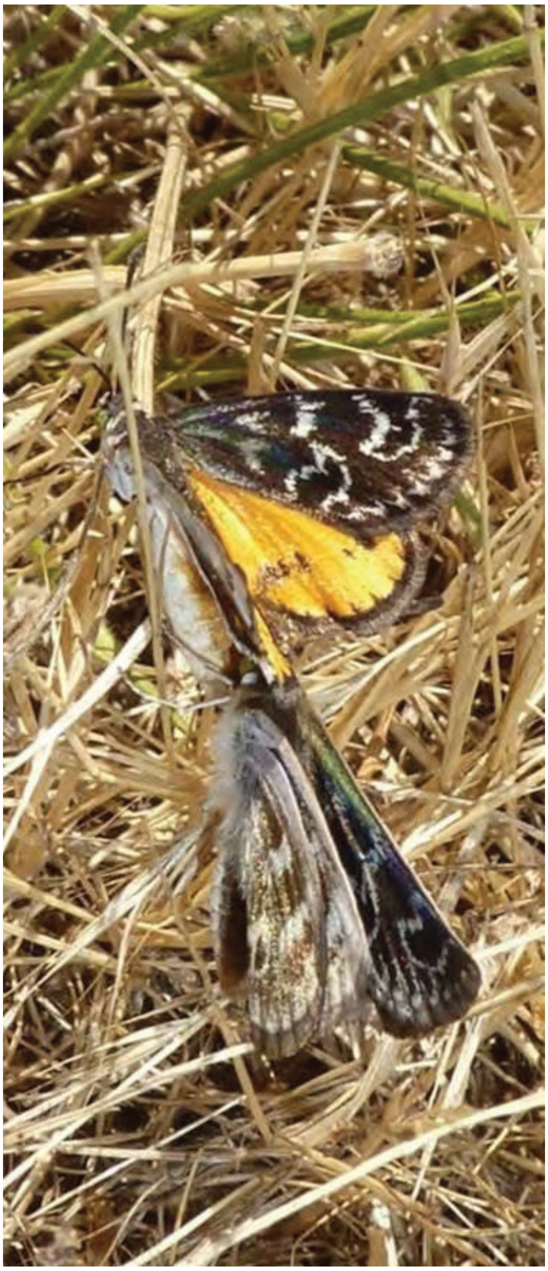
The following are descriptions from Armstrong *et al.* (2013) of the nine grassland associations found in the ACT that are likely to contain Natural Temperate Grassland.

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

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

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

Golden Sun Moth (D. Rees)



increase in density at ecotones with adjacent woodland and forest communities. Relatively undisturbed sites may have a variety of uncommon grassland forbs, including *Prasophyllum wilkinsoniorum*, *Diplarrena moraea* and *Thysanotus tuberosus*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Community r6 is an open to dense, mid-high to tall tussock grassland dominated by one or more of the following in the upper stratum: *Poa sieberiana*, *Rytidosperma* spp., *Themeda triandra*, *Austrostipa scabra* and *Austrostipa bigeniculata*. There is a diversity of forbs and other grasses in the inter-tussock spaces, including *Chrysocephalum apiculatum*, *Acaena ovina*, *Asperula conferta*, *Wahlenbergia* spp., *Scleranthus diander*, *Anthosachne scabra*, *Plantago varia*, *Poa meionectes*, *Bothriochloa macra*, *Brachyscome heterodonta*, *Enneapogon nigricans* and *Leptorhynchos squamatus*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus lacrimans*, *Acacia dealbata* or *Acacia rubida*. Isolated patches of shrubs may also occur, generally containing *Einadia nutans*, *Melicytus* sp. 'Snowfields', *Cryptandra amara*, *Pimelea glauca*, *Discaria* *pubescens*, *Mirbelia oxylobioides* and *Dodonaea procumbens*. Trees and shrubs increase in density in ecotones with adjacent woodland communities or on rocky sites. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Geranium antrorsum*, *Rutidosis leiolepis*, *Swainsona sericea*, *Cullen tenax*, *Pimelea curviflora* and *Stackhousia monogyna*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Blue Grass Liley (J. Lidner)

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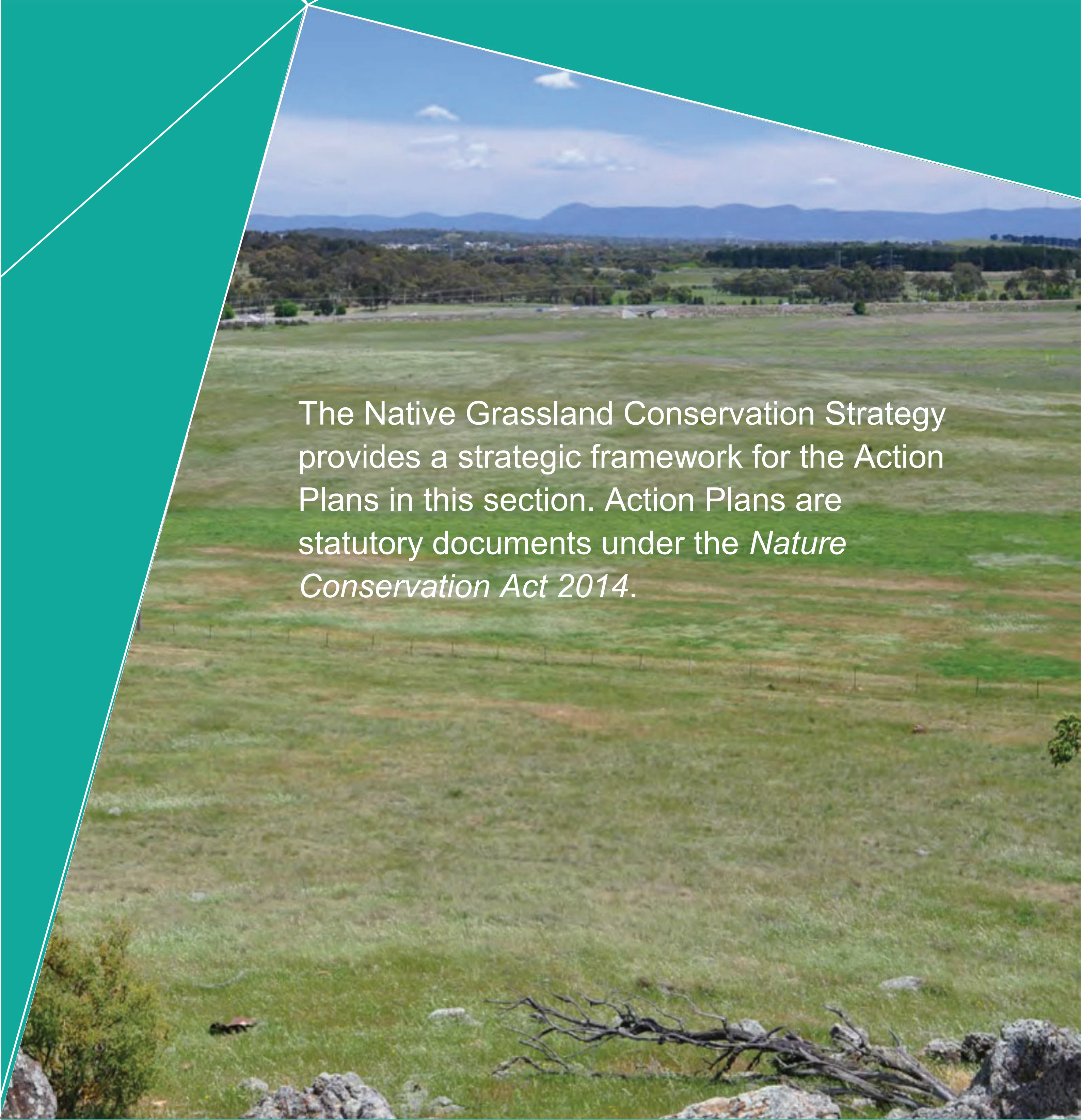
PART B
ACTION PLANS



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, *Austrostipa* 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*).

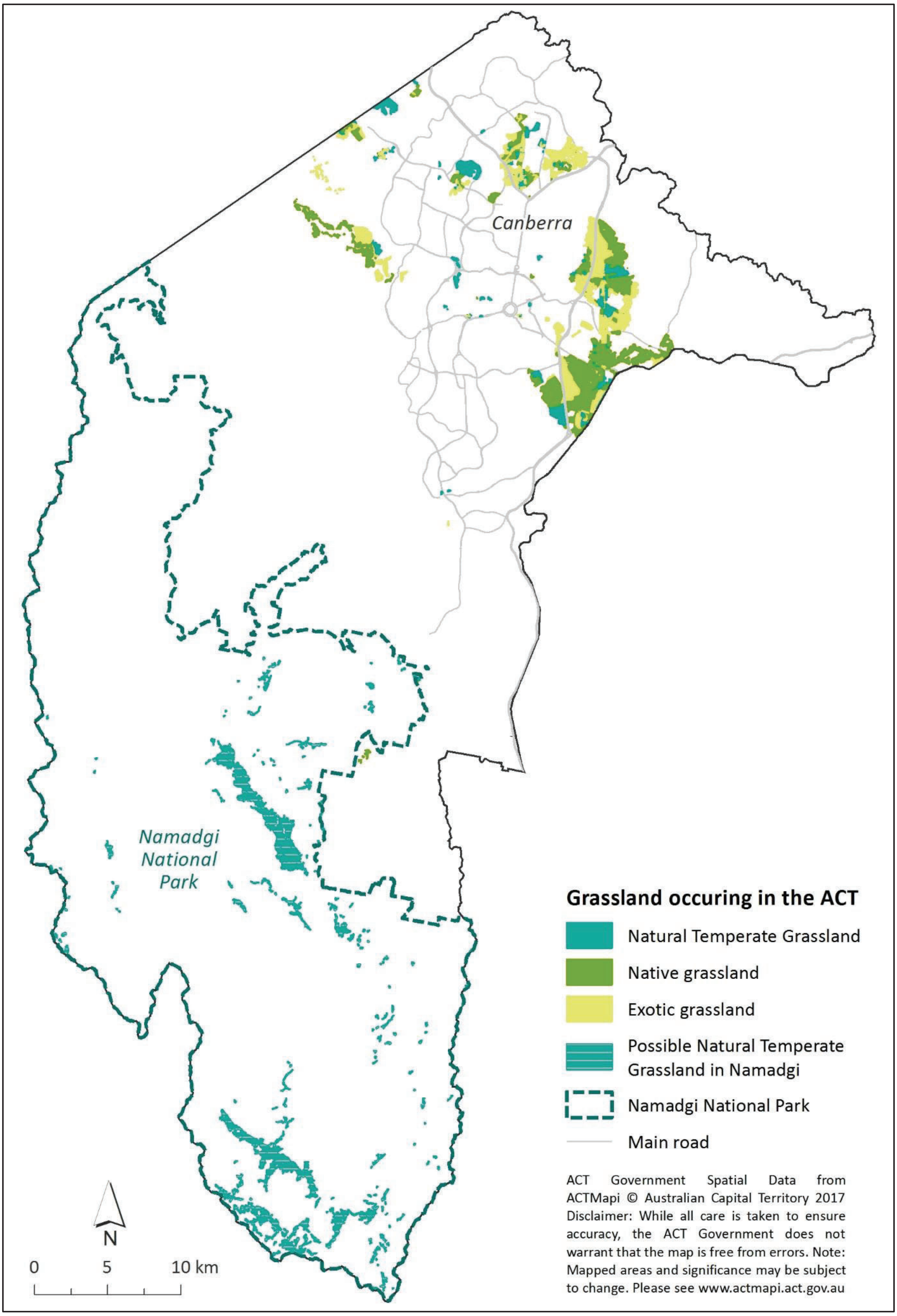
More detailed information on the description, habitat and ecology of native grasslands (including Natural Temperate Grassland), is given in section 8 of the strategy (Part A of this document).

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). Each grassland community type is differentiated by structure, dominant and co-dominant native grass species, native forb composition, and distribution across the landscape.

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.

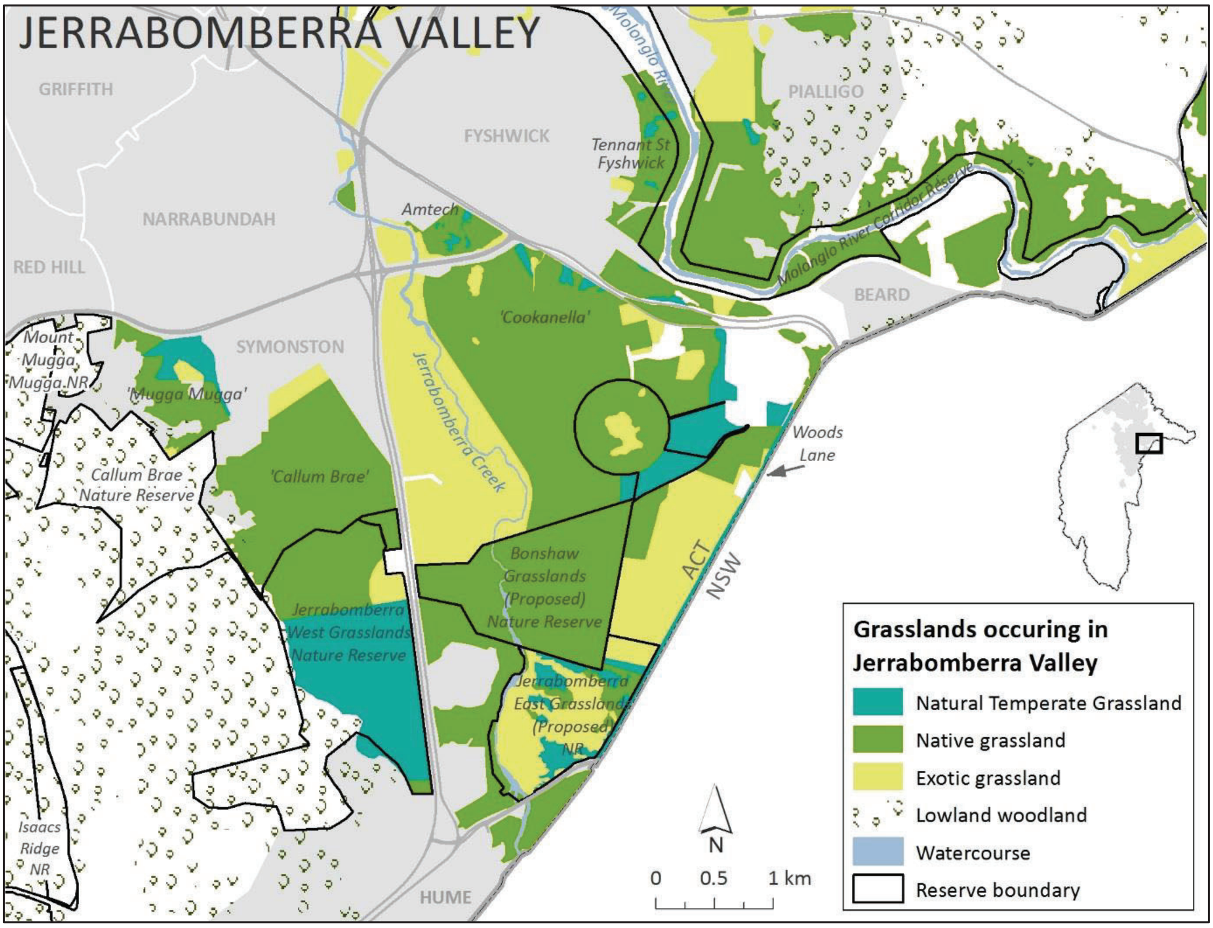


Figure 3. Natural Temperate Grassland distribution in the Majura Valley.

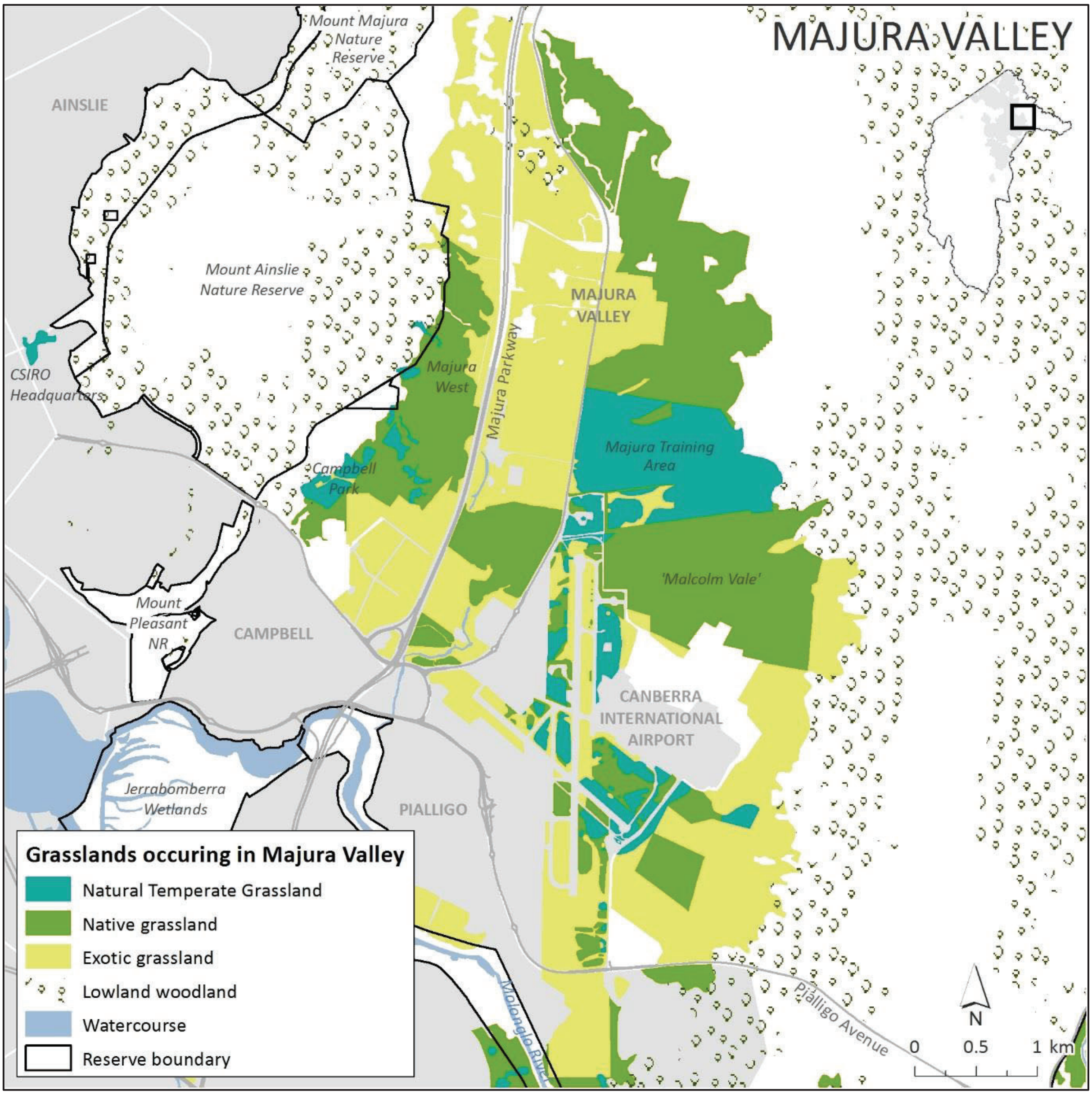
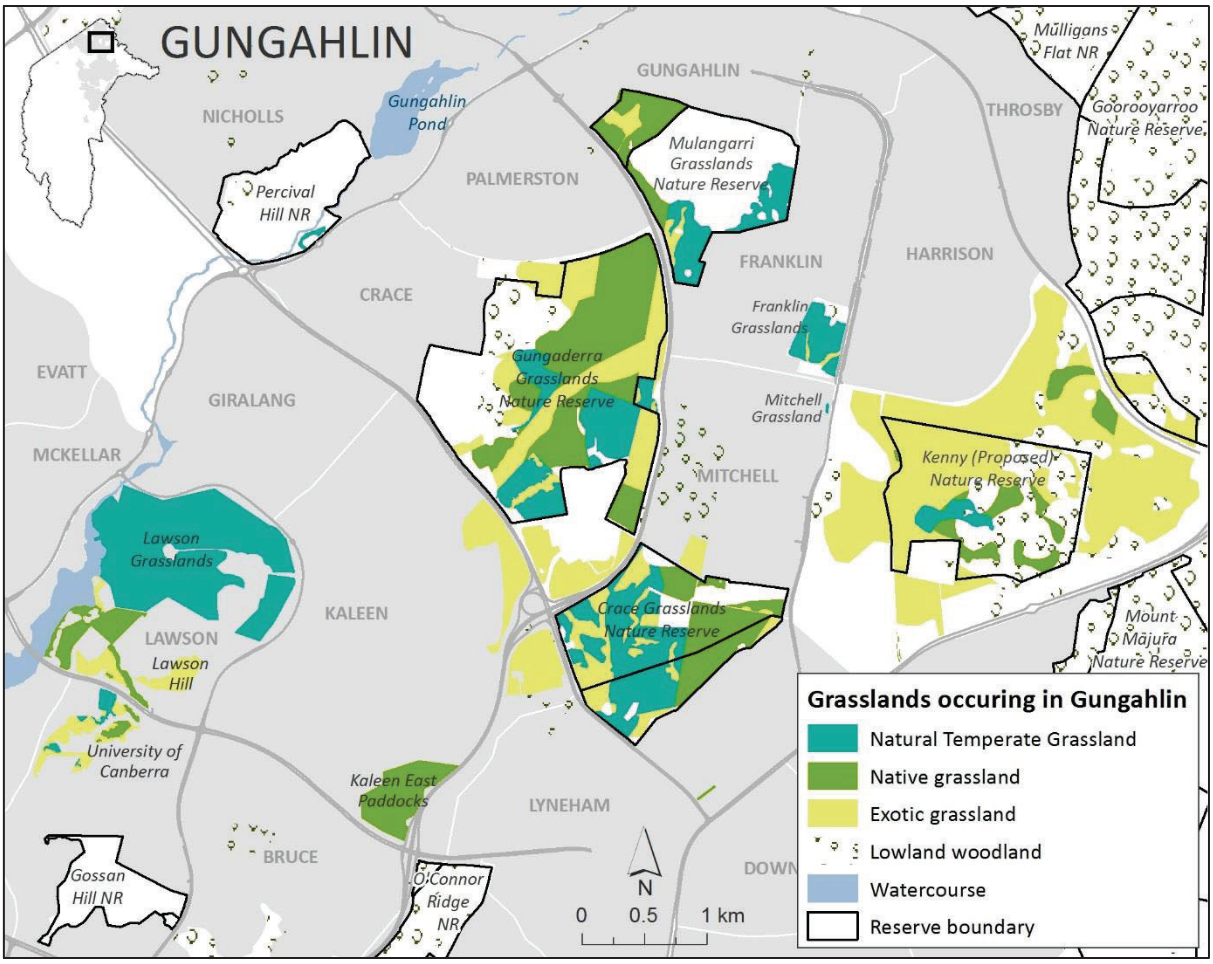


Figure 4. Natural Temperate Grassland distribution in Gungahlin.



Dry Tussock Grassland

Figure 5. Natural Temperate Grassland distribution in Belconnen.

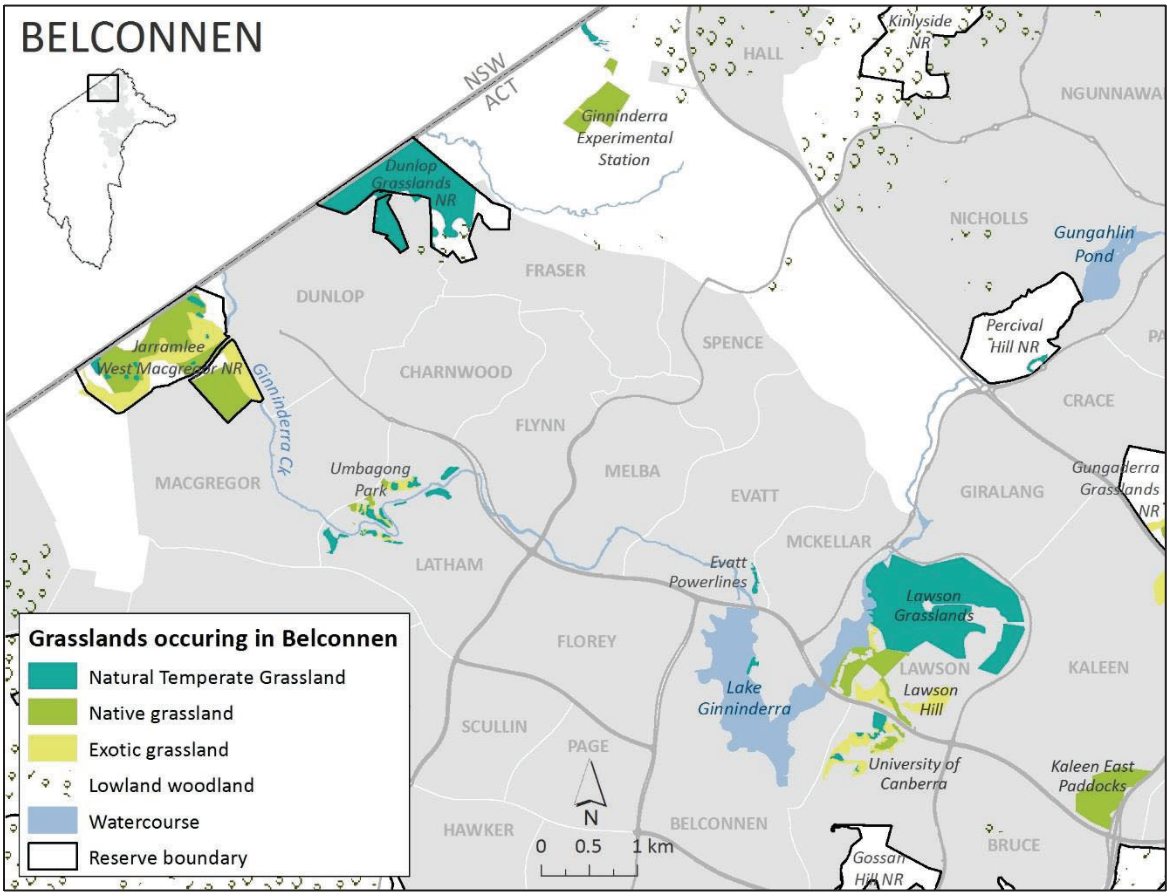


Figure 6. Natural Temperate Grassland distribution in West Belconnen.

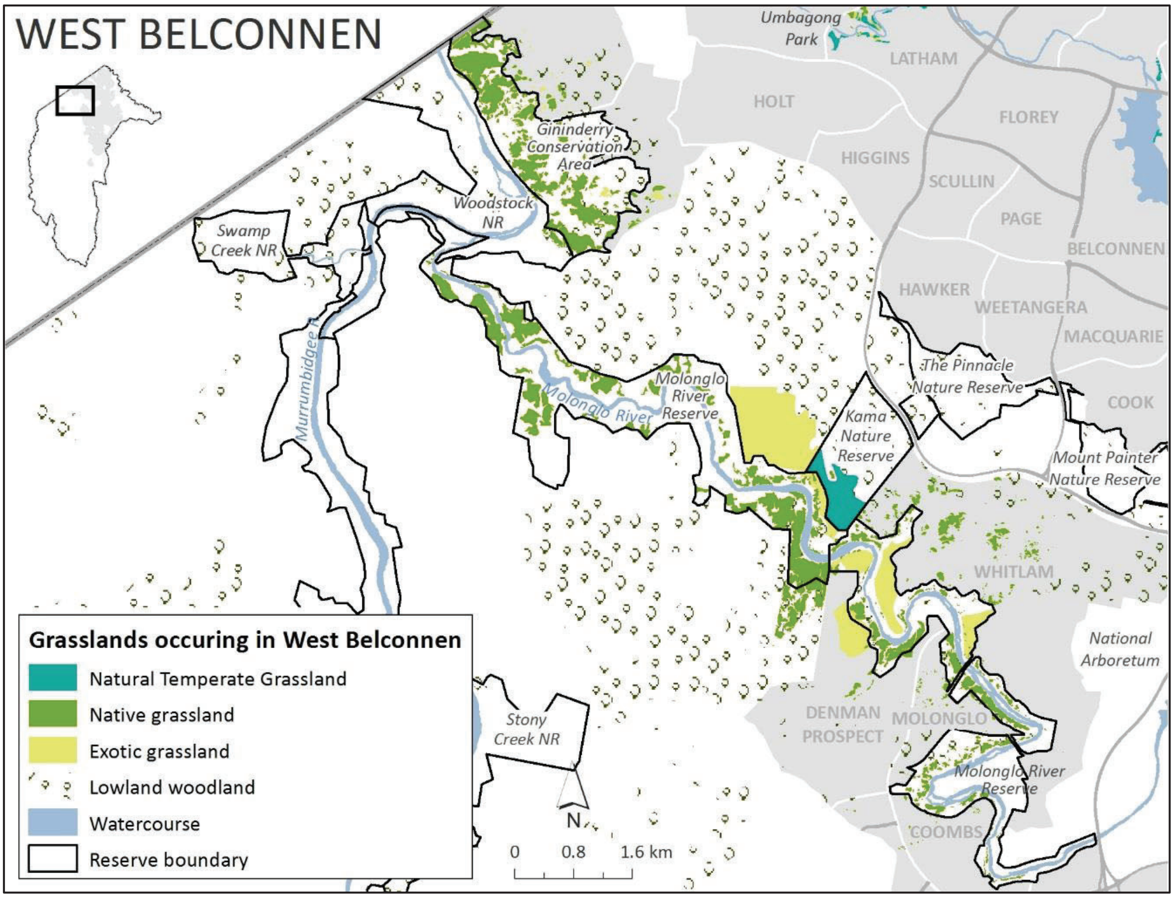
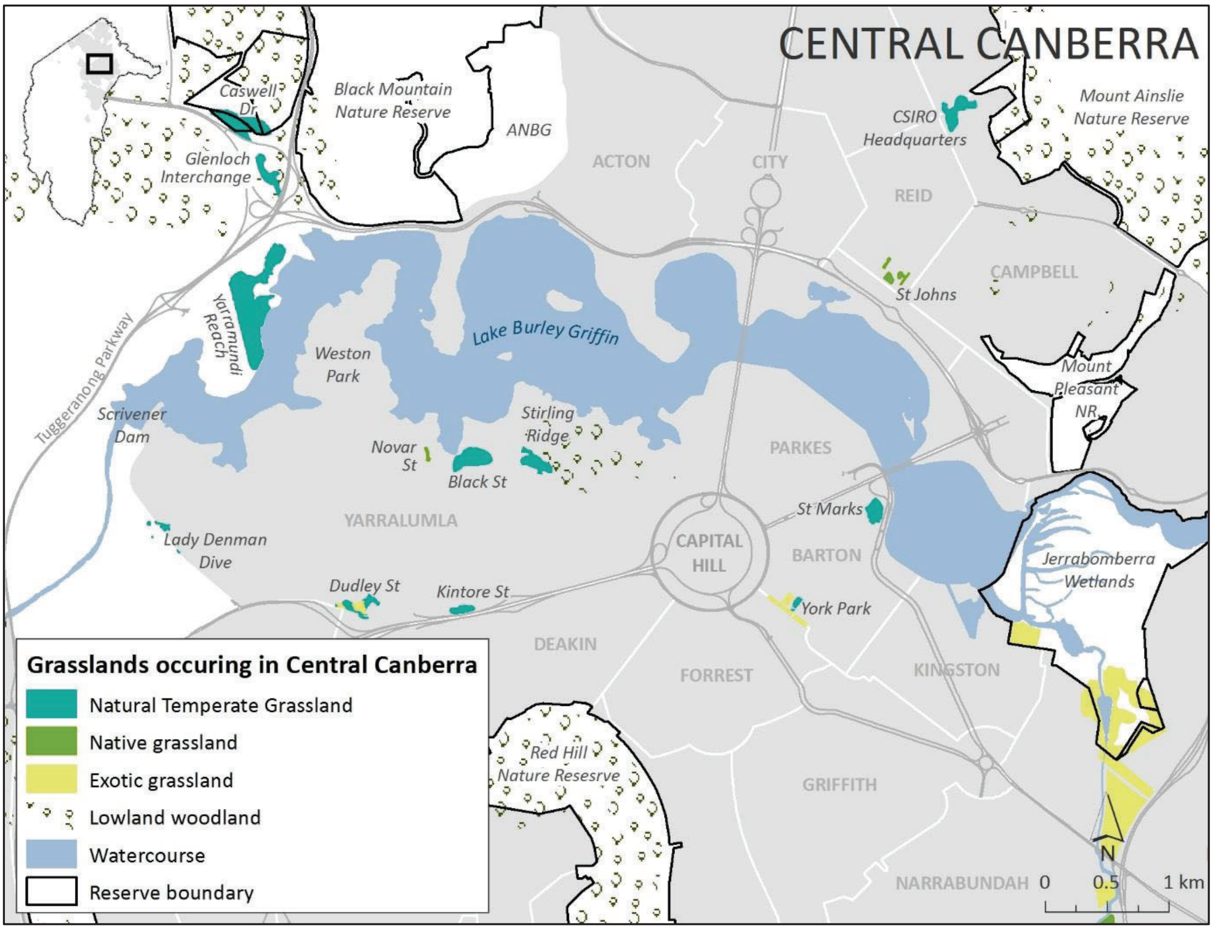


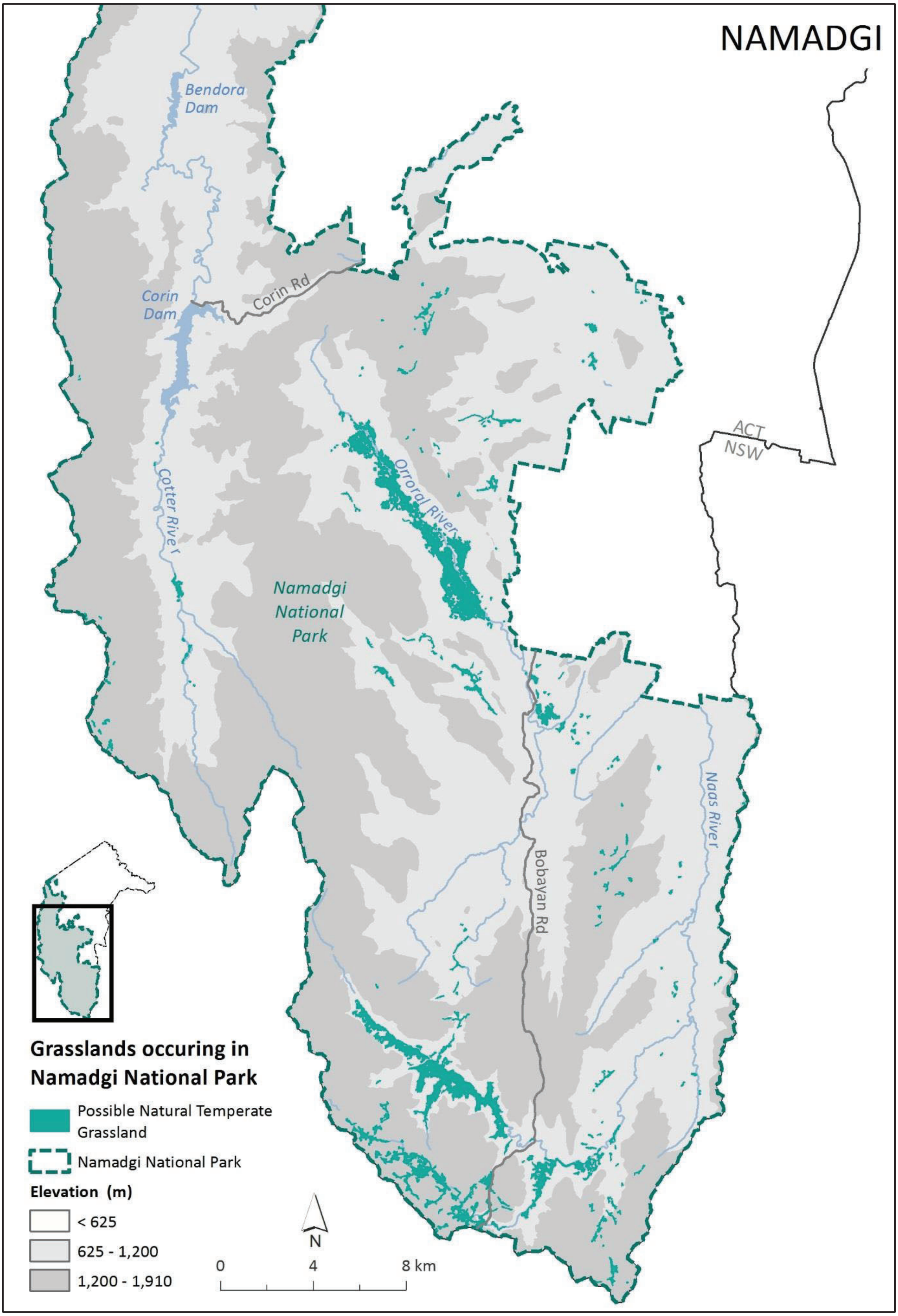
Figure 7. Natural Temperate Grassland distribution in Central Canberra.



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 *et al.* (2013).
- 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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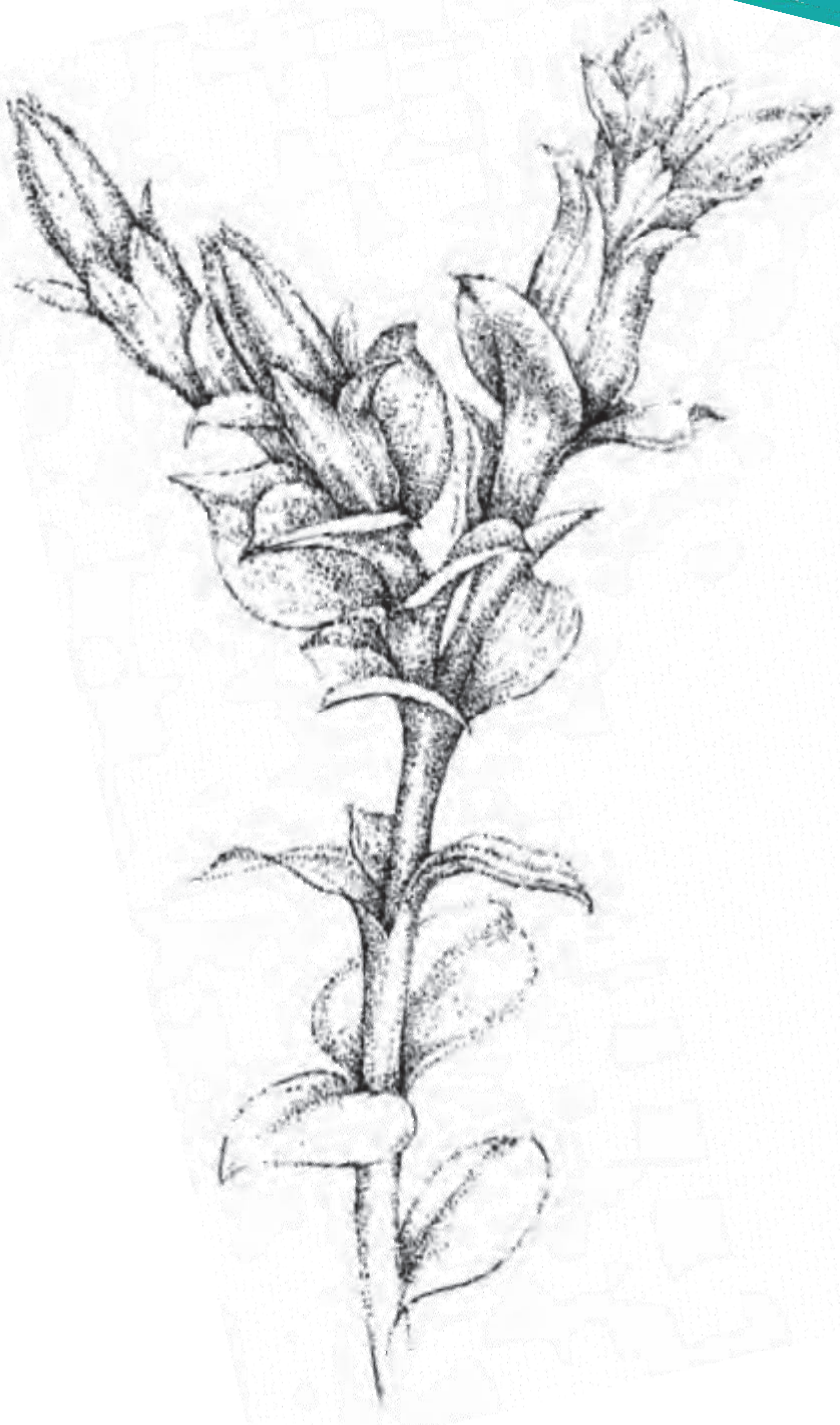
BAEUERLEN'S GENTIAN

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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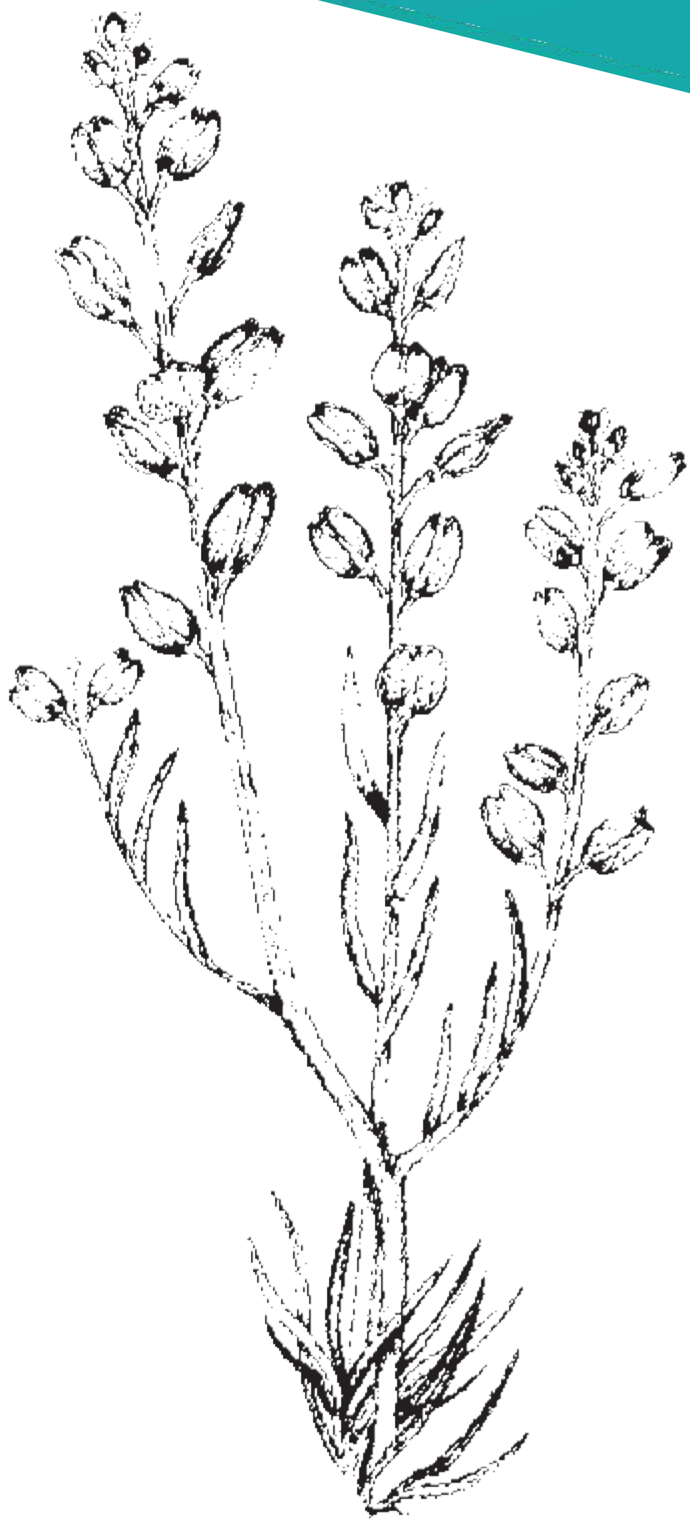
GINNINDERRA PEPPERCRESS

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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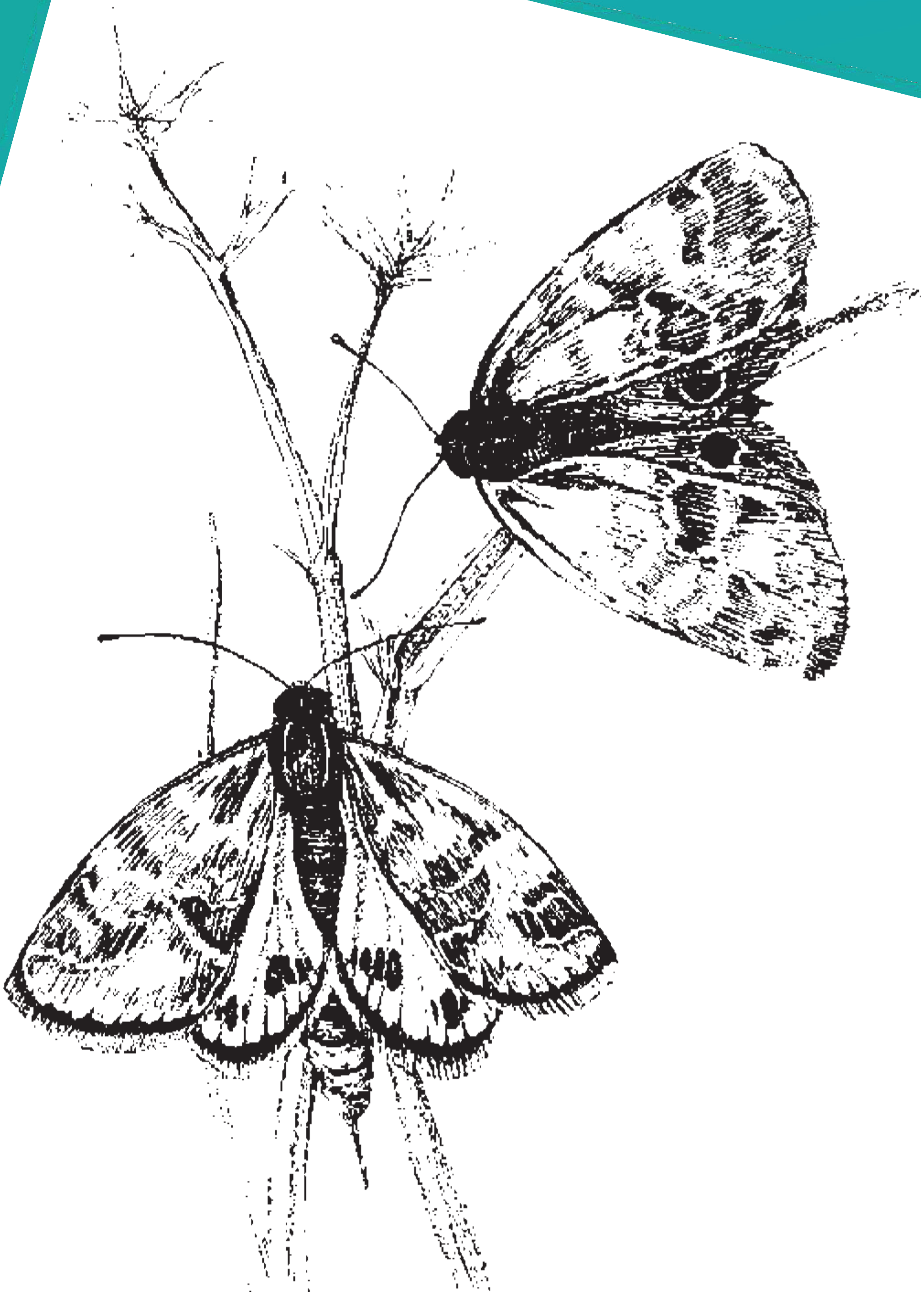
GOLDEN SUN MOTH

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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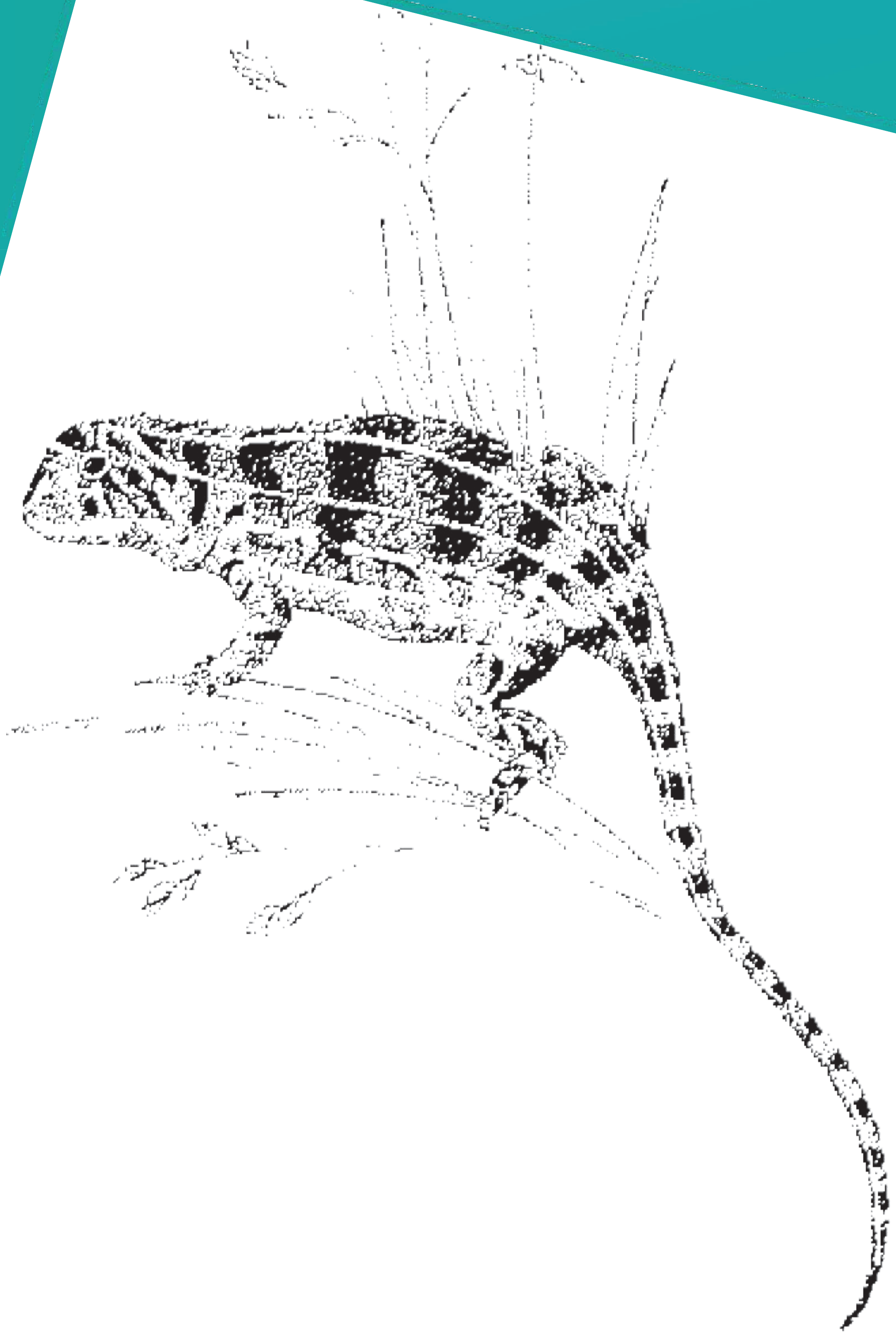
GRASSLAND EARLESS DRAGON

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 proportion to their abundance (i.e. were not

Grassland Earless Dragon (photo M. Evans)

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

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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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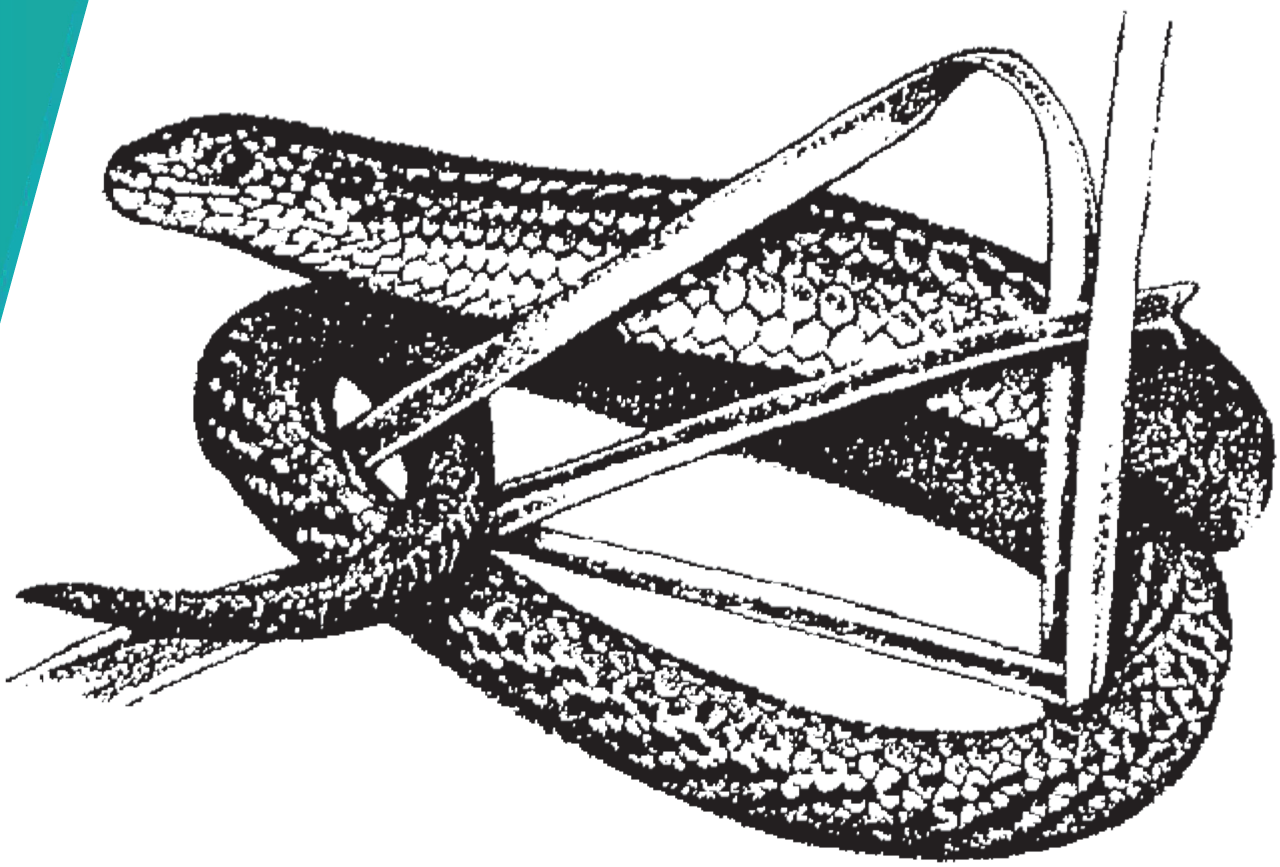
STRIPED LEGLESS LIZARD

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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FIELD OBSERVATIONS ON THE ECOLOGY OF THE GOLDEN SUN MOTH, *SYNEMON PLANA* WALKER (LEPIDOPTERA: CASTNIIDAE)

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Abstract

Surveys for the distribution and relative abundance of the golden sun moth, *Synemon plana* Walker, were carried out in remnant grasslands of Macgregor West in western Belconnen, ACT. These surveys revealed that *S. plana* is concentrated mainly along the Ginninderra Creek corridor and its drainage lines, with the highest density of sun moths occurring in an open-grassland flood plain comprising improved pasture where the putative larval food plant, *Nassella neesiana* (Trin. & Rupr.) Barkworth (Chilean needle grass) (Poaceae), grows as the dominant species. The flood plain habitat and the sun moth's association with this perennial exotic grass from South America are both unique in terms of current ecological knowledge of this threatened castniid. Supplementary observations made at Reid in central Canberra, ACT, strongly suggest that *Bothriochloa macra* (Steud.) S.T. Blake (redleg grass) is also utilised. Further studies are needed to determine larval diet breadth and food plant preferences of *S. plana*, and to clarify the extent to which the species utilises introduced perennial grasses, in order to provide an effective conservation management plan.

Introduction

The golden sun moth, *Synemon plana* Walker, is currently listed as 'Critically Endangered' nationally, and 'Endangered' in all States and Territories where it occurs. It is limited to native temperate perennial grasslands and grassy open woodlands in southeastern Australia, and has been a flagship species for the conservation of these habitats.

Prior to European settlement, *S. plana* was widespread within this broad geographic area; historical records show it has been recorded from many localities from near Bathurst, New South Wales (NSW), through the Australian Capital Territory (ACT) and Victoria, to Bordertown, South Australia (Edwards 1993, 1994). However, as a direct result of habitat loss and degradation, its area of distribution has contracted substantially, with only a limited number of relatively small, isolated populations surviving within the now very fragmented landscape (Douglas 1993, 2004, Clarke and O'Dwyer 1997, O'Dwyer and Attiwill 1999, ACT Government 2005). Possibly less than 1% of the original breeding habitat now remains and weeds heavily degrade much of this. Clearing and habitat modification, particularly the conversion of native perennial grasslands for agriculture, either by ploughing or with the introduction of pasture grasses, are the primary factors responsible for the widespread loss of native habitat, particularly in NSW and Victoria. Urban and industrial development has also contributed to habitat loss and fragmentation (ACT Government 2005).

Prior to 2000, *S. plana* was known only from 12 sites in the ACT (Clarke and O'Dwyer 1997, Clarke and Dunford 1999) but, between 2002 and 2004, one of us (MD) located a number of additional sites in the ACT (sites being defined on the extent of their discontinuity with other habitat patches, and/or according to land tenure).

Currently, *S. plana* is recorded from 31 sites within the ACT and from 42 sites in NSW, all within 85 km of the northern and northeastern borders of the ACT (ACT Government 2005, Department of Environment and Conservation NSW 2005, M. Dunford unpublished data). These sites vary in size and quality: of the ACT sites, 14 (45%) are relatively small (< 10 ha, with a combined total area of about 50 ha), and some are possibly no longer extant, while 17 (55%) sites are considerably larger (> 10 ha, with a combined total area of about 740 ha). However, ACT Government (2005) estimates that only about 20% of grassland patches where the species is known to occur in the ACT are protected in reserves, although this is likely to increase to around 25%. Eight of the ACT sites are significant in terms of the extent of the breeding area and/or relative abundance, and have high conservation value (ACT Government 2005). All sites in the ACT and nearby areas in NSW occur below 700 m.

The life history and larval food plants of *S. plana*, and indeed for the genus *Synemon* Doubleday, are poorly recorded in the literature, with only *S. magnifica* Strand described in detail (Common and Edwards 1981, Edwards *et al.* 1999). The food plants of *Synemon* comprise various monocotyledons, including Poaceae, Cyperaceae, Ecdeiocoleaceae and Lomandraceae (Edwards 1996, Edwards *et al.* 1999).

The putative larval food plants of *S. plana* include species of native perennial grasses in the genera *Austrodanthonia* H.P. Linder (wallaby grass) and *Austrostipa* S.W.L. Jacobs & J. Everett (speargrass) (both Poaceae). In the ACT, the preferred species is apparently *Austrodanthonia carphoides* (Benth.) H.P. Linder (Edwards 1990, 1993), although at some sites where this grass is absent or in very low abundance other species are almost certainly utilised (A. Rowell pers. comm.). In Victoria, *S. plana* is associated with several species of *Austrodanthonia* (Douglas 1993, O'Dwyer and Attiwill 1999), as well as *Austrostipa scabra* (Lindl.) S.W.L. Jacobs & J. Everett in the Wimmera (F. Douglas unpublished data). The larvae of *S. plana*, like many other Australian castniids, feed underground on the roots.

Here, we report on general observations made on the habitat preference and putative larval food plant of *S. plana* at a hitherto unknown site in Macgregor West, ACT, which one of us (MFB) first located in December 2002. The site occurs 3 km south-west of an extant colony in the Dunlop Grasslands Nature Reserve of western Belconnen. Additional observations made at a site in Reid in central Canberra, first recorded in November 2003 by MD, are also included.

Field observations

Macgregor West

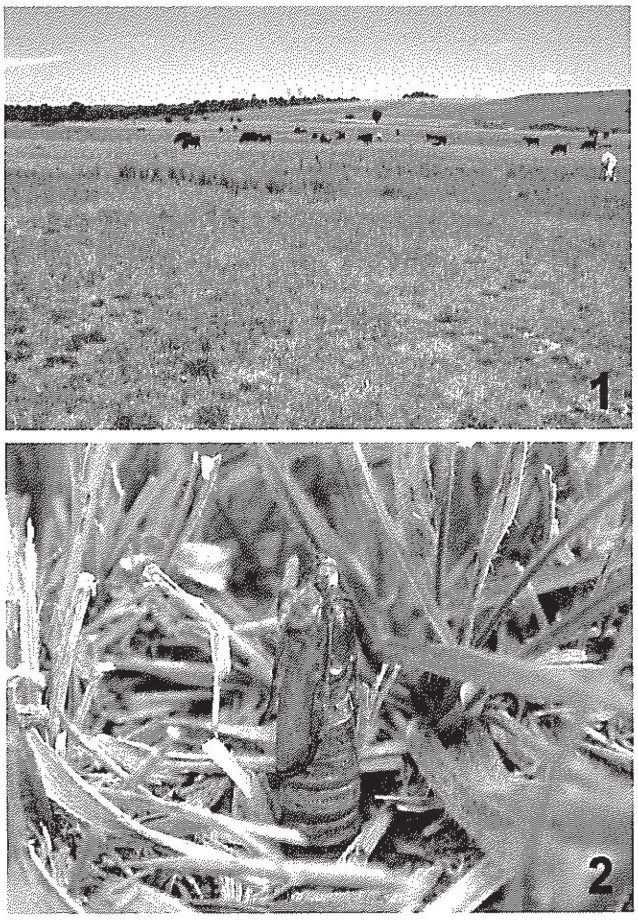
Field surveys for the presence and relative abundance of *Synemon plana* were conducted in remnant grasslands of the Macgregor West district (35°12'S, 149°00'E; 560 m a.s.l.) in western Belconnen, ACT, during 7, 17 December 2003 and 5, 11-22 December 2004 (Braby 2005). These surveys revealed that *S. plana* was abundant and widespread in the area (total breeding area *ca* 70 ha) and more extensive than the colony nearby at Dunlop Grasslands Nature Reserve, the only other known extant site in western Belconnen. However, the population was found to be concentrated mainly along Ginninderra Creek and its drainage lines, with the core breeding area occurring in an open grassland flood plain comprising improved pasture (Fig. 1). This flood plain habitat stretched as a broad linear strip, approximately 700 m long by 100-200 m wide, along the Ginninderra Creek corridor north-west to the confluence of Gooromon Creek, and then continued more narrowly (*ca* 30-40 m wide) for about 1 km south-west along Ginninderra Creek towards the ACT/NSW border.

Within the flood plain habitat, patrolling males of *S. plana* were noted to be strongly associated with extensive patches of introduced Chilean needle grass, *Nassella neesiana* (Trin. & Rupr.) Barkworth (Poaceae), formerly known as *Stipa neesiana* Trinius & Ruprecht (Jacobs and Everett 1996). This grass species is the dominant plant in the flood plain habitat at Ginninderra Creek (Rowell 2005). Subsequently, 12 empty pupal shells (5 of which were collected, 1 lodged in ANIC) were discovered protruding out of the soil amongst tussocks of *N. neesiana* in various locations along the flood plain (Fig. 2). In each case, no other species of grass, native or introduced, was found near the pupal shells, indicating that *N. neesiana* is probably used as a larval food plant in the Ginninderra Creek flood plain.

A second, smaller, concentration of sun moths was found to occur in open grassland comprising degraded native pasture on higher sloping ground in Macgregor West, about 300 m west of Ginninderra Creek. The larval food plant was not determined in this habitat; however, the slopes are dominated by *Austrostipa bigeniculata* (Hughes) S.W.L. Jacobs & J. Everett, with *Austrodanthonia* comprising only a small component (Rowell 2005).

Reid

At St John's Anglican Church, Reid (35°17'S, 149°08'E; 570 m a.s.l.) in central Canberra, ACT, a female *S. plana* was observed emerging from its pupal shell at 1115 h (EDST) on 14 November 2003. The specimen was captured and held for about 25 minutes while it expanded and dried its wings, and then released. The pupal case was noted protruding from a plant of *Bothriochloa macra* (Steud.) S.T. Blake (redleg grass), a native species endemic to southeastern Australia. Nine empty pupal shells (1 lodged in ANIC) were subsequently discovered protruding from within, or directly adjacent to, tussocks of *B. macra* on 22 November 2003. In each case, the nearest other grass species was 30 cm or more from the pupal shell. A further four pupal shells were found closely associated with *B. macra* on 8 December 2005, when several females were also observed ovipositing at the base of this species between 1300-1400 h (EDST). The St John's Anglican Church site comprised a small (*ca* 0.2 ha), fragmented and highly disturbed urban remnant patch of grassland dominated by *B. macra, Trifolium* spp. and *Paspalum dilatatum* Poir.



Figs 1-2. *Synemon plana* ecology at Ginninderra Creek, Macgregor West, ACT: (1) open grassland flood plain habitat, with patches of *Nassella neesiana* in foreground; note cattle grazing in background. (2) pupal exuvium protruding from tussock of *N. neesiana*. Photos: M.F. Braby.

Discussion

The presence of *Synemon plana* in an open grassland flood plain ecosystem and its association with *Nassella neesiana*, an exotic grass introduced from South America, closely related to *Stipa* L. and more distantly related to *Austrostipa* (Gardner *et al.* 1996, Jacobs and Everett 1996), represent a unique situation that contrasts markedly with all other known sites of *S. plana* throughout its range (Edwards 1994, Douglas 2004, ACT Government 2005). The density of sun moths in this flood plain habitat is also extremely large; for example, during the peak flight period in mid December 2004, close to 1200 individuals were counted along a 650 m x 50 m transect in the Ginninderra Creek flood plain (Braby 2005). Much of the habitat in the flood plain has been grazed by cattle (Fig. 1), which have significantly reduced both the plant biomass and competition from other weeds, creating conditions beneficial to *S. plana*, although in early 2005 cattle were excluded from the area (Rowell 2005).

Further long-term studies are needed to determine if the occurrence of *S. plana* in the flood plain represents the normal situation or is an unusual (short-term) response to extreme dry conditions that have occurred over the past three seasons (2002-2005). *S. plana* also occurs in significant numbers in the central drier slopes of Macgregor West, a short distance from Ginninderra Creek; it is possible that this secondary area serves as an important breeding habitat during wetter years when the flood plain may be potentially unsuitable for larval survival.

Although the presence of pupal shells provides only circumstantial evidence, it is highly likely that *S. plana* is utilising, as larval food plants, *N. neesiana* at the Ginninderra Creek flood plain in Macgregor West and *Bothriochloa macra* at the St John's Anglican Church site in Reid, particularly since the larvae are believed not to move underground between roots of adjacent grass tussocks (F. Douglas pers. comm., A. Rowell pers. comm.). Moreover, in the former habitat, *Austrodanthonia* comprises a relatively minor component (< 5% cover), whereas *N. neesiana* is the dominant species, growing in relatively large patches with up to 70% cover abundance in surveyed quadrats (Rowell 2005). Similarly, at the latter site, *Austrodanthonia* comprises less than 10% cover (M. Dunford unpublished data).

In the Ginninderra Creek flood plain, *N. neesiana* has possibly displaced much of the native grasses normally utilised by *S. plana*. Presumably, *S. plana* has been able to supplement or even switch its larval diet to a related but non-indigenous plant. Such a switch, however, does not necessarily imply that *S. plana* is dependant on *N. neesiana*; nor has it adapted to a range of other introduced grasses, many of which are weeds in the Australian landscape. On current knowledge, *S. plana* should be regarded as an ecological specialist dependent on a narrow range of native grasses (*Austrodanthonia*, *Austrostipa*, *Bothriochloa*) and, in some circumstances, also utilises an introduced grass (*Nassella*) when the native grasses have been significantly depleted. Clearly, further studies are needed on the ecological requirements of *S. plana* and to clarify the extent to which the sun moth utilises *N. neesiana*.

The association of *S. plana* with *N. neesiana* is of biogeographical interest because the castniids have a Gondwanan distribution pattern, with disjunct occurrences in Australia, Central and South America, and Asia (Edwards *et al.* 1999). Members from Australia and Central and South America belong in the subfamily Castniinae, while those from Asia are currently placed in the subfamily Tascininae.

The Castniinae are composed of two tribes: the Synemonini, which are restricted to Australia, and the Castniini, which are endemic to Central and South America. [The Castniinae have recently become established in the Mediterranean through accidental introduction: Sarto I Monteys *et al.* 2005]. Both of these tribes are believed to be monophyletic and represent vicariant sister groups that differentiated after the break-up of southern Gondwana (Australia-Antarctica-South America) (Holloway and Hall 1998). It is therefore possible that the association of *Synemon* (endemic to the Australian Region) with *Nassella* (endemic to the Neotropical Region) may reflect an historical biogeographic relationship between the castniids of Australia and South America.

In South America, *N. neesiana* occurs widely in the cool montane areas of the Andes in Ecuador, Peru, Bolivia and Argentina, as well as in the temperate areas of southern Brazil, Paraguay and Uruguay (Missouri Botanic Garden 2005). In Chile, however, it is rare and restricted, currently protected and listed as a threatened species (A. Ugarte pers. comm.). *Nassella* is not known to serve as a larval food plant for the Neotropical castniids, but food plants (all monocots, including the families Arecaceae, Bromeliaceae, Marantaceae, Musaceae, Orchidaceae, Poaceae) have been recorded for only a few species of Castniini (Edwards *et al.* 1999, Sarto I Monteys *et al.* 2005), most of which occur in tropical forest. Only one species, *Castnia eudesmia* Gray, which feeds internally on the flower stems of *Puya chilensis* Molina (Bromeliaceae), is known to occur in the temperate areas of Chile (A. Ugarte pers. comm.).

Acknowledgements

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ARCHIVAL RECORD

REFERENCE No. 6

Clarke, G 1993
'The Golden Sun Moth, *Synemon plana* - an endangered species'
ANIC NEWS, No. 2

Will Osborne

ANIC NEWS

The official newsletter of the Australian National Insect Collection, CSIRO Division of Entomology. No. 2 March 1993

Section Head's Report

Establishing the *ANIC News* was a new task added to the ANIC's activities. However, we all clearly have the feeling that it is an excellent investment of our time: we are both stimulated and very pleased with all the feed-back we have received and I can assure you that *ANIC News* is here to stay.

Looking back at 1992 it has, from the ANIC perspective, been a year of challenge, change and significant recognition for us. Ironically at the same time as we learned that *The Insects of Australia* had won the Whitley Award (see this issue) we felt the impact of the Federal Government's efficiency dividend on the Section and our ability to operate. The fact that this could mean that we might not be able to produce a possible third edition of *The Insects of Australia*, which has been widely lauded as an outstanding example of accomplishment of "the clever country", attracted considerable attention - the most 'pinning' perhaps being the cartoon in *The Australian* 12 August 1992 shown on the next page.

There are also other reasons for concern. In Prime Minister Paul Keating's December 1992 statement on the environment, *Australia's Environment: a Natural Asset*, it is stated that "funding for the Australian Biological Resources Survey [sic!] (ABRS) will be boosted by $3 million" and that "the Commonwealth Government will commit $1 million per year" to the Australian Biological Resources Study (ABRS). While it is highly gratifying that new funds are made available to ABRS it is also a potentially confusing statement: it is not stated that the announced boost of $1 million per year is to the 1990/91 funding level, to which the ABRS automatically reverts following the last two years of increased funding. If the 1992/93 funding level is not maintained the so-called 'boost' means that ABRS has approximately $525 000 less available per year. This will have a significant impact on ABRS's activities, including the *Fauna of Australia*, the *Zoological Catalogue of Australia* and the funding for taxonomic research on the Australian flora and fauna taking place in our universities, state museums and herbaria and national collections.

Looking at the funding available for the study of Australia's natural resources one could easily forget that we live in the time of biodiversity and sustainable development. It is therefore heartening to see that the House of Representatives, Standing Committee on Environment, Recreation and the Arts' report of January 1993, *Biodiversity - the role of protected areas*, acknowledged that funding for biological surveys and taxonomy "has dropped in recent years and needs to be greatly increased". Also the recent report from the Federal Government's Joint Committee of Public Accounts on *Public Sector Research and Development* (Report 318) recommends that the Government take action to redress the reduction in funding for long term basic research, including taxonomy, entomology and soil science, and that the research costs of the CSIRO be exempted from the application of the efficiency dividend.

Each year the CSIRO reallocates research funding to new National Research Priority areas. One of the areas supported during the last round was Conserving Biodiversity for Australia's future. The Division of Entomology/ANIC is involved with two of the projects: capturing data for an atlas of Australian biodiversity and biodiversity in soil and litter and on the soil surface. Planning for these activities is well advanced and the projects will formally commence in July.

It is also gratifying to recognise the increased use of the ANIC and other biological collections. The collections are increasingly being used for extraction of information with a view to environmental issues and there is an

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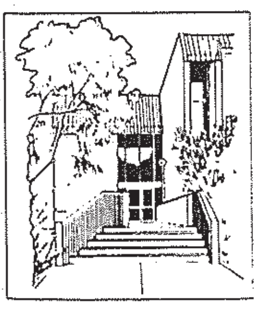

CSIRO AUSTRALIA

Resting male of Synemon plana

Research Activities

The Golden Sun Moth, *Synemon plana* - an endangered species

The family Castniidae contains about 200 species worldwide, consisting of about 160 species in central and South America, about 40 species in Australia and three species in South East Asia. They have a number of features that commend them for a detailed taxonomic study. The Australian species have not been revised this century. They attract considerable public interest because they are colourful and day flying and have been believed, in times past, to be closely related to the butterflies. Their biology is poorly known, leaving much scope for original work, and because they are day flying, the large numbers of butterfly collectors can make a useful contribution. The number of species is small so that a revision can be done in a practicable time frame and the Australian species form a discrete, well-defined group most easily studied within Australia. The distribution pattern displayed by the family is part of one of the classical, gondwanan patterns and further information on their taxonomy may lead to a better knowledge of the age and origins of the family and possibly also of some other groups of ditrysian moths. There is evidence that some of the species are endangered.

A pilot study on the single species occurring in Canberra yielded information on which applications for funding for a wider taxonomic study of the family have been based. The two sexes of the Canberra species differ but they were first correctly associated in Tillyard's *Insects of Australia and New Zealand.* The female had been described as *Synemon plana* Walker in 1854 and the male as *Synemon hesperioides* Felder in 1874. The first outcome of the present study was to replace the then used *S. hesperioides* with the older name *S. plana.*

The next problem was to collect *S. plana.* The ANIC contained Canberra specimens but in recent years none had been collected. The problem was solved in 1982 when Andrew Atkins discovered *S.plana* at the eastern end of Ainslie Avenue. Here they occurred in a tiny patch of *Danthonia carphoides* native grassland. Weekend surveys then revealed other sites in Canberra. They occurred only where *D. carphoides* or other *Danthonia* species dominated the grassland. Pupal shells were found protruding from the soil beside and within *Danthonia* tussocks and females were observed many times laying eggs into *Danthonia* tussocks. The areas of this grassland remaining in Canberra are so tiny and fragile that tussocks have not been dug up in an attempt to find larvae. In subsequent years 4 other closely related *Synemon* species found in southern N.S.W. and Victoria have been observed to be also associated with *Danthonia.*

It was evident from the remnant sites in the A.C.T. and the lack of surviving *Danthonia* grasslands in adjacent N.S.W. that *S. plana* was endangered. While there are numerous records from early this century there are very few modern records. In historical times it occurred in a wide belt of south eastern Australia from Bathurst, N.S.W., to Bordertown, just into S.A. Most records are from Victoria. The largest known surviving site is the Belconnen Naval Station in the A.C.T. There is a plan for this site to be used for housing development in the next few years.

The *S. plana* moth has a wingspan of about 5 cm. The adults fly from mid November until mid December. The males patrol the grassland searching for females from about 11 am until late afternoon but only when the sun is shining. The adult moths cannot feed or drink as they have no mouthparts and probably do not live for more than a day or two. The females emerge from the pupae with all their eggs fully developed. By exposing the bright yellow hindwing, hence the common name Golden Sun Moth, when a male flies over, the female attracts a mate soon after emergence, then the females lay their eggs into the bases of the *Danthonia* plants using their long ovipositors to force eggs into the crevices. The larvae feed on the underground parts of the *Danthonia* by boring through the soil. Just prior to pupation the larva constructs a vertical tunnel to the soil surface up which the pupa moves when the moth is ready to emerge. It is not known how long the life cycle takes but two years is the most likely guess.

Within the family, *S. plana,* has several unique features. The females have much smaller wings than would be expected for a moth of similar body size. Normally the female, with a weight of eggs to carry, has larger wings than the male but in this case the females have reduced wings because they rarely fly. They can fly but do so only when disturbed. They spend their time scuttling from tussock to tussock laying eggs. This is one reason they need a grassland dominated by their foodplant to survive. This sedentary behaviour has probably contributed to the development of the bright yellow hindwings of the female used effectively to signal patrolling males. In other castniids the sexes are much more similar to one another in colour.

Synemon plana is now one of the grassland invertebrates that we know enough about to consider it endangered and it has attracted considerable public interest in Canberra. Indeed after an initial article appeared in the National Parks Association of the A.C.T. Bulletin all subsequent articles and activities related to it have been done at the request of conservation bodies, government departments, educational institutions, the conservation industry and private individuals. It has provided a useful focus for a considerable awakening in conservation bodies for the need to conserve and study examples of the rapidly disappearing grasslands. The National Capital Planning Authority is providing funding to monitor the population on the site at York Park. The native grassland at this site is to be retained amid the building activities in the surrounding area and ways are being sought to cause it minimal disturbance. Even so, with the exception of the Belconnen Naval Station and possible areas on the Army firing range near the airport, the known sites in Canberra are very small and at considerable risk of being overrun by introduced weeds.

On the basis of some of this work funding has now been provided by ABRS for a taxonomic study of the family in Australia. This work, by Ted Edwards, Ebbe Nielsen and Tracy Harwood, is now in progress and will be reported on in further issues of the *ANIC News.*

Further reading:

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Bogong 12: 4-6, 1991

Ecos 69: 34-35, 1991

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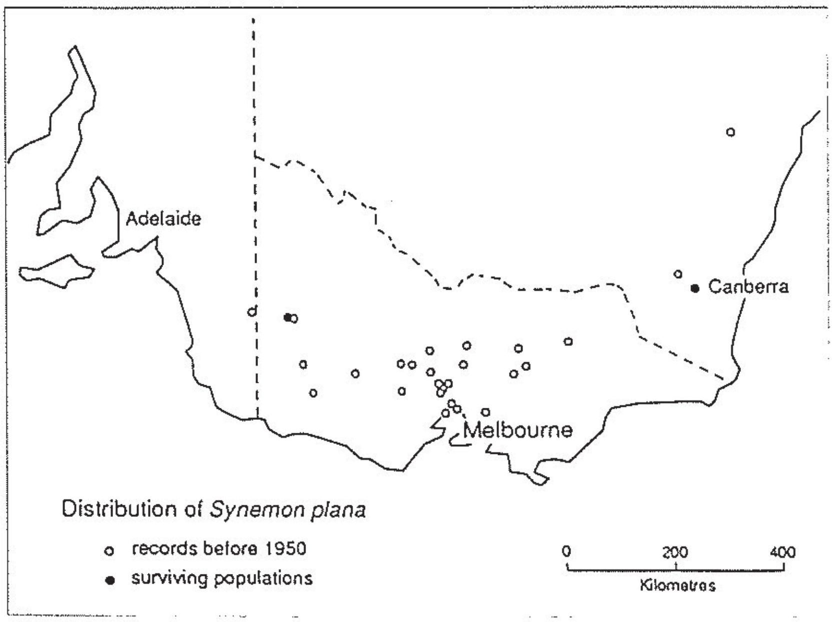

Distribution of Synemon plana showing distribution before 1950 and surviving populations

ARCHIVAL RECORD

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Clarke, G 2000
'Inferring demography from genetics – a case study of the endangered golden sun moth, *Synemon plana*,'
Genetics, Demography and Viability of Fragmented Populations, eds Young, A, Clarke, G, Cambridge University Press, London, pp. 213-225

(12)

Inferring demography from genetics: a case study of the endangered golden sun moth, *Synemon plana*

GEOFFREY M. CLARKE

ABSTRACT

The development and application of quantitative methods for assessing the viability and risk of extinction of populations requires considerable background demographic and life-history data of the modelled species and populations. Typically such data are difficult to obtain for most invertebrate species due to time or resource constraints. Quantitative sampling methodologies are not well developed for the bulk of invertebrate species and field-based estimates of migration, survival, fecundity, etc. are problematic. However the use of genetic-marker technologies such as allozymes and mitochondrial DNA (mtDNA) sequence data has the potential for inferences to be made about underlying demographic processes within and among populations useful for quantitative model development. In this paper I will show how such marker technologies have been applied to an endangered species of grassland-inhabiting moth, *Synemon plana*, to infer some fundamental life-history and demographic parameters.

INTRODUCTION

Effective conservation management of threatened species requires considerable detailed information on the life history, demographics and population structure of the taxa of interest. In addition, the development of quantitative models of population persistence [e.g. population viability analyses (PVA)] almost universally requires parameters such as generation time, fecundity, fertility, adult and juvenile mortality and migration as model inputs (e.g. Burgman *et al.*, 1993; Lacy, 1993*b*). For many species, the acquisition of such data is not overly problematic (although may involve many years of detailed field work), and these are the same types of data used in the original determination of the species' threatened status. Indeed for many threatened species, such data are available at the individual in addition to the population level, and often at fine spatial scales, leading to the developmental of individual-based spatially explicit models (DeAngelis & Gross, 1992; Dunning *et al.*, 1995). This is particularly true for many mammals and birds for which many such models have been developed (e.g. Price & Kelly, 1994; Letcher *et al.*, 1998), and is becoming more common for threatened plants (e.g. Burgman & Lamont, 1993; McCarthy, 1996).

For the vast majority of threatened species demographic and life-history data have been accumulated through direct or indirect observations of field or captive individuals and populations. Identification and tracking of individuals within and between areas is made possible through a variety of now commonly used techniques such as banding, radio-telemetry and remote video. Although genetic data are seldom required or incorporated into most quantitative models, such data are rapidly being used either to directly estimate or to infer many demographic and life-history parameters otherwise unattainable (Goldstein *et al.*, 1999). In particular the development of highly variable microsatellite markers has made it possible to 'genetically' mark individuals (Bruford *et al.*, 1996). In addition, recent advances in DNA extraction techniques have led to the development of a series of non-invasive sampling techniques (e.g. faecal or hair sampling), such that actual sighting and 'capture' of individuals is no longer required (Morin & Woodruff, 1996). In addition to providing routine estimates of levels of genetic diversity and variability within and among populations, genetic data have also been used to determine otherwise difficult demographic parameters, e.g. breeding structure, parentage, home ranges and patterns of migration (see Smith & Wayne, 1996). One of the major advantages of genetic data is that they make it possible to infer historic, as well as recent, population processes, e.g. bottlenecks, fragmentation, gene flow and inbreeding (e.g. Moritz *et al.*, 1996)

The invertebrates are a group of organisms for which the application of genetic data for inferring basic life-history and demographic parameters may prove valuable. For the vast majority of invertebrate species direct field observation is difficult as they are small and/or cryptic, seasonal, and may undergo highly variable population density cycles. This makes even simple parameters such as numbers of individuals within a population very difficult to determine. As a result, criteria such as population size are seldom used in determining the threatened status of invertebrate taxa (number of populations and patch size are the most commonly used criteria). This difficulty in assessing basic life-history and demographic parameters is undoubtedly one of the reasons invertebrates are under-represented on lists of threatened species worldwide. Despite making up almost 80% of the world's named species, invertebrates account for fewer than 10% of threatened species listed in the 1996 *Red List of Threatened Species*. That is, less than 0.2% of the known invertebrate fauna is regarded as being threatened, compared with over 20% for mammals and an average of over 5% for most other groups. Unfortunately, there is a general lack of empirical data to test whether or not this under-representation represents biological reality or not.

There have been very few long-term or detailed studies of the impacts of fragmentation on invertebrate species (Margules *et al.*, 1994; Van Dongen *et al.*, 1998). Again the most probable explanation is the difficulty in accruing basic biological and ecological data. The most notable exceptions are those involving highly conspicuous butterflies (Brookes *et al.*, 1997; Lewis *et al.*, 1997; Thomas & Hanski, 1997). This lack of data is unfortunate as studies involving invertebrates have considerable potential for investigating and testing hypotheses of the demographic and genetic impacts of fragmentation. The relatively small spatial scale and rapid generation time of most invertebrate species make them particularly useful in this regard. Frankham and colleagues have shown how useful invertebrates are under laboratory conditions for understanding and testing of many of the basic tenets of modern conservation biology (Loebel *et al.*, 1992; Spielman & Frankham, 1992; Briton *et al.*, 1994; Woodworth *et al.*, 1994).

In the remainder of this paper I will focus on the genetic analysis of the endangered golden sun moth, *Synemon plana* (Lepidoptera: Castniidae). In particular, I will show how genetic data have been used to infer some basic life-history, demographic and population parameters for this species.

SYNEMON PLANA

The golden sun moth, *Synemon plana*, is a medium-sized (wing span approximately 32 mm) diurnal moth, the larvae of which are thought to feed exclusively on native grasses within the genus *Austrodanthonia*. The species is one of approximately 44 occurring in this Australian endemic genus, many of which are also restricted to, and thus fully dependent on, native grasslands. *Synemon plana* was once widespread throughout south-eastern Australia, matching the distribution of native grasslands and grassy woodlands. Temperate grasslands are the most endangered of all vegetation types in Australia with less than 1% of the approximately 2 million ha existing prior to European settlement still remaining (Kirkpatrick *et al.*, 1995), and have recently been listed as an endangered ecological community under the Commonwealth Endangered Species Act. The remaining grasslands are threatened by urban and agricultural expansion, weed invasion and grazing by stock and rabbits. Consequently the remaining populations of *S. plana* are highly fragmented. *S. plana* is currently known from approximately 48 sites the majority of which are less than 3 ha in area (Clarke, 1999*a*). The species is listed in all three States in which it occurs under their respective threatened species legislation and has been nominated for listing under the Commonwealth Act.

The life history of the species is very poorly known. The adults are short-lived (one to four days) and do not feed, having no functional mouth parts. Males are capable of active and prolonged flight, but they will not fly long distances (> 100 m) away from suitable habitat. Females have reduced hind wings and are reluctant to fly even when disturbed and are thus rarely encountered in the field. The sex ratio appears heavily male-biased; however, the cryptic nature of the females does not allow for an accurate estimate. Adult emergence is continuous throughout the annual flying season which typically lasts six to eight weeks in early summer (November–December). Males fly only in bright sunshine during the warmest part of the day. The cues initiating adult emergence are unknown. The larval and pupal stages and their duration (and hence generation time) are unknown. Females are known to carry up to 200 eggs (following dissection) (Edwards, 1994). However, it is not known how many are actually laid, or if eggs are laid singly or in clusters. Eggs are thought to be laid at the base of the grass clumps. It is assumed that larvae feed underground on the roots of the grass plants. The number of plants required for the development of a single larvae is unknown. Rates of adult and juvenile mortality are also unknown. Since formal listing of this species it has not been possible to undertake any research which involves habitat disturbance or manipulation, and all attempts to breed the moth *ex situ* have failed.

Detailed census work, using mark–release–recapture techniques, has been conducted at a single 0.4-ha site over a three-year period (Harwood *et al.*, 1995). The population at this site appears relatively stable at approximately 1500 individuals (assuming a 1:1 sex ratio). Assuming females lay their entire complement of eggs this suggests that up to 99% of total potential fecundity is unrealised.

METHODS

Samples

A total of 1200 adult males were collected from 36 of the 48 extant sites during the 1997 and 1998 flying seasons using a hand net (Fig. 12.1). Five of these populations were sampled in both seasons. Although up to 30 males were taken from each site, the timing of collection was designed to enhance the collection of post-reproductive males. In addition, at all sites sampled, *Synemon plana* is locally abundant. Captured individuals were returned alive to the laboratory and placed at −20 °C until dead. Individual abdomens were then removed and stored at −80 °C until required.

Electrophoresis

A total of 16 enzyme systems representing 20 loci were analysed by cellulose acetate electrophoresis. Details of protocols and loci can be found in Clarke & O'Dwyer (2000).

RESULTS AND DISCUSSION

Full details of the genetic data for both years' samples can be found elsewhere (Clarke, 1999*b*, *c*; Clarke & O'Dwyer, 2000) and I will only present summary information here in the context of the current discussion.

Generation time

Although not tested, generation time in *Synemon plana* was thought to be in the range of one to three years based on known generation time for other species within the genus (Edwards, 1994). A generation time of two years was considered most likely despite the fact that adult moths can be found each year within *S. plana* populations. It is conceivable that over evolutionary time moths could become present annually, even with a two-year generation time, if larval development displayed some level of plasticity and climatic determinants varied during the period. However, one would also expect that as conditions stabilised then these odd- and even-year cohorts would become genetically differentiated in more recent times.

An examination of both allele and genotype frequencies from five populations sampled in successive years revealed no significant differences between years (Clarke, 1999*c*). Thus the genetic data strongly suggest that generation time is approximately one year. It is difficult to imagine larval development time to be variable enough to maintain such genetic homogeneity across years, particularly as the timing of the flight season varies only marginally each season.

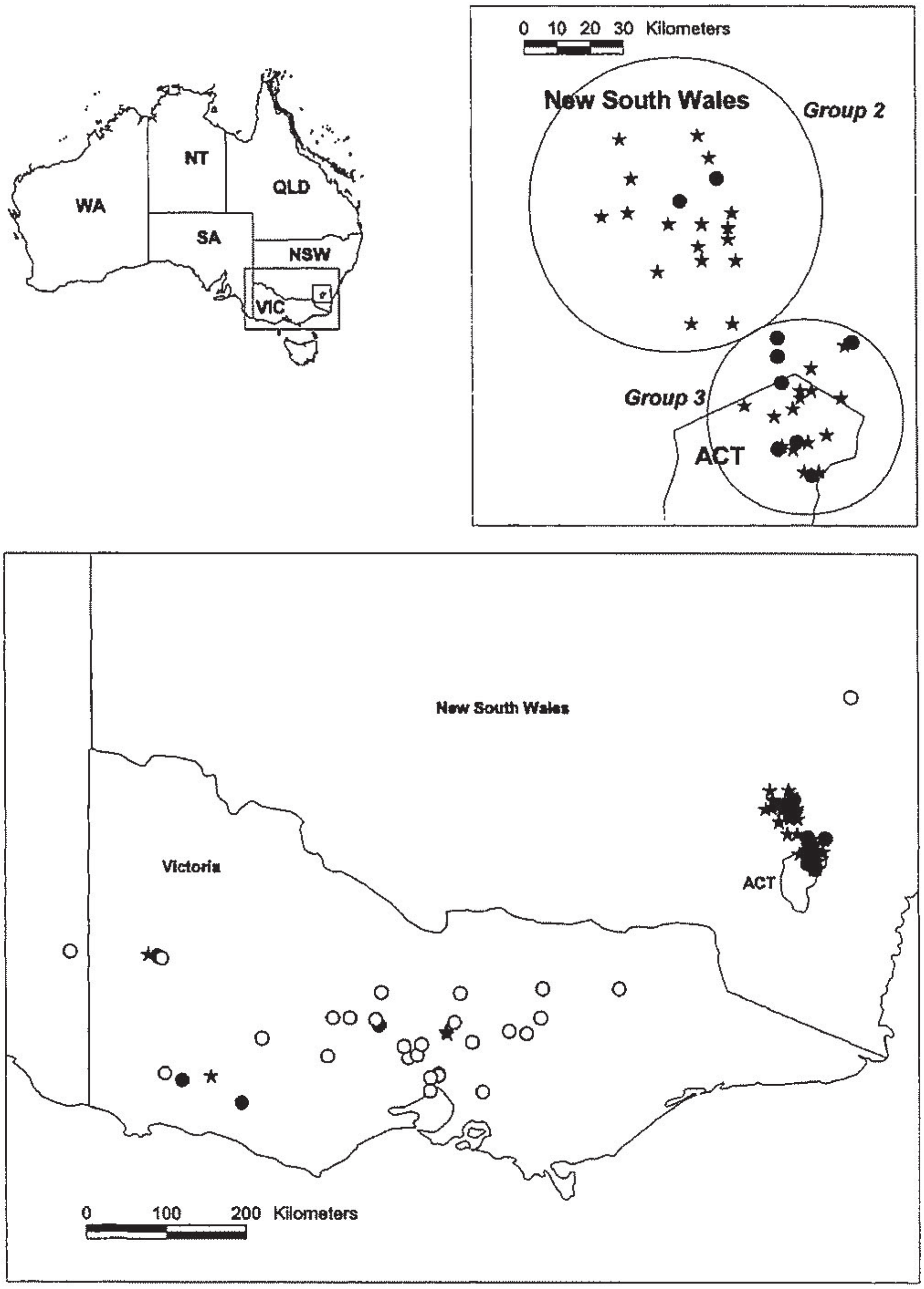


Fig. 12.1. Historic and present distribution of *Synemon plana* populations. ○ represents historic (presumably extinct) populations; ● represents current extant populations; ★ represents sampled populations.

Inbreeding and population subdivision

An interesting result from the first year of sampling (in which 20 populations were analysed) was the significant level of inbreeding present in almost all populations (mean $F = 0.190$, $P < 0.005$; range 0.045–0.326) (Clarke & O'Dwyer, 2000). Observed heterozygosities were consistently lower than that expected under random mating, primarily due to the fact that the majority of rare alleles were found in homozygous condition, rather than as heterozygotes as expected. This appeared to be independent of population size (although accurate estimates of size were not possible crude relative estimates are available). It was hypothesised that this high level of apparent non-random mating may be due to temporal subdivision of populations. The average life span of adult moths (1–4 days) is considerably shorter than the duration of the flying season (6–8 weeks). Thus moths emerging early in the season have no chance of mating with individuals emerging late in the season. If larval development was reasonably synchronous, such that eggs laid early in one season developed into adults which emerged early in the following season, then it could be imagined how a single 'population' may become temporally subdivided. Each cohort would be effectively isolated from all others and thus would become genetically differentiated over time. As the sampling regime collected adults on a single day these would represent a single cohort (or perhaps two) and thus represent a considerably smaller 'population' which could promote inbreeding.

This hypothesis was tested in the second year's sampling by collecting moths at three times (early, mid and late) throughout the season from four sites. Pairwise comparisons of both allele and genotype frequencies between each sampling date within each population were all non-significant, indicating that temporal subdivision of populations was unlikely (Clarke, 1999*c*). Again the inbreeding values of each sample were in the same range as that observed previously. It would thus appear as though larval development time is variable enough to maintain genetic homogeneity within the population.

In the context of the current discussion the importance of this result is not the lack of evidence for subdivision, but more the fact that genetic data were used to construct an hypothesis concerning demographic and life-history parameters which could be tested by genetic means. This has led to the development of an alternative testable hypothesis, viz. that the high F values are due to partial parthenogenesis in this species. It is worth noting that *S. plana*'s closest relative (*S. selene*) has both sexual and parthenogenetic forms.

Effective population size

The estimation of effective population sizes is one of the most common uses of genetic data in conservation (see Neigel, 1996). The effective size of a population can be defined simply as the number of individuals making a contribution to the next generation. Factors such as fluctuating population size, unequal sex ratio and differences in adult survival and fitness mean the effective size is typically less than the census size, often by an order of magnitude (Frankham, 1995c). Effective population sizes (N_e) can be estimated from genetic data by looking at changes in either inbreeding coefficients, gene frequencies or levels of heterozygosity between generations. These estimates are based on the fact that finite populations will lose genetic variation each generation due to genetic drift at a rate that is inversely proportional to the effective population size (Wright, 1978). Thus repeated genetic sampling of populations over time presents the possibility of estimating the population effective size (see Lande & Barrowclough, 1987; Neigel, 1996). It must be stressed, however, that these estimates are based on a number of assumptions such as random mating, no mutation, migration and selection, almost all of which are violated in natural populations.

Of the five populations sampled in both 1997 and 1998 only one showed a decrease in heterozygosity over time (Clarke, 1999c). The four remaining populations showed slight increases. In terms of inbreeding coefficient, again only one population showed an increase in F with the remaining populations showing appreciable decreases. These data suggest that effective sizes are close to census size for these populations; however estimates based on differences between two successive generations are subject to considerable error, particularly if the population undergoes natural temporal size fluctuations, as is typical for many insect species. The accuracy of estimates is enhanced if the time between sampling is increased.

Adult and larval mortality

These data on effective population sizes, albeit crude, can be used to make inferences about patterns of adult and juvenile mortality within the sampled populations. If mortality occurred predominantly at the adult stage then one might expect effective population size to be considerably less than census size as only a small proportion of the total females present in the population would mate and oviposit. Alternately, if mortality predominantly occurred at the larval stage, and assuming that such mortality was randomly distributed amongst larval cohorts, then effective sizes might be expected to more closely match census size. Obviously, interpretation of effective population size in this manner is problematic, given that N_e can be

Table 12.1. Estimates of genetic diversity, heterozygosity and gene flow within and among population groups of *Synemon plana*

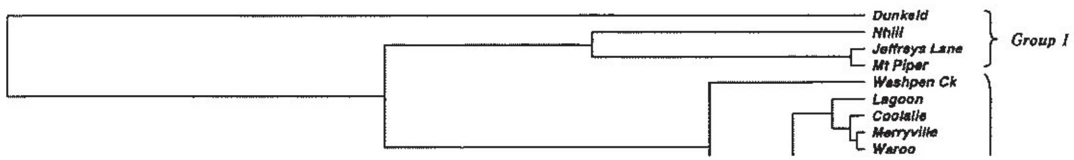
Group	Genetic diversity (A_p)	Heterozygosity		Migrants per generation (N_m)
		Expected (H_e)	Observed (H_o)	
Group 1	2.60	0.114	0.185	0.99
Group 2	2.40	0.121	0.148	3.52
Group 3	2.20	0.083	0.096	9.55

determined by many population and evolutionary processes other than mortality. However, in the absence of other data, these assumptions may provide a starting point for model parameterisation, particularly in the case in which effective size is close to census size, as this would indicate that adult mortality is not appreciable.

Population structure, fragmentation and colonisation

The analysis of patterns of genetic structuring among sampled populations has been used not only to investigate relationships among populations in the conventional sense, but also for the determination of priority populations, or groups of populations, for conservation management, e.g. evolutionarily significant units (ESUs) or management units (MUs) (see Moritz, 1999*b*). The genetic relationships among all sampled populations of *S. plana* are shown in Fig. 12.2. The names of individual populations are unimportant in the current context and suffice to say that they fall into three main clusters which correspond closely with geographic location (see Fig. 12.1). This pattern of structuring fits an isolation-by-distance model in which the further apart populations are geographically the more genetically different they are ($R^2 = 0.740$, $P < 0.0001$; Fig. 12.3). This pattern is to be expected due to the limited dispersal ability of the species.

In conjunction with estimates of genetic diversity and gene flow within populations and population clusters, it is possible to use this pattern of structuring to infer patterns of colonisation and fragmentation for this species. The four Victorian populations in Group 1 display the greatest average levels of allelic diversity and genetic variation compared with the other two groups of populations (Table 12.1). The 15 populations within Group 3 display the lowest levels of diversity, with the populations in Group 2 being intermediate. Given that we know that current extant populations of *S. plana* are effectively isolated due to the limited dispersal ability of the adults, gene flow estimates can be used to infer historic patterns of connectedness between populations. Estimates of gene flow among the popula-



Dunkeld
Nhill
Jeffreys Lane
Mt Piper
Group I
Washpen Ck
Lagoon
Coolalie
Merryville
Waroo

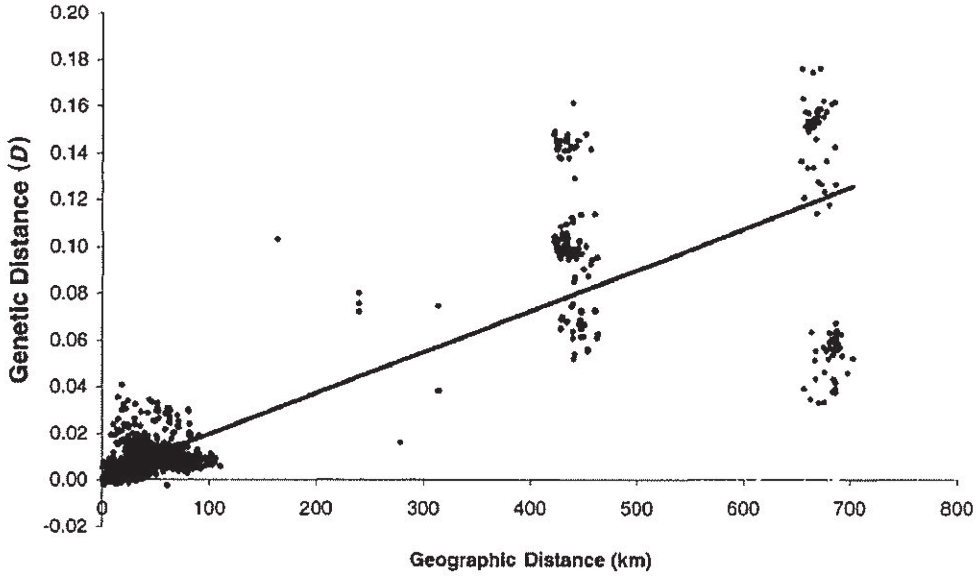


Fig. 12.3. Scatterplot of genetic distance versus geographic distance of sampled populations of *Synemon plana*.

tions in Group 3 are almost 10 migrant individuals per generation. This very high level indicates that these populations were very recently connected and the time since isolation has been insufficient to erase the signature of connectedness. The estimates for populations within Groups 1 and 3 are approximately 1 and 3.5 respectively, indicating longer periods of isolation.

These inferences are supported by the genetic diversity data and what we know of the fragmentation history of the areas where these populations occur. The area containing the Group 3 populations has been heavily fragmented within the last 70 years due to the increase in urban and agricultural expansion associated with the establishment and settlement of the Australian Capital Territory region. In fact much of the fragmentation has occurred in the last 30–40 years. The low levels of genetic variability within these populations are consistent with reductions in population size following fragmentation of near-contiguous habitat into a number of very small patches. The history of fragmentation of the areas containing the populations in Groups 1 and 2 is much older, dating back 150–200 years, with agricultural expansion soon after European settlement. It thus might be expected that these populations would contain higher levels of variation.

Overlying this history of fragmentation is the pattern of colonisation of this species over evolutionary time. The current hypothesis is that the genus *Synemon* originated in central Australia and has since radiated both eastward and westward (E.D. Edwards, personal communication). The closest relatives of *S. plana* occur in South Australia and Victoria. This would suggest that the Victorian populations of *S. plana* are the oldest with colonisation moving eastward resulting in the current distribution. The timing of this is unknown and it is possible the current distribution is quite ancient as no further easterly movement is possible due to an hypothesised altitudinal barrier. Thus again, it might be expected that Victorian populations would contain greater levels of variation and diversity compared with more recent colonists. These conjectures are supported by preliminary DNA sequence data (based on two mitochondrial genes and one nuclear gene) which show Victorian sequences to be ancestral to those from populations in the other two groups. In fact the pattern of population structuring revealed by the allozyme data is matched by the sequence data.

THE FUTURE

Although genetic data have been useful in unravelling some of the life history and demographics of *Synemon plana* populations as well as assisting in the development of testable hypotheses, there remain many unresolved issues. Many of these may be addressed by genetic techniques, particularly through the development and application of highly variable microsatellite markers. Many of the questions still surrounding generation time, effective population sizes and patterns of mortality may be more readily answered by the increased resolution associated with tracking of multilocus microsatellite genotypes over time. Unfortunately, microsatellite markers have proved difficult to isolate within the Lepidoptera in general. There are also some questions which can only be resolved by detailed long-term ecological studies, particularly those relating to habitat requirements and usage. Given the current threatened status of this species, the establishment of an experimental *ex-situ* population may be required for these studies.

CONCLUSIONS

With over 1200 individuals from 36 populations, representing over 24 000 individual genotypes, this study is one of the largest and most comprehensive genetic analyses of any threatened invertebrate. Not only has it provided much-needed information on some of the fundamental life-history and demographic attributes of the species but it has also given insight into the evolutionary, historic and recent population processes that have contributed to its current distribution and population structure. This study has also provided much-needed empirical data on the impacts of fragmentation on invertebrate species. At least in this case it would appear as though insects are not immune to the genetic and demographic consequences of habitat loss commonly observed in other taxonomic groups, viz. reductions in population size, loss of genetic diversity and increased inbreeding.

Given this greater knowledge of *Synemon plana* population structure and dynamics we are now in a much stronger position to implement effective conservation management strategies. In addition, we are better placed to begin developing quantitative models of population viability. Thus I believe this study has shown that it is possible to generate valuable, practical data for use in conservation management in circumstances where conventional ecological and demographic studies are problematic.

Although this paper has been focused on the potential uses of genetic data for inferring demographic and life-history parameters and for understanding past and recent population processes it must be stressed that genetic data alone should not be viewed as being either comprehensive or exclusive. It is only through the integration of studies from genetics, ecology, resource management, economics, politics and sociology that we can ever hope to achieve comprehensive effective long-term management of threatened species.

ACKNOWLEDGMENTS

I would like to thank Ted Edwards for providing much of the background information on *Synemon plana* life history and taxonomy. Cheryl O'Dwyer, Wendy Lee and Suellen Grosse are thanked for assistance in the field. This work has been supported by the New South Wales National Parks and Wildlife Service and Environment ACT.

ARCHIVAL RECORD

REFERENCE No. 8

Clarke, G & Dear, C 1998

A Survey of Native Grassland Sites in Southeastern New South Wales for the Endangered Golden Sun Moth, *Synemon plana*

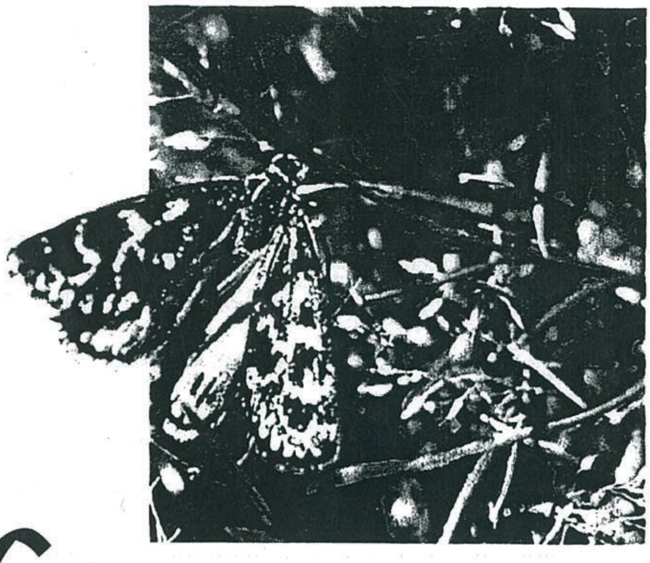
CSIRO Entomology, Canberra

ARCHIVAL RECORD

REFERENCE No. 9

Clarke, G & O'Dwyer, C 1998
Genetic analysis of populations of the endangered golden sun moth Synemon plan prepared for the Threatened Species Unit, NSW National Parks and Wildlife Service, Southern Zone, and the Wildlife Research and Monitoring Unit
Environment ACT, CSIRO, Canberra

Will Osborne



Genetic Analysis of Populations of the Endangered Golden Sun Moth, *Synemon plana*

A report prepared for
the Threatened Species Unit,
NSW National Parks and Wildlife Service,
Southern Zone,
and
the Wildlife Research and Monitoring Unit,
Environment ACT

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CSIRO

Table of Contents

Introduction

Genetic diversity is the variation among the various copies of related genes present in different individuals, populations or species of organisms. Levels and patterns of genetic diversity are the result of both evolutionary and ecological processes and as such reflect the integrity and functioning of evolutionary and ecosystem processes within populations and species (Brown *et al.* 1997).

Genetic diversity is of crucial concern in the maintenance of biological diversity for three main reasons:

1. *Short term viability of individuals and populations* - the ability of individuals to survive and reproduce (i.e. their fitness) depends largely on their genetic makeup (genotype), in particular their levels of heterozygosity and allelic diversity.

2. *Evolutionary potential of populations and species* - evolution is fully dependent on the level of genetic variation, in particular allelic diversity, within a population and species. Populations depauperate in genetic diversity are less able to respond to environmental change than more variable populations and thus are more prone to extinction.

3. *Direct use of genetic resources* - genetic variation is the mainstay of animal and plant breeders developing new and improved varieties for human use, and in the development of new and effective medicines.

Therefore the conservation of genetic diversity (allelic richness) and variation (heterozygosity) within populations should be considered among the primary aims of any conservation related project.

Assessment of genetic diversity can be approached at a number of different levels from gross morphological (phenotypic) variation to detailed DNA sequence variation. In general terms, the information content of each approach is directly proportional to the cost and difficulty of the technique used. Phenotypic variation, while relatively easy and cheap to measure, suffers from poor information content due to the confounding factors of virtually uncontrollable environmental variation, whereas sequence data is information rich but relatively costly and technically demanding. It is therefore critical to clearly identify the type and amount of information required to address the question of concern **before** embarking on a genetic investigation.

Isozyme analysis has been the approach of first choice in most conservation-based genetic studies. The techniques are well founded in population genetics theory and are relatively easy and inexpensive (Richardson *et al.* 1986). The approach provides a realistic and manageable level of variation for analysis, and the resulting data are suitable for species diagnosis, phylogenetic reconstruction, genetic distance and gene flow (migration) estimation, and assessment of levels of among-population differentiation. This approach, relies on variation being present at a relatively small subsample of the genome, and suffers when the level of variation within populations is low, as often occurs in small populations. Under these circumstances it may be necessary to utilise more sensitive approaches such as DNA-based marker technologies. The methods of choice here have been mitochondrial DNA and microsatellite fragment analysis (Dowling *et al.* 1996) and direct DNA sequencing (Hillis *et al.* 1996), although other techniques are available. The advent of polymerase chain reaction (PCR) technologies and automated sequencing has considerably reduced both the time and cost of these approaches, and given the greater information content of the data, they are now the first choice of many laboratories.

The aim of the current project is to assess levels of genetic diversity and variation within and among populations of the endangered golden sun moth, *Synemon plana* via isozyme analysis. Results will be used to assess the relative conservation value of each population (in terms of conservation of genetic diversity) and assist in conservation management of the species both locally and throughout its range.

The golden sun moth, *Synemon plana* (Lepidoptera: Castniidae), is a conspicuous day-flying moth, the larvae of which are thought to feed exclusively on native grasses within the genus *Danthonia*. The moth was once widespread in south eastern Australia, matching the distribution of native grasslands. Temperate native grasslands are the most endangered of all vegetation types in Australia, having been cleared for agriculture (predominantly free range grazing and broad-acre cropping) and urban development. Less than one percent of the original cover still remains, much of which is heavily degraded by weed invasion and grazing by stock and rabbits. The remaining grasslands are under considerable threat from urban and agricultural expansion. As a result, *S. plana* is now known to exist from eleven sites within New South Wales (NSW) (Clarke and Dear 1998), approximately twelve sites within the Australian Capital Territory (ACT) (Edwards 1994) and five sites in Victoria (Vic) (Dear 1997). The species has been listed as endangered in all States in which it occurs under their respective endangered species legislation (NSW - Threatened Species Conservation Act 1995, ACT - Nature Conservation Act 1980 and VIC - Flora and Fauna Guarantee Act 1988).

In general, the life history of the species is poorly known. The adults are short-lived (1–4 days) and do not feed, having no functional mouth parts. Males spend their entire adult life patrolling the grassland for females, with females, once mated, spending their time laying eggs within the clumps of *Danthonia*. Females have reduced hind wings and are reluctant to fly, even when disturbed. The males are capable of active and prolonged flight but will not fly long distances (> 100 m) away from areas of suitable habitat. Thus populations separated by distances of greater than 200 m can be considered effectively isolated, and populations that have gone extinct, or vacant patches of suitable habitat, are highly unlikely to be (re)colonised.

The flight period is relatively short, typically lasting for 6–8 weeks during November and December. Males will fly only in bright sunshine during the warmest part of the day (1000–1400 hrs). Adult emergence occurs continuously throughout the flying season. The starting date and duration of the flight season vary yearly, probably being dependent on spring weather conditions, with the season starting earlier (late October) following warm dry spring conditions.

Estimates of female fecundity are between 100–150 eggs (Edwards 1994). It is not known if females lay eggs singly or in clusters within the grass clumps. Based on census data available from a single ACT site it has been estimated that up to 99% of total potential fecundity is unrealised, although nothing is known of the possible causes. Estimates of adult and larval mortality are not known. Predation of adults by birds and predatory insects may be a significant contributor to adult mortality with as many as 30% of observed moths at one site being taken by predators (personal observations). Larval feeding occurs underground on the roots of the grass plant. The larval development time (and thus generation time) is unknown and may vary between one and three years. The number of plants required for development of a single larva is also not known although field studies at Mt. Piper in Victoria have shown that a minimum density of 40% *Danthonia* cover is required to sustain a *S. plana* population (Dear 1997).

Methods

Samples

Adult males were collected by hand netting from ten sites in the ACT, eight sites in NSW and two sites in Victoria during the period 7 November – 11 December 1997 (Table 1). Distances between sites sampled are given in Appendix 1. Captured individuals were returned alive and placed at -20°C until dead. Individual abdomens were then removed and placed into individual cryotubes and stored at -80°C until required.

Electrophoresis

Individual abdomens were homogenised in 100 µl of grinding buffer (100 ml distilled water, 10 mg NADP, 100µl β-mercaptoethanol). Samples were then centrifuged at 13,000 rpm for 5 minutes. Approximately 1µl of homogenate was loaded onto cellulose acetate plates (Titan III Helena Laboratories) and electrophoresed at 200V for 15 minutes. Genotypes were visualised by histochemical

Table 1. Site details for *Synemon plana* samples collected in 1997

Site Name	Code	N	Latitude	Longitude	Elevation	Area
ACT						
Campbell Pk	CPK	30	35.17.13S	149.10.16E	580	9
Majura	MFR	30	35.16.00S	149.13.00E	580	142
Mulanggary	MGY	24	35.11.42S	149.07.53E	620	3.3
Mulligans 1	MF1	30	35.09.02S	149.09.06E	680	5
Mulligans 2	MF2	33	35.09.58S	149.08.59E	660	5
Naval Station	NS	30	35.13.00S	149.05.00E	600	106
West Belconnen	WBC	30	35.11.25S	149.00.16E	580	20
Woden	WH	31	35.22.26S	149.09.44E	600	72
Yarralumla	YL	31	35.18.10S	149.06.09E	560	4
York Park	YP	30	35.18.50S	149.07.47E	560	0.4
NSW						
Bendenine Rd	BRD	30	34.40.08S	148.41.23E	520	2.5
Binalong	BIN	32	34.40.38S	148.37.20E	480	0.2
Ginninderra Rd	GRD	32	35.08.59S	149.10.32E	640	91
Gundaroo	GTC	31	35.01.51S	149.16.19E	590	1
Letchworth	LTH	30	35.22.12S	149.11.49E	600	55
Rye Park	RPK	20	34.31.05S	148.54.28E	530	0.5
Sutton	SUT	9	35.09.39S	149.15.25E	620	1
Tarengo TSR	TAR	30	34.28.19S	148.39.56E	580	10
VIC						
Dunkeld	DNK	30	37.41.50S	142.21.36E	240	2
Mount Piper	MTP	13	37.12.07S	145.00.36E	230	0.6

N = Sample size
Elevation given in metres.
Area (ha) estimates are based on the area believed to represent suitable habitat for *S. plana* and generally equates to the area of medium to high density *Danthonia* at each site. This area does not necessarily represent the total area of the site.

staining using recipes contained in Richardson *et al.* (1986). A total of 16 enzyme systems representing 20 loci were analysed (Table 2).

Statistical analysis of genotype data was performed using the software packages BIOSYS ver. 1.7 (Swofford and Selander 1989), POPGENE ver. 1.21 (Yeh *et al.* 1997), FSTAT ver. 1.2 (Goudet 1995) and GENEPOP ver. 3.1 (Raymond and Rousset 1995).

Results and Discussion

Population Structure

A total of 556 individuals were collected with almost 11,000 genotypes analysed, making this the largest genetic study of a threatened invertebrate in the world to date. Allele frequencies for each locus and population are given in Appendix 2.

Based on these frequencies, pairwise genetic distances, (D) (Nei 1978) and genetic differentiation, (F_{ST}) (Wright 1978) between populations were estimated (Table 3). These estimates were tested for significance using exact probability tests for differences in allele frequencies between populations. These estimates were then used to construct the UPGMA (unweighted pair group method with arithmetic averages) (Sneath and Sokal 1973) phenogram shown in Figure 1. The branch lengths in this phenogram represent relative genetic distances between populations and groups.

Table 2. Enzyme and locus details

Enzyme name	Abbrev.	EC No.	# Loci	Buffer[†]
Aconitate hydratase	*Acon*	4.2.1.3	2	TC
Adenylate kinase	*Ak*	2.7.4.3	1	TC
Fumarate hydratase	*Fum*	4.2.1.2	1	TC
Glucose-6-phosphate dehydrogenase	*G6pd*	1.1.1.49	1	TC
Glucose-phosphate isomerase	*Gpi*	5.3.1.9	1	TC
Glutamic-oxaloacetic transaminase	*Got*	2.6.1.1	2	TM
Glycerol-3-phosphate dehydrogenase	*αGpd*	1.1.1.8	1	TC
β-hydroxybutyrate dehydrogenase	*Hbdh*	1.1.1.30	1	TM
Isocitrate dehydrogenase	*Idh*	1.1.1.42	2	TC
Lactate dehydrogenase	*Ldh*	1.1.1.27	1	TC
Malate dehydrogenase	*Mdh*	1.1.1.37	2	TC
Malic enzyme	*Me*	1.1.1.40	1	TM
Phosphoglucomutase	*Pgm*	2.7.5.1	1	TM
6-phosphogluconate dehydrogenase	*6pgd*	1.1.1.44	1	TM
Triose-phosphate isomerase	*Tpi*	5.3.1.1	1	TM
Xanthine dehydrogenase	*Xdh*	1.1.1.204	1	TC

[†]TC = 0.1M Tris-citrate pH 6.0; TM = 0.05M Tris-maleate pH 7.8

A number of things are readily evident from this phenogram. Firstly, the populations cluster into 5 major groupings, which correspond almost perfectly with geographic location of the populations. Group 1 (Victoria) comprises the two Victorian populations; Group 2 (Nth NSW) comprises four populations located in the Binalong/Boorowa area approximately 80-100 km northeast of the ACT; Group 3 (Border) comprises 5 populations located in the area of the ACT/NSW north-northeastern border; Group 4 (Nth ACT) comprises 3 populations located north of Lake Burley Griffin and Group 5 (Sth ACT) contains the remaining 6 populations. Statistically these groupings are reasonably well supported (≥ 45% support from 1000 bootstrap samples), particularly Groups 1–4. Group 5 is less well supported which is not surprising given the very low genetic distances among populations. It might have been expected that the Mulligans Flat 2 and Naval Station populations may have clustered in Groups 3 and 4 respectively rather than Group 5, however, with genetic distances this low the allocation to particular groupings is essentially random and can be influenced by even small differences in allele and genotype frequencies.

Statistical analysis of this population structuring (using Nei's gene diversity estimates (Nei 1987) and Wright's *F*-statistics (Wright 1978)) reveals significant population differentiation, with approximately 20% of the total genetic variation observed due to differences among populations ($P < 0.005$). In addition, exact tests for population differentiation revealed significant differences in both allele and genotype frequencies for a range of loci among populations. The average pairwise genetic distances and F_{ST} values between these groups are given in Table 4.

It can be seen from the figure and Table 4, that Group 1 is significantly different from all the remaining groups. This is based on both the presence of different alleles and significant differences in allele frequency across a number of loci. In particular, these two Victorian populations show significant differentiation at *Acon-1*, *Mdh-1*, *Mdh-2*, *Got-1*, *Gpi*, and *Hbdh*. Such highly significant and consistent genetic differences between this and the other populations strongly suggest that they have been isolated for a significant period of time, representing historical, rather than recent fragmentation. In addition, the two Victorian populations themselves are very different from each other ($D = 0.083$, $F_{ST} = 0.273$). This is primarily based on

Table 3. Pairwise matrix of Nei's (1978) genetic distance, *D* (below diagonal) and Wright's F_{ST} (above diagonal). Significant values (following exact tests) shown in italic

Pop	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
BIN		0.0081	***0.0538***	***0.3984***	0.0301	***0.0353***	***0.0347***	0.0278	***0.0462***	***0.0486***	0.0357	***0.3653***	***0.0340***	0.0078	0.0071	0.0021	***0.0399***	***0.0327***	***0.0418***	***0.0405***
BRD	0.0006		***0.0685***	***0.4027***	***0.0410***	***0.0432***	***0.0429***	***0.0414***	***0.0560***	***0.0689***	***0.0521***	***0.3816***	***0.0427***	0.0068	0.0127	0.0083	***0.0461***	***0.0358***	***0.0468***	***0.0566***
CPK	***0.0095***	***0.0115***		***0.4723***	0.0375	0.0496	0.0124	0.0373	0.0189	0.0087	0.0150	***0.5038***	0.0205	***0.0946***	0.0384	***0.0697***	0.0160	0.0068	0.0008	0.0058
DNK	***0.1380***	***0.1351***	***0.1553***		***0.4975***	***0.4484***	***0.4716***	***0.4840***	***0.5067***	***0.4783***	***0.4646***	***0.2732***	***0.4806***	***0.4365***	***0.4379***	***0.3728***	***0.5058***	***0.4790***	***0.4793***	***0.4740***
GRD	0.0050	***0.0065***	0.0052	***0.1598***		0.0002	0.0347	0.0044	0.0034	0.0485	0.0224	***0.5259***	0.0036	0.0511	0.0005	***0.0476***	0.0024	0.0072	0.0147	0.0275
GTC	***0.0063***	***0.0073***	0.0070	***0.1627***	0.0011		0.0231	0.0129	0.0114	0.0443	0.0348	***0.5148***	0.0008	0.0471	0.0210	***0.0433***	0.0028	0.0033	0.0165	0.0232
LTH	***0.0063***	***0.0074***	0.0027	***0.1521***	0.0048	0.0038		0.0182	0.0005	0.0035	0.0029	***0.5055***	0.0016	0.0540	0.0101	***0.0377***	0.0204	0.0073	0.0069	0.0117
MF1	0.0051	***0.0070***	0.0054	***0.1598***	0.0006	0.0025	0.0031		0.0036	0.0452	0.0174	***0.5049***	0.0019	0.0528	0.0082	***0.0415***	0.0158	0.0093	0.0133	0.0127
MF2	***0.0069***	***0.0080***	0.0029	***0.1584***	0.0013	0.0021	0.0010	0.0006		0.0244	0.0017	***0.5518***	0.0119	***0.0729***	0.0103	***0.0604***	0.0056	0.0070	0.0060	0.0044
MFR	***0.0084***	***0.0113***	0.0003	***0.1569***	0.0063	0.0062	0.0017	0.0062	0.0035		0.0105	***0.5085***	0.0197	***0.0873***	0.0276	***0.0640***	0.0212	0.0092	0.0039	0.0006
MGY	0.0068	***0.0092***	0.0000	***0.1538***	0.0035	0.0052	0.0011	0.0031	0.0013	0.0002		***0.4954***	0.0039	0.0689	0.0167	***0.0512***	0.0077	0.0021	0.0087	0.0073
MTP	***0.1108***	***0.1118***	***0.1472***	***0.0825***	***0.1446***	***0.1500***	***0.1450***	***0.1431***	***0.1497***	***0.1470***	***0.1431***		***0.5100***	***0.4300***	***0.4643***	***0.3618***	***0.5395***	***0.5142***	***0.5117***	***0.5099***
NS	***0.0061***	***0.0072***	0.0035	***0.1580***	0.0014	0.0012	0.0010	0.0008	0.0000	0.0033	0.0016	***0.1472***		0.0533	0.0170	***0.0474***	0.0053	0.0080	0.0039	0.0064
RPK	0.0009	0.0013	***0.0138***	***0.1439***	0.0071	0.0072	0.0081	0.0077	***0.0090***	***0.0125***	0.0102	***0.1161***	0.0079		0.0202	0.0047	0.0609	0.0485	***0.0630***	0.0723
SUT	0.0052	0.0062	0.0074	***0.1598***	0.0023	0.0005	0.0018	0.0014	0.0012	0.0059	0.0046	***0.1460***	0.0006	0.0062		0.0187	0.0002	0.0104	0.0053	0.0003
TAR	0.0016	0.0035	***0.0125***	***0.1291***	***0.0077***	***0.0077***	***0.0069***	***0.0073***	***0.0090***	***0.0112***	***0.0096***	***0.1158***	***0.0084***	0.0028	0.0077		***0.0618***	***0.0404***	***0.0521***	***0.0478***
WBC	***0.0063***	***0.0071***	0.0028	***0.1644***	0.0008	0.0013	0.0032	0.0026	0.0015	0.0033	0.0019	***0.1498***	0.0015	0.0080	0.0022	***0.0098***		0.0034	0.0038	0.0232
WH	***0.0058***	***0.0061***	0.0019	***0.1546***	0.0018	0.0015	0.0004	0.0020	0.0003	0.0021	0.0010	***0.1473***	0.0002	0.0072	0.0014	***0.0071***	0.0007		0.0129	0.0033
YL	***0.0075***	***0.0081***	0.0013	***0.1585***	0.0027	0.0031	0.0006	0.0027	0.0005	0.0017	0.0005	***0.1511***	0.0008	***0.0095***	0.0025	***0.0094***	0.0008	0.0000		0.0014
YP	***0.0070***	***0.0092***	0.0018	***0.1525***	0.0039	0.0037	0.0000	0.0024	0.0006	0.0011	0.0005	***0.1456***	0.0004	0.0103	0.0025	***0.0084***	0.0034	0.0007	0.0011	

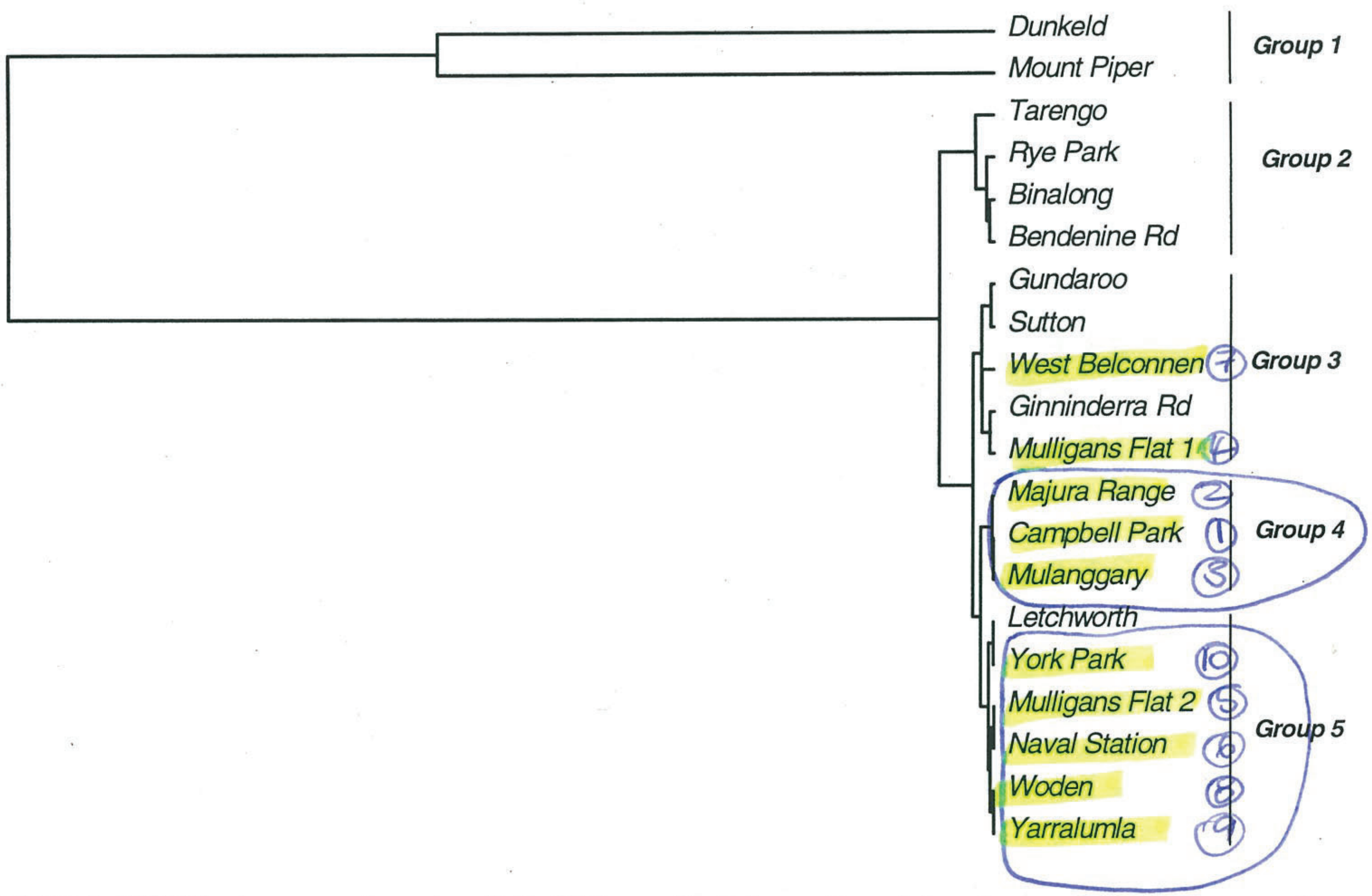

Figure 1. UPGMA phenogram based on Nei's 1978 genetic distance. Branch lengths represent relative genetic distance

Table 4. Pairwise average genetic distances (below diagonal) and F_{ST} (above diagonal) between groups of *Synemon plana* populations. Significant values shown in italic

Group	# Pops	1	2	3	4	5
1 Victoria	2		*0.3589*	*0.4895*	*0.4531*	*0.4398*
2 Nth NSW	4	*0.123*		*0.0423*	*0.0639*	*0.0518*
3 Border	5	*0.152*	*0.006*		*0.0362*	*0.0116*
4 Nth ACT	3	*0.149*	*0.009*	*0.004*		*0.0131*
5 Sth ACT	6	*0.150*	*0.007*	*0.001*	*0.001*	

significant allele frequency differences at *Acon-1*, *Mdh-1*, *Pgm*, and *Hbdh* loci. Such genetic differentiation is perhaps not surprising given that these two populations are separated by a distance of 220 km, and again probably represents historic separation.

The average genetic distances between Group 1 and the remaining groups (range 0.123–0.152) can be considered quite high, and are typical of values that distinguish subspecies or races in other species (Avise 1994). For example, the average genetic distance between subspecies of *Drosophila willistoni* is 0.17. The pairwise genetic distances between each of these Victorian populations and the remaining populations again average 0.15, supporting the idea that the Victorian populations may represent a separate race of even subspecies of *S. plana*. It would seem as though considerably more research into the formal taxonomy of this group, using both morphological and genetic approaches, is warranted.

By removing the Victorian populations and rescaling figure 1, the genetic interrelationships between the remaining populations are clearer (Figures 2 & 3).

Group 2 is significantly different from the three other groups, with an average genetic distance of 0.007 (Table 4). The level of population differentiation remains significant after removal of the Victorian populations, with approximately 4% of total variation attributable to among population differences ($P < 0.005$), again indicating that this group of populations likely represents an historical separation between them and the remaining populations.

Group 3 is likewise significantly different from the remaining two groups, which are in turn significantly different from each other (Table 4). The average genetic distances in the range of 0.001–0.004 are typical of intraspecific population differences (Avise 1994).

On a pairwise population basis, it can be seen (Table 3) that the Dunkeld and Mt Piper populations are significantly different from all others (including each other). Three of the four Nth NSW populations (Binalong, Bendenine Rd and Tarengo) are similarly different from almost all other populations, with the Rye Park population not showing as many pairwise differences. However, these four populations show no significant differences among themselves. All other pairwise comparisons are not significant, although the differences between all Groups are significant (Table 4). This result indicates that these populations have been recently connected.

Overall these populations conform to an isolation by distance model, in which genetic distance is correlated with geographical distance ($R^2 = 0.943$ $P < 0.001$), that is, the further apart two populations are geographically the greater the genetic distance between them. This relationship is shown graphically in Figure 4. Up to distances of approximately 100 km there appears to be little genetic differentiation or structuring among populations. At distances around 200 km significant differentiation starts to occur which appears to plateau off (at least for these populations) at distances greater than 400 km. For most mobile organisms this lack of significant genetic differentiation over relatively short distances would

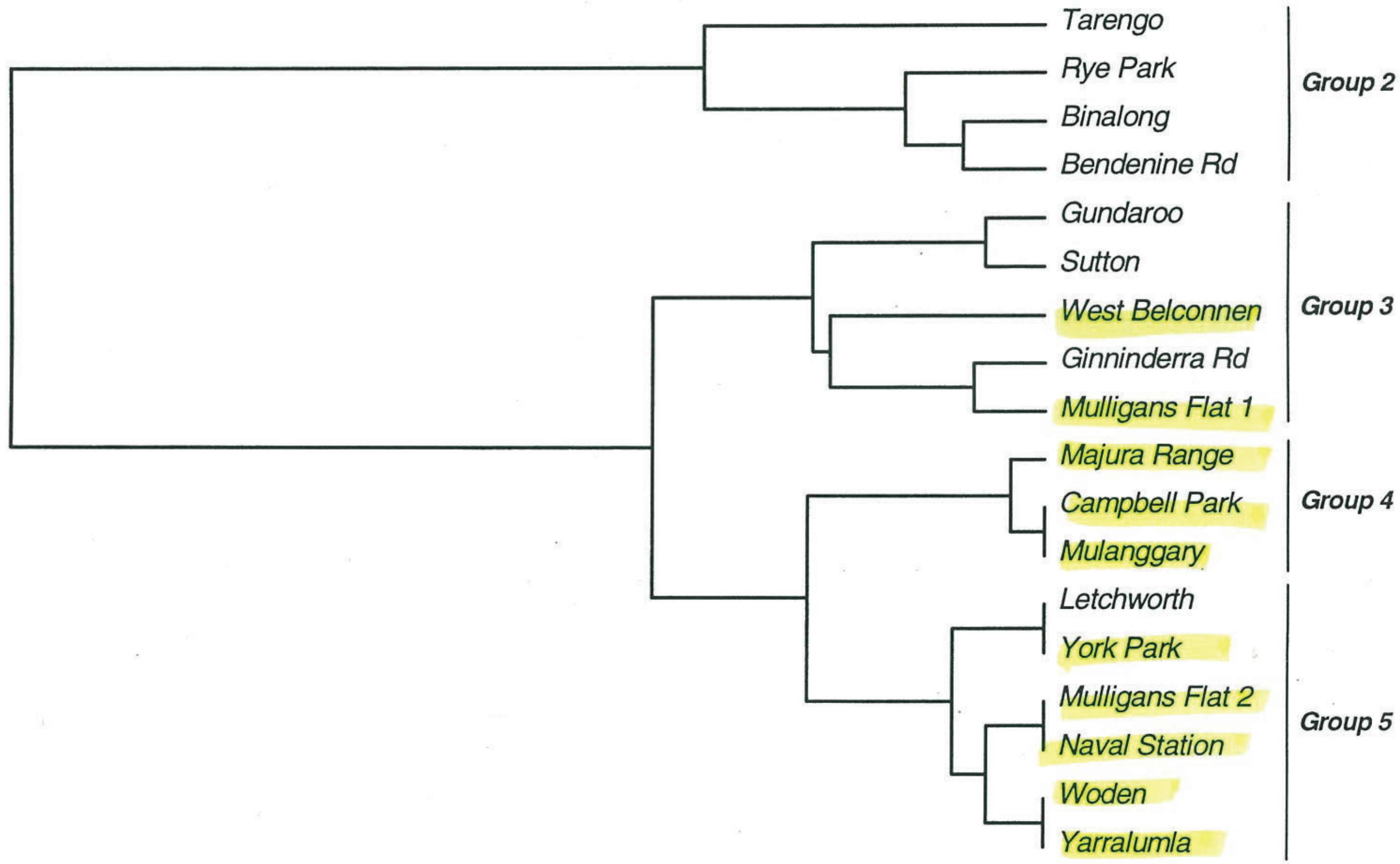

Figure 2. UPGMA phenogram following removal of Victorian populations and rescaling

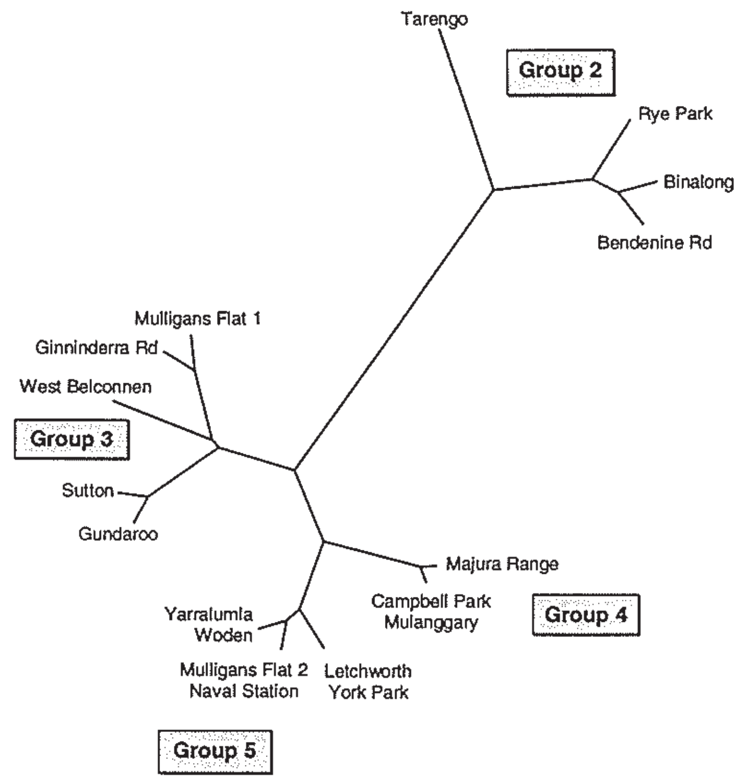

Figure 3. UPGMA based unrooted network. Branch lengths represent relative genetic distance

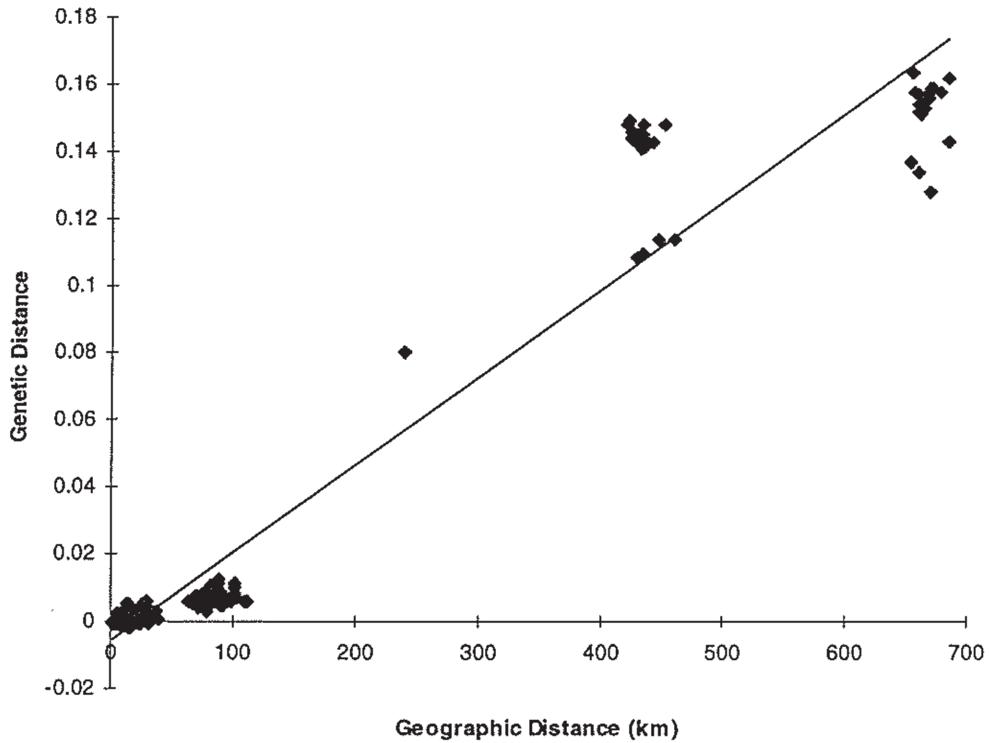

Figure 4. Scatterplot of geographic distance against genetic distance

primarily be due to migration of individuals between populations, thus maintaining gene flow and increasing genetic homogeneity among populations. However, in the case of *Synemon plana,* in which we assume that these populations are effectively genetically isolated, due to the restricted flying capabilities of males and females, this lack of differentiation between closely located populations, may indicate that these were all historically connected and have only recently undergone fragmentation. The rate of loss of genetic variance over time is inversely proportional to the effective population size (see below), that is, large populations tend to lose variation more slowly than small ones. As such, without some estimate of effective population sizes of these populations it is difficult to estimate the time since separation of these populations. The use of more sophisticated molecular markers, in particular mitochondrial DNA (mtDNA) sequences has the potential to estimate time since divergence.

From a conservation management perspective, these five groups of populations could be considered to represent separate conservation or management units. Certainly the first two groups contain significant allelic diversity (over 90% of total diversity) not represented in the remaining populations. The differences between Group 3 and the remaining two populations are primarily attributable to allele frequency differences rather than the presence of additional alleles.

Genetic Diversity and Variability

Estimates of genetic diversity and variability for each population are given in Table 5. An explanation of each of the parameters follows: *P* estimates the percentage of loci examined that are polymorphic (variable) within each population; *A* estimates allelic diversity, that is, the observed number of alleles per locus; *Ap* is the average number of alleles per polymorphic locus; H_e estimates gene diversity (Nei 1987) and represents the average expected heterozygosity across all loci within a population assuming random mating; H_o is the observed (or actual) average heterozygosity within individuals across loci within a population; *F* is the fixation index and represents the reduction in genetic diversity (average heterozygosity) due to non-random mating events such as inbreeding, assortative mating or through population subdivision (Nei 1987).

This 'significance' of the absolute magnitudes of these parameters is difficult to assess and relies on comparisons with published estimates for other species. Unfortunately, there have been very few genetic studies of insects undertaken in general (with the exception of *Drosophila*), and even fewer on rare or threatened taxa. However, these parameters are useful for among population comparisons within a species, for which relative differences can be informative. As such, it is possible to rank populations relative to each other based on genetic diversity indices.

We will first discuss the results in general terms before addressing their implications for effective conservation management of the populations and the species in general.

The overall level of polymorphism of 62% is higher than the average for insect species in general (P = 0.35 (Nevo *et al.* 1984)). However, this parameter is subject to considerable bias as the choice of loci examined within allozyme studies is rarely random, with researchers actively choosing variable loci for examination.

Allelic richness, as estimated from the average number of alleles per locus, is closely related to the number of polymorphic loci within a population. Populations with a high proportion of polymorphic loci will, by definition, have a higher number of alleles per locus than populations with a relatively low number of polymorphic loci. Therefore, a more meaningful estimate is the average number of alleles per polymorphic locus. Estimates of allelic diversity for insects are rare in the literature, however, a recent paper on the rare British butterfly, *Plebejus argus* (Brookes *et al.* 1997) provided an estimate of 2.9 alleles per polymorphic locus across nine populations. In a study of fragmented populations of the winter moth *Operophtera brumata* in Belgium (Van Dongen *et al.* 1998) the average was 3.31 (average across 5 loci). The estimates for *Synemon plana* are somewhat less than these, however, inferences based on allele number are

Table 5. Estimates of gene diversity and variation. SE in parentheses

Population	*P*	*A*	A_p	H_e	H_o	*F*
Victoria						
Dunkeld	80	1.9 (0.2)	2.31 (0.1)	0.173 (0.045)	0.122 (0.036)	0.297
Mt Piper	70	1.8 (0.2)	2.60 (0.2)	0.150 (0.047)	0.127 (0.045)	0.162
Group Mean	**75.0**	**1.85**	**2.46**	**0.162**	**0.125**	**0.229**
Nth NSW						
Binalong	75	2.0 (0.2)	2.40 (0.1)	0.147 (0.037)	0.123 (0.035)	0.170
Bendenine Rd	65	2.0 (0.2)	2.46 (0.1)	0.137 (0.038)	0.102 (0.030)	0.257
Rye Park	55	1.6 (0.2)	2.50 (0.3)	0.104 (0.038)	0.070 (0.028)	0.326
Tarengo	75	2.0 (0.2)	2.36 (0.2)	0.159 (0.041)	0.129 (0.039)	0.192
Group Mean	**67.5**	**1.90**	**2.43**	**0.137**	**0.107**	**0.236**
Border						
Ginninderra Rd	50	1.5 (0.2)	2.29 (0.2)	0.087 (0.030)	0.071 (0.027)	0.191
Gundaroo	65	1.5 (0.1)	2.10 (0.1)	0.097 (0.032)	0.081 (0.032)	0.173
Mulligans 1	55	1.6 (0.2)	2.50 (0.2)	0.096 (0.035)	0.092 (0.035)	0.045
Sutton	50	1.4 (0.1)	2.14 (0.1)	0.101 (0.036)	0.078 (0.030)	0.238
West Belconnen	60	1.5 (0.1)	2.11 (0.1)	0.083 (0.027)	0.071 (0.025)	0.154
Group Mean	**56.0**	**1.50**	**2.23**	**0.093**	**0.078**	**0.160**
Nth ACT						
Campbell Pk	70	1.6 (0.1)	2.00 (0.0)	0.101 (0.033)	0.082 (0.029)	0.175
Majura	50	1.5 (0.1)	2.13 (0.1)	0.098 (0.037)	0.081 (0.037)	0.175
Mulanggary	55	1.5 (0.2)	2.25 (0.2)	0.098 (0.036)	0.088 (0.036)	0.109
Group Mean	**58.3**	**1.53**	**2.13**	**0.099**	**0.084**	**0.153**
Sth ACT						
Letchworth	60	1.6 (0.2)	2.44 (0.2)	0.097 (0.035)	0.077 (0.033)	0.213
Mulligans 2	50	1.4 (0.1)	2.14 (0.1)	0.078 (0.032)	0.058 (0.023)	0.256
Naval Station	60	1.6 (0.2)	2.20 (0.1)	0.098 (0.034)	0.092 (0.035)	0.057
Woden	65	1.5 (0.1)	2.00 (0.0)	0.096 (0.031)	0.084 (0.032)	0.124
Yarralumla	70	1.7 (0.2)	2.27 (0.1)	0.100 (0.031)	0.074 (0.028)	0.259
York Park	50	1.5 (0.2)	2.42 (0.2)	0.096 (0.036)	0.085 (0.037)	0.115
Group Mean	**59.2**	**1.55**	**2.25**	**0.094**	**0.078**	**0.171**
Mean	**62.0**	**1.64**	**2.28**	**0.110**	**0.089**	**0.190**

P = % polymorphic loci
A = allelic richness (average number of alleles per locus)
A_p = average number of alleles per polymorphic locus
H_e = gene diversity (average expected heterozygosity) (Nei 1978)
H_o = average observed heterozygosity per individual
F = fixation index (Wright 1978)

problematic, as the number of alleles observed in a population is dependent on sample size. Most outbreeding populations contain many rare alleles, that is, they occur at very low frequency. Thus, the chances of detecting such alleles depend on the number of individuals sampled within each population. However, when sample sizes are relatively equal across sampled populations (as is the case here) allelic diversity can serve as a reliable parameter for among population comparisons. Allelic richness is consistently higher in populations in Groups 1 and 2 than in the remaining groups, with few exceptions, *viz.* Mulligans 1, Letchworth and York Park. Allelic diversity can be reduced via a number of population processes, the most important being either a drastic reduction in effective population size (bottleneck), or continually low effective population size. Under these circumstances genetic drift is the major evolutionary force at play and rare alleles are lost through chance sampling events during mating (Hartl and Clark 1989).

The average observed heterozygosity within individuals (H_o) across all populations of 8.9% compares favourably with other insect species, for which the average over 122 species is also 8.9% (Nevo *et al.* 1984). However, this average includes a number of haplo-diploid species for which heterozygosity values are very low. The average for 27 Lepidoptera species is somewhat higher at 12.7% (Nevo *et al.* 1984). Only the Victorian and Nth NSW populations approach this level of variation with the other populations showing up to 50% less variability.

There are very few reported estimates of average expected heterozygosity (H_e) for insect species in the literature from which to draw comparisons. In the study of *Plebejus argus* mentioned above (Brookes *et al.* 1997) average heterozygosity estimated from 12 allozyme loci across nine populations averaged 23.6%. In the study on *Operophtera brumata* in Belgium (Van Dongen *et al.* 1998) average H_e was estimated at 46% (average across 5 loci). Both these values are significantly higher than the 11.0% average for *S. plana*. Once again it can be seen that the Victorian and Nth NSW populations contain up to 50% more gene diversity than the remaining populations. However, low levels of heterozygosity cannot **always** be viewed as being problematic for individual fitness or population viability (Avise 1994). Numerous examples of common and widespread species lacking significant levels of heterozygosity exist. In addition, although many rare and threatened species contain relatively low levels of heterozygosity, in most cases this has been shown to be the outcome of population bottlenecks rather than a cause for their threatened status. However, most conservation geneticists would agree that the maintenance of high levels of heterozygosity is desirable.

Overall the level of genetic diversity and variation within populations can be considered lower (particularly within the populations in Groups 3–5) than that within other lepidopteran species examined. This may be attributable to founder events (population bottlenecks) during the process of population fragmentation. Depending on the time scale over which any fragmentation events occurred, it is conceivable that relatively few 'founder' individuals remained within the intact grassland fragment. Genetic variation (particularly allelic richness) is known to be reduced following bottlenecks. Any subsequent increase in variation depends on how long small population sizes persist within the newly created fragment. In the absence of migration from outside populations average heterozygosity will rebound more rapidly than allelic diversity (which relies on mutational events).

The relative differences in genetic diversity between populations within Groups 1, 2 and the remainder may represent different time scales for habitat fragmentation. The populations within Groups 1 and 2 lie within agricultural habitats that were cleared between 100 and 150 years ago. Although relatively recent in evolutionary terms, there has been considerable potential for restoration of genetic diversity if any bottlenecks accompanied the fragmentation. The populations within Groups 3–5 have only more recently been fragmented, primarily through the urban and agricultural expansion around the ACT over the last 70 years and in many cases the last 20 years. Thus, the chances for recovery of genetic diversity within these populations have been limited.

All the populations examined show a reduction in observed heterozygosity compared with that expected under random mating (i.e. positive F values) (Table 5). An examination of the genotype frequency distributions for conformity to Hardy-Weinberg expectations (random mating) reveals that in all populations a number of loci (between 1 and 5) failed to comply. In most cases this involved loci with relatively rare alleles which were present as homozygotes rather than the expected heterozygotes (under random mating expectations rare alleles should be more frequent in heterozygous combination with common alleles than as homozygous combinations). In a sample size of 30 individuals the chances of detecting a rare homozygote are considerably less than that of detecting the corresponding heterozygote. For example, for a locus with two alleles with frequencies A = 0.90 and B = 0.10, there is only a 1% chance of detecting the rare BB homozygote compared with a 20% chance of detecting the AB heterozygote.

With more than two rare alleles the chances of picking up both as homozygotes are increasingly small if the population is undergoing random mating. When additional loci with rare alleles are involved the probability of them all showing similar patterns under a random mating model are infinitesimally small. Given that this is the general pattern observed across all the *S. plana* populations examined, it is clear that these are not undergoing random mating.

As mentioned above, the fixation index (*F*) relates to the decrease in heterozygosity within an individual due to non-random mating events. In essence it measures the difference between observed heterozygosity (H_o) and that expected under random mating (H_e). More technically, it measures the probability that the two alleles at a given locus are derived from a common ancestor, averaged across all loci within a population. Non-random mating can arise from a number of population processes. *Inbreeding* occurs when related individuals mate. When population sizes are small the chance of mating with unrelated individuals decreases, and hence the frequency of inbreeding and thus homozygosity increases. *Assortative mating* occurs when mating takes place between individuals having similar phenotypic characteristics, such as in humans. Unlike inbreeding however, homozygosity only increases at the loci responsible for the characters concerned. *Population subdivision* refers to the situation where a population contains several separate mating units or subpopulations. Even though the mating within each subpopulation may be effectively random, when averaged across the entire population increased homozygosity can result. This property is known as the Wahlund principle (Hartl and Clark 1989). In addition, *selection* can also influence the relative frequency of heterozygotes at a particular locus, depending on whether or not selection favours heterozygotes over homozygotes or *vice versa*. In practice these four processes may be occurring simultaneously within a population.

As the loci examined within the current *S. plana* populations are selectively neutral (following Ewens-Watterson tests (Hartl and Clark 1989)), selection can be ruled out as a probable cause. Likewise assortative mating can be discounted as it is unlikely that the loci examined contribute significantly to phenotypic characteristics. It is not possible to detect the presence of Wahlund effects without structured sampling within a population across spatial and temporal scales. However, in effect, any such population subdivision promotes inbreeding due to the reduction in effective population size within any subpopulation. In addition, unless these subpopulations are continuously isolated, a single generation of random mating between them will restore Hardy-Weinberg equilibrium.

Hence, inbreeding would appear to be the most probable cause of the observed deviation from random mating. Therefore, effective population sizes can be assumed to be quite low within these populations. The effective population size (N_e) refers to the actual number of individuals contributing to the next generation, which for most organisms is typically less than the total number of individuals in a population, or census size (*N*). This is due to the fact that under most circumstances not all individuals have an equal chance of mating and leaving offspring which develop though to adulthood.

There are a number of possible scenarios to explain the results observed in these *S. plana* populations. Taking the York Park population as an example (as it is the only *S. plana* population for which we have good census data over a number of years) the evidence suggests that the population size (census size) is relatively stable at approximately 1000–1500 individuals (assuming a 1:1 sex ratio) (Harwood *et al.* 1995). If all females mate and lay eggs, and at least some of those from each female reach adulthood, the effective population size will approximately equal the census size. However, as the average fecundity of *S. plana* females is approximately 100 eggs, the majority of these (~ 98%) must fail to develop for the population to remain stable. Alternatively, most matings may be carried out by very few males (assuming that males mate more than once). Under this scenario progeny resulting from individual females mated by the same male will be half sibs. This situation would appear unlikely in a species which does not feed, as males are unlikely to have sufficient resources (and are unable to obtain more through feeding)

At this stage it is not possible to provide accurate estimates of effective population size for these populations. Estimates based on genetic data require that changes in genetic diversity (heterozygosity) be monitored over time (generations). Some preliminary estimates for three ACT populations suggest N_e's of between 5 and 30 individuals. However, it must be stressed that these estimates are subject to considerable error and are based on the assumption of a one-year generation time, which is not confirmed. However, the upper estimate of 30 individuals is unlikely to be far off the mark given that N_e/N ratios of 0.1 or even 0.01 have been reported in insect species (Frankham 1995).

It must be pointed out that inbreeding *per se* does not always lead to a reduction in fitness through the effects of inbreeding depression. The cost of inbreeding, in terms of reduction in survival following full sib mating, has been shown to vary across two orders of magnitude (Avise 1994). It has been argued that populations which have been exposed to inbreeding for long periods of time have the ability to purge any deleterious recessive alleles responsible for inbreeding depression and fitness reduction. At this stage the potential for fitness decreases following inbreeding in *S. plana* is unknown.

Conservation and Management Implications

It must be stressed at the outset that genetic data in isolation do not provide all the answers for effective conservation management. The overly prescriptive use of genetically-derived information in planning can be fraught with danger. However, its careful use in conjunction with demographic, land use and resource management information has the potential for objective management decisions to be made.

From a genetics perspective, the primary conservation goals are to conserve as much genetic diversity and variability as possible. In addition, it is important to conserve those evolutionary processes responsible for the generation, maintenance and partitioning of that diversity within and among populations (Avise 1994).

Given the significant degree of genetic differentiation among the five groups of populations it would seem reasonable to treat these as separate management units. Conservation planning needs to take into consideration that much of this differentiation (particularly that between Groups 1, 2 and the remainder) represents historic evolutionary processes rather than recent fragmentation events. Similarly, within Group 1 the two populations are significantly different from each other, and all other populations, that they will need separate management in order to conserve the underlying genetic diversity.

From the point of view of translocation of individuals among populations for the purposes of population supplementation (in order to increase population size or genetic variability), it would be considered unwise to mix individuals **between** groups given this underlying significant level of population structuring and differentiation. The potential for outbreeding depression increases with increasing genetic separation between populations. However, given the relatively low levels of genetic differentiation among populations **within** groups, movement of individuals among these populations should not pose any genetic difficulties.

to pose - darstella

Similarly in the case of species (re)introduction programmes (i.e. translocation of individuals into currently unoccupied sites), it would seem reasonable not to mix individuals from different population groups. Again the use of individuals from different populations within a group may be desirable in order to maximise genetic diversity.

However, **any** translocation that involves mixing of individuals from different populations must be viewed with caution and undertaken for sound reasons. Each case should be thoroughly examined on its own merits and more research may be warranted. If the hypothesised significant temporal subdivision within populations is a reality, then careful planning would be needed before any translocation proceeded.

Within Groups 2–4, the lack of significant genetic differences among populations could be argued to display some degree of genetic or population redundancy, and thus afford the opportunity to focus on certain populations at the expense of others. For example, large populations may be viewed as being more viable in the long term than small ones, or alternately, several small populations may be preferable to one large. Populations with more secure land tenure may be 'easier' to manage than less secure ones etc. There are however dangers with this type of reasoning, and the ultimate aim must be to conserve and manage as many populations as possible, if nothing other than to safeguard against the loss of one or more populations through local 'catastrophes' such as fire or drought.

However, one of the realities of modern conservation management is that it is impossible to conserve or protect everything and priorities have to be decided upon. Given that our ultimate aim, from a genetic perspective, is to conserve as much allelic diversity and heterozygosity as possible, it is possible to rank populations based on these parameters in order to establish priority lists. Ideally such rankings need to be combined with similar site rankings based on patch size and quality, and land tenure. Such combined information can then be used to identify populations for focussing attention and resources.

Obviously based on the results here, both Victorian populations are of considerable conservation importance. However, until these populations can be placed in the broader context of other Victorian populations it would be unwise to make any more specific recommendations. As such they will not be considered further in this report.

For the remaining groups, a minimum of two replicate populations within each group should be considered for priority conservation management. Ideally these should be as large as possible and obviously represent those populations containing the greatest level of genetic diversity and variation. Large populations are desirable for a range of reasons; not only do they minimise the chances of inbreeding and genetic drift, but also because they are less prone to extinction through catastrophes and chance events. However, for the same reasons, small sites might warrant more interventionist type management to ensure their protection.

Within Group 2 (Nth NSW) the choice of populations is difficult. All four populations contain similar numbers of private alleles (i.e. alleles only found in one population within the group). Thus in order to conserve the total range of allelic diversity within this group, all populations should be targeted for attention. The Tarengo and Rye Park sites are both public land, the Binalong site a mixture of both public and private and Bendenine Rd is private freehold. The Tarengo and Bendenine Rd sites are relatively large whereas the other two are very small (< 0.5 ha). It should be noted that an additional population has been located in the area at Moorby's Lane, approximately mid way between the Bendenine Rd and Rye Park sites, however insufficient material was available for analysis (Clarke and Dear 1998). Also, it is very likely that additional populations exist in the area. As such, considerably more survey work in the area seems warranted. However, based on the four current populations it would seem appropriate to give them equal priority for conservation based on their distinctive allelic compositions.

In Group 3 (Border) both Ginninderra Rd and West Belconnen do not contain any alleles not present within the remaining three populations. Gundaroo and Mulligans 1 each have two private alleles and Sutton has one, and another shared only with Ginninderra Rd. Thus these three populations (GTC, MF1, SUT), contain all the allelic diversity in the group and have the highest levels of variation (it must be noted that some of these alleles are present within populations in Group 2). Of these, the MF1 site occurs in the ACT with both Gundaroo and Sutton in NSW. The distinctiveness of the West Belconnen site within this group (Figures 2 & 3), is a result of its general lack of these rare alleles. However, it displays similar allele frequencies (for the common alleles) with the other members of the group, hence its inclusion in this cluster. The three priority sites all contain areas of public land, however, represent the three smallest sites within the Group. The very large

Ginninderra Rd site is a complex of four private freehold properties (Clarke and Dear 1998), yet undoubtedly has the highest quality grassland of all the sites within the group and the largest population size. As such, it may represent a higher priority than the Sutton site, which is very small and has very low population density. The single private allele present in the Sutton population also occurs in the Binalong and both Victorian populations at low frequency. The West Belconnen site has the lowest priority, and although a large site, is quite degraded and weed infested compared with the other sites in this group.

Within Group 4, Campbell Park contains four private alleles, Mulanggary two and Majura one. None of these alleles are unique to this group, although two of them are only shared with one other population. All three populations have similar levels of heterozygosity and all sites have significant patches of quality *Danthonia* dominated grassland. Both the Majura and Mulanggary sites have reasonably secure land tenure being Defence Force (Commonwealth) and Nature Reserve (ACT Government) respectively. Although the Campbell Park and Majura sites are in close proximity (4.7 km) they are genetically quite distinct. In summary, these three populations all have equal ranking.

Within Group 5, the Yarralumla population contains three private alleles, two of which are unique within ACT populations, and another which is only found in this population. The Belconnen Naval Station population has two private alleles, one of which in unique within ACT populations, and another only shared with Binalong and Bendenine Rd populations. York Park has one allele only shared with Campbell Park. Woden has one private allele although shared with populations from other groups as does Letchworth. The Mulligans 2 site contains no unique alleles. With the exception of Mulligans 2, all populations within the group display similar levels of variation.

Land tenure among these sites is highly variable, with only few offered any formal protection. Within the ACT, Yarralumla is designated Urban Open Space (ACT Government); York Park is a Conservation Site; Mulligans 2, a Nature Reserve; Woden is private leasehold; and Belconnen Naval Station although currently Defence Force is earmarked for urban development. The NSW site of Letchworth is currently vacant crown land under the control of the Queanbeyan City Council, and is subject to a development proposal on its northern end. This site is in very close proximity to another *S. plana* site at The Poplars (private freehold), also subject to development application.

On purely genetic grounds, the Yarralumla and Naval Station sites warrant the highest conservation priority based on their unique allelic diversity both within the ACT and beyond. The Letchworth site, being the only NSW site in the group (although probably very similar genetically to The Poplars from which sampling was not permitted) is also of high conservation value. Although not genetically significantly different from other populations, it has a number of other characteristics of conservation importance. It is a large site of high quality grassland and contains at least one other species of conservation concern, the daisy *Rutidosis leptorrhynchoides*. Unlike other *S. plana* sites within NSW, it is in close proximity to a major population centre, thus offering considerable educational opportunities in conservation related activities. Similarly, the York Park population, being situated within the Parliamentary Triangle of Canberra, its high profile and considerable research focus in past years, deserves special attention. The remaining two populations (Woden and Mulligans 2) warrant no special attention in terms of conserving genetic diversity with *S. plana* populations, although both represent areas of good quality native grassland.

The relatively high frequency of non-random mating observed in these populations may not be of great concern at this stage. The fact that the pattern was observed across all populations suggests that it is a normal feature of the breeding system of *S. plana*, rather than a consequence of fragmentation. However, until further research is conducted in this area, and the potential for temporal subdivision within populations and fitness reduction through inbreeding thoroughly investigated, we should remain cautious. Every attempt should be made to prevent further population size reduction.

Summary

This study has provided valuable information on the genetic structure both within and among *S. plana* populations throughout its current range. In addition, it has provided insight into some of the fundamental biology of the species in terms of breeding structure and possible population subdivision.

Five distinct groups of *S. plana* populations have been identified which correspond closely with geographic location. One of these groups may be sufficiently different genetically to be regarded as a separate subspecies or race. These five groupings should be treated as separate units for conservation management.

Levels of genetic variation within all populations are somewhat lower than that observed in other lepidopteran species, although the amount of data available for comparative purposes from other species is limited. The evidence suggests that this level of variation may have resulted from population bottlenecks and founder events following fragmentation, particularly within ACT and surrounding populations.

Within each group, populations have been ranked in terms of the conservation significance for the primary aim of conserving as much genetic diversity and variability within and among populations and the species in general.

Knowledge Gaps and Future Research

Although considerable new information has been provided which will assist the conservation management of *S. plana*, there are still some gaps in knowledge which need to be addressed in an effort to make such management more effective. Some of these are (in no priority order):

- In order to place the Victorian results in a broader context, inclusion of additional Victorian populations for genetic analysis in needed
- Similarly, additional survey work in the area containing Group 2 populations and in the area between these and the Victorian populations would provide a better understanding of the species distribution and population structuring
- To investigate the potential subspecific status of Victorian populations morphological and molecular taxonomic study is needed
- Further isozyme analysis of a subset of these populations is needed to monitor any changes in genetic diversity and variation and more accurately assess effective population sizes
- To assess potential founder effects through population bottlenecks molecular genetic analyses of these populations (focussing on mitochondrial DNA variation) is needed
- To assess the potential for temporal within population subdivision genetic analysis of samples collected at different times throughout the flying season should be undertaken
- An assessment of the potential for fitness reduction following inbreeding is required to determine any effect of the relatively high levels of non-random mating
- Detailed demographic studies are needed to determine fundamental life history characteristics of the species, such as fecundity, generation time, adult and larval mortality, which may be impacting the genetic structure and processes within populations

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Appendix 1. Distance matrix showing distances (km) between sampled populations of *Synemon plana*

Pop	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
BIN		6.3	84.2	654	72.8	71.1	93.1	71.4	72.5	85.0	73.9	429	73.2	31.5	79.4	23.2	66.8	91.7	82.1	84.5
BRD	6.3		81.5	660	69.4	66.6	90.6	68.1	69.3	81.9	71.0	434	70.6	26.0	75.7	22.0	64.6	89.4	79.8	82.1
CPK	84.2	81.5		665	15.3	29.9	9.5	15.3	13.6	4.7	10.8	429	11.2	88.7	15.5	102	18.5	9.7	6.5	4.8
DNK	654	660	665		672	686	663	670	669	669	666	240	661	686	678	670	656	660	658	660
GRD	72.8	69.4	15.3	672		15.8	24.6	2.2	3.0	13.5	6.5	438	11.2	74.3	7.6	88.5	16.2	24.9	18.3	18.7
GTC	71.1	66.6	29.9	686	15.8		38.3	17.2	18.7	26.7	22.3	452	26.8	66.0	15.1	83.2	30.1	39.4	33.9	34.0
LTH	93.1	90.6	9.5	663	24.6	38.3		24.7	23.1	11.6	20.3	427	19.9	98.3	23.3	111	26.5	3.2	11.4	8.7
MF1	71.4	68.1	15.3	670	2.2	17.2	24.7		1.7	14.2	5.3	436	9.6	73.7	9.7	87.5	14.1	24.8	17.5	18.3
MF2	72.5	69.3	13.6	669	3.0	18.7	23.1	1.7		12.7	3.6	435	8.2	75.3	9.8	88.9	13.5	23.1	15.8	16.5
MFR	85.0	81.9	4.7	669	13.5	26.7	11.6	14.2	12.7		11.1	434	13.3	87.8	11.8	102	21.0	12.9	11.1	9.5
MGY	73.9	71.0	10.8	666	6.5	22.3	20.3	5.3	3.6	11.1		432	5.0	77.9	11.9	90.9	11.5	20.1	12.2	13.2
MTP	429	434	429	240	438	452	427	436	435	434	432		427	461	443	448	422	424	423	425
NS	73.2	70.6	11.2	661	11.2	26.8	19.9	9.6	8.2	13.3	5.0	427		79.3	16.8	91.1	7.7	18.9	9.7	11.6
RPK	31.5	26.0	88.7	686	74.3	66.0	98.3	73.7	75.3	87.8	77.9	461	79.3		78.7	22.8	75.2	97.9	89.0	90.7
SUT	79.4	75.7	15.5	678	7.6	15.1	23.3	9.7	9.8	11.8	11.9	443	16.8	78.7		94.1	23.1	24.6	20.7	20.1
TAR	23.2	22.0	102	670	88.5	83.2	111	87.5	88.9	102	90.9	448	91.1	22.8	94.1		85.6	110	101	103
WBC	66.8	64.6	18.5	656	16.2	30.1	26.5	14.1	13.5	21.0	11.5	422	7.7	75.2	23.1	85.6		24.9	15.3	17.8
WH	91.7	89.4	9.7	660	24.9	39.4	3.2	24.8	23.1	12.9	20.1	424	18.9	97.9	24.6	110	24.9		9.6	7.3
YL	82.1	79.8	6.5	658	18.3	33.9	11.4	17.5	15.8	11.1	12.2	423	9.7	89.0	20.7	101	15.3	9.6		2.8
YP	84.5	82.1	4.8	660	18.7	34.0	8.7	18.3	16.5	9.5	13.2	425	11.6	90.7	20.1	103	17.8	7.3	2.8	

Appendix 2. Allele frequencies for populations of *Synemon plana* collected in 1997

Locus	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
G6pd	31	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Idh-1	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.000	0.000	0.033	0.033	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	1.000	1.000	0.967	0.950	1.000	0.968	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Idh-2	31	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	1.000	0.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.923	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Acon-1	30	29	29	30	32	30	30	29	31	30	24	13	30	19	9	29	30	31	30	30
A	0.000	0.000	0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.000	0.000	0.017	0.000
B	0.983	0.983	1.000	0.650	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.885	1.000	1.000	1.000	0.965	1.000	1.000	0.966	1.000
C	0.017	0.017	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000
D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Acon-2	30	28	29	30	32	30	29	29	31	30	24	13	30	19	9	28	25	31	30	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000
B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.967	1.000	1.000	1.000	1.000	0.984	0.934	1.000
C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.016	0.033	0.000
αGpd	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.078	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000
B	0.922	0.933	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.983	1.000	1.000	1.000	1.000
6pgd	30	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.017	0.100	0.000	0.000	0.000	0.000	0.017	0.017	0.000	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000
C	0.983	0.883	0.950	0.983	1.000	1.000	0.966	0.966	1.000	1.000	1.000	0.923	0.983	1.000	1.000	0.967	0.966	0.952	0.936	1.000
D	0.000	0.017	0.050	0.000	0.000	0.000	0.017	0.017	0.000	0.000	0.000	0.039	0.017	0.000	0.000	0.033	0.017	0.048	0.064	0.000

Locus	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
Me	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.016	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.984	1.000	0.983	0.950	1.000	0.968	1.000	1.000	1.000	1.000	1.000	0.962	1.000	0.975	1.000	0.967	1.000	0.968	1.000	1.000
C	0.000	0.000	0.017	0.000	0.000	0.032	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.025	0.000	0.033	0.000	0.032	0.000	0.000
Fum	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.016	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.016	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.000	0.111	0.000	0.000	0.000	0.000	0.000
C	0.968	1.000	1.000	0.966	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.962	1.000	1.000	0.889	1.000	1.000	1.000	1.000	1.000
Mdh-1	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.000
B	1.000	1.000	1.000	0.200	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.917	1.000	1.000	1.000	1.000
C	0.000	0.000	0.000	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mdh-2	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.016	0.000	0.017	0.000	0.000	0.032	0.017	0.000	0.000	0.000	0.021	0.038	0.000	0.000	0.000	0.033	0.017	0.000	0.016	0.000
C	0.016	0.000	0.000	0.700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.808	0.000	0.000	0.000	0.033	0.000	0.000	0.000	0.000
D	0.968	1.000	0.983	0.300	1.000	0.968	0.983	1.000	1.000	1.000	0.979	0.077	1.000	1.000	1.000	0.934	0.983	1.000	0.984	1.000
Ldh	32	30	30	30	32	31	29	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
B	0.891	0.933	0.767	1.000	0.922	0.903	0.845	0.933	0.924	0.733	0.771	1.000	0.917	0.950	0.889	0.900	0.817	0.871	0.823	0.866
C	0.109	0.067	0.233	0.000	0.078	0.097	0.155	0.067	0.076	0.267	0.187	0.000	0.083	0.050	0.111	0.100	0.183	0.129	0.177	0.117
Got-1	32	30	30	30	32	31	30	30	33	30	24	12	30	20	9	30	30	31	31	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000
B	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	0.266	0.233	0.200	0.000	0.141	0.242	0.383	0.250	0.258	0.283	0.250	0.000	0.283	0.325	0.333	0.350	0.167	0.274	0.258	0.333
D	0.578	0.550	0.800	0.000	0.844	0.758	0.600	0.733	0.742	0.717	0.750	0.000	0.717	0.550	0.611	0.533	0.833	0.726	0.742	0.667
E	0.156	0.217	0.000	1.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.100	0.056	0.100	0.000	0.000	0.000	0.000
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000

Locus	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
Got-2	32	30	30	30	32	31	30	30	33	30	24	12	30	20	9	30	30	31	31	30
A	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C	0.125	0.067	0.067	0.033	0.219	0.194	0.117	0.283	0.182	0.050	0.104	0.000	0.183	0.050	0.222	0.167	0.117	0.113	0.113	0.150
D	0.875	0.916	0.933	0.950	0.781	0.806	0.883	0.717	0.818	0.950	0.896	1.000	0.817	0.950	0.778	0.833	0.883	0.887	0.887	0.850
Pgm	31	30	30	30	32	31	30	30	32	30	24	13	30	20	9	30	30	31	31	30
A	0.032	0.100	0.033	0.383	0.078	0.161	0.050	0.017	0.031	0.033	0.021	0.038	0.100	0.075	0.111	0.066	0.083	0.113	0.048	0.050
B	0.839	0.850	0.967	0.617	0.891	0.774	0.917	0.966	0.969	0.900	0.979	0.808	0.900	0.850	0.889	0.717	0.917	0.887	0.952	0.900
C	0.129	0.050	0.000	0.000	0.031	0.065	0.033	0.017	0.000	0.067	0.000	0.154	0.000	0.075	0.000	0.217	0.000	0.000	0.000	0.050
Ak	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.000	0.017	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.969	0.983	1.000	0.983	1.000	1.000	1.000	1.000	1.000	0.967	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
C	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gpi	32	30	30	30	32	31	30	30	33	30	24	13	30	20	9	30	30	31	31	30
A	0.250	0.250	0.067	0.517	0.110	0.016	0.050	0.100	0.030	0.017	0.083	0.577	0.017	0.275	0.000	0.317	0.050	0.065	0.048	0.017
B	0.750	0.750	0.933	0.483	0.890	0.984	0.950	0.900	0.970	0.983	0.917	0.423	0.983	0.725	1.000	0.683	0.950	0.935	0.952	0.983
Hbdh	25	30	30	30	32	31	30	30	33	29	24	13	30	20	9	30	29	31	31	30
A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.230	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	0.220	0.167	0.483	0.717	0.266	0.226	0.400	0.300	0.364	0.448	0.438	0.000	0.333	0.125	0.222	0.283	0.259	0.355	0.371	0.450
C	0.760	0.750	0.517	0.283	0.734	0.774	0.600	0.683	0.636	0.552	0.562	0.385	0.650	0.875	0.778	0.700	0.741	0.645	0.629	0.550
D	0.020	0.083	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.017	0.000	0.000	0.000	0.000
E	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.385	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tpi	28	22	28	30	31	27	28	28	27	30	22	13	27	16	8	24	23	28	29	27
A	0.053	0.046	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000
B	0.929	0.932	0.982	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.982	1.000	1.000	0.958	1.000	1.000	1.000	1.000
C	0.018	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Locus	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
Xdh	31	28	30	29	31	31	30	29	30	30	23	13	29	19	9	30	30	31	31	30
A	0.210	0.125	0.133	0.259	0.097	0.065	0.033	0.121	0.033	0.150	0.108	0.654	0.070	0.132	0.056	0.117	0.067	0.048	0.016	0.100
B	0.790	0.875	0.867	0.741	0.903	0.935	0.934	0.879	0.934	0.850	0.848	0.346	0.860	0.816	0.944	0.883	0.933	0.952	0.952	0.867
C	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.033	0.000	0.044	0.000	0.070	0.052	0.000	0.000	0.000	0.000	0.032	0.033

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Genetic variability and population structure of the endangered golden sun moth, *Synemon plana*

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Abstract

Allozyme electrophoresis was used to assess levels of genetic variation and diversity and investigate patterns of population structure in the endangered golden sun moth, *Synemon plana*. Twenty populations were sampled from throughout the geographic range of the species. Levels of genetic variation within most populations were lower than that observed in other lepidopteran species. The evidence suggests that this level of variation may have resulted from population bottlenecks and founder events following habitat fragmentation. Five distinct groups of *S. plana* populations have been identified which correspond closely with geographic location. One of these groups may be sufficiently different genetically to be regarded as a separate subspecies or race. These five groupings should be treated as separate units for conservation management.

Keywords: Conservation; Genetics; Lepidoptera; Habitat fragmentation; Grasslands

1. Introduction

Habitat fragmentation is recognised as one of the major environmental factors threatening the survival of populations and species worldwide. However, although the genetic and demographic consequences of fragmentation on vertebrate and plant species have been well documented (Wilcove et al., 1986; Saunders et al., 1991; Young et al., 1996), the impacts of fragmentation on invertebrate species has received less attention. Most invertebrate studies have investigated the effects of fragmentation on species diversity of selected groups in both natural (Webb and Hopkins, 1984; Niemelä et al., 1988; Usher et al., 1993) and experimental systems (Davies and Margules, 1998). Very few invertebrate studies have considered the impacts, in particular the genetic consequences of fragmentation, on single species (Margules et al., 1994; Brookes et al., 1997; Thomas and Hanski, 1997; Lewis et al., 1997; Van Dongen, 1998). Although generalisations are difficult with so few studies, there appears to be agreement with the general expectation and patterns observed in both plants and vertebrates, that genetic differentiation among invertebrate populations increases following fragmentation whereas genetic diversity within populations decreases.

The golden sun moth, *Synemon plana* Walker (Lepidoptera: Castniidae), is a conspicuous day-flying moth, the larvae of which are thought to feed exclusively on native grasses within the genus *Austrodanthonia* (previously *Danthonia*; Linder, 1997). The moth was once widespread in south eastern Australia, matching the distribution of native grasslands. Temperate native grasslands are the most endangered of all vegetation types in Australia, having been cleared for agriculture (predominantly free range grazing and broad-acre cropping) and urban development (Kirkpatrick, 1995). Less than 1% of the approximately 2 million ha existing prior to European settlement still remains, much of which is heavily degraded by weed invasion and grazing by stock and rabbits. The remaining grasslands are under considerable threat from urban and agricultural expansion. Consequently, the remaining *S. plana* populations are highly fragmented. The species is now known to exist at 11 sites within New South Wales (NSW) (Clarke and Dear, 1998), approximately 12 sites within the Australian Capital Territory (ACT) (Edwards, 1994) and five sites in Victoria (Vic) (Dear, 1997) (Fig. 1).

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The species has been listed as endangered in all states in which it occurs under their respective endangered species legislation (NSW: Threatened Species Conservation Act 1995; ACT: Nature Conservation Act 1980; VIC: Flora and Fauna Guarantee Act 1988).

The life history of the species is poorly known. The adults are short-lived (1–4 days) and do not feed, and have no functional mouth parts. Males spend their entire adult life patrolling the grassland for females, and females, once mated, spend their time laying eggs within the clumps of *Austrodanthonia*. Females have reduced hind wings and are reluctant to fly, even when disturbed. The males are capable of active and prolonged flight but will not fly long distances (>100 m) away from areas of suitable habitat. Thus populations separated by distances of greater than 200 m can be considered effectively isolated, and sites

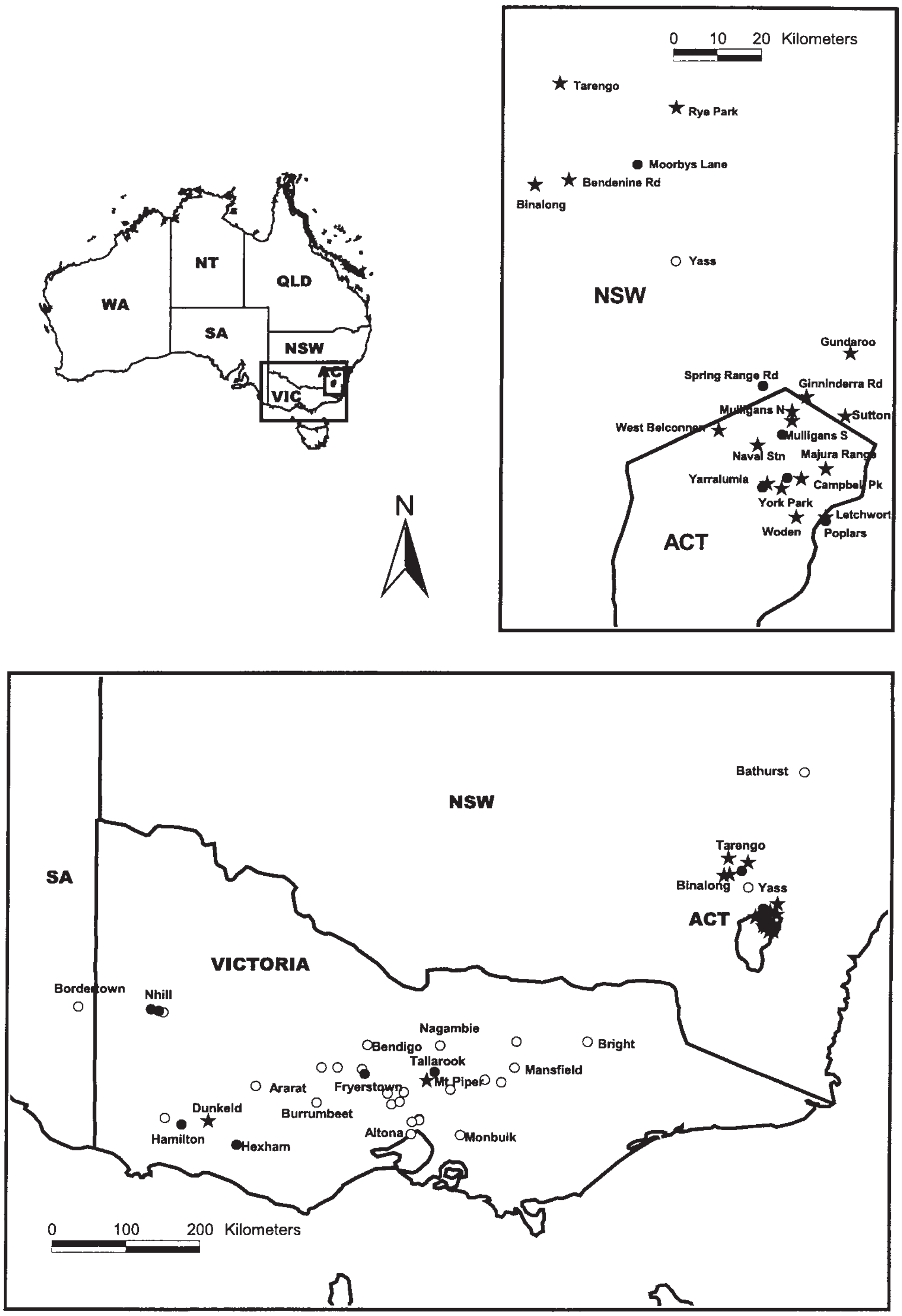

Fig. 1. Historic and present distribution of *Synemon plana* populations: ○, represents historic (presumably extinct) populations; ●, represents current extant populations; ★, represents sampled populations.

from which the moth has gone extinct, or vacant patches of suitable habitat, are highly unlikely to be (re)colonised. The flying season is relatively short, typically lasting for 6–8 weeks during November and December. Males will fly only in bright sunshine during the warmest part of the day (1000–1400 h). Adult emergence occurs continuously throughout the flying season. The starting date and duration of the flying season vary yearly, probably depending on spring weather conditions, with the season starting earlier (late October) following warm dry spring weather.

Females are estimated to lay 100–150 eggs (Edwards, 1994). It is not known if females lay eggs singly or in clusters within the grass clumps. Based on census data available from a single ACT site it has been estimated that up to 99% of total potential fecundity is unrealised, through either adult or immature mortality. However, estimates of adult and larval mortality are not known. Predation of adults by birds and predatory insects may be a significant contributor to adult mortality with as many as 30% of observed moths at one site being taken by predators (personal observations). Larvae feed underground on the roots of the grass plant. The larval development time (and thus generation time) is unknown and may vary between 1 and 3 years. The number of plants required for development of a single larva is also not known although field studies at Mt. Piper in Victoria have shown that a minimum density of 40% *Austrodanthonia* cover is required to sustain a *S. plana* population (Dear, 1997).

Genetic diversity, measured as both within-individual heterozygosity and allelic richness, is important for both the short term viability and long-term evolutionary potential of individuals, populations and species (Wright, 1978). Thus the maintenance of genetic variability, and the underlying evolutionary and ecological processes responsible for its maintenance and patterning, is a major consideration in the conservation management of many threatened species (Hedrick et al., 1986). Genetic techniques are routinely used in many conservation programmes to both assess the level of genetic diversity within and among populations and also as a tool for understanding past and present evolutionary and demographic processes. The results of such analyses are able to provide conservation managers with estimates of how much variation is present within each population and how and where that variation is partitioned both within and among populations. Such information can assist in the identification of populations that are of priority for the conservation of genetic diversity within the species and thus contribute to its overall conservation management.

The aims of the current study were to (1) assess levels of genetic variation within a series of *S. plana* populations from throughout its current distribution, (2) investigate patterns of past and recent population structuring, and (3) identify any priority populations for the conservation of genetic diversity within the species.

2. Methods

2.1. Sampling

Adult males were collected from 10 sites in the ACT, eight sites in NSW and two sites in Victoria during the period 7 November–11 December 1997 using a hand net (Table 1, Fig. 1). Although up to 30 males were sampled from each site, the timing of collection was designed to enhance the collection of post-reproductive males. In addition, in all populations sampled *S. plana* is locally abundant, thus the removal of a relatively small number of males is expected to have minimal impact on population viability. Captured individuals were returned alive to the laboratory and placed at −20°C until dead. Individual abdomens were then removed and stored at −80°C until required.

2.2. Electrophoresis

Individual abdomens were homogenised in 100 μl of grinding buffer (100 ml distilled water, 10 mg NADP, 100 μl β-mercaptoethanol). Samples were then centrifuged at 13,000 rpm for 5 min. Approximately 1 μl of homogenate was loaded onto cellulose acetate plates (Titan III Helena Laboratories) and electrophoresed at 200 V for 15 min. Genotypes were visualised by histochemical staining using recipes contained in Richardson et al. (1986). A total of 16 enzyme systems representing 20 loci was analysed (Table 2).

2.3. Analysis

The following genetic diversity parameters were estimated: P, the percentage of polymorphic loci; A, A_p, allelic richness (number of alleles per locus and the number of alleles per polymorphic locus respectively); H_e, gene diversity (expected heterozygosity; Nei, 1978); H_o, observed heterozygosity; F, the inbreeding coefficient (Wright, 1978). Population differentiation was assessed using estimates of genetic distance (Nei, 1978) and F statistics (Wright, 1978). Statistical analysis of genotype data was performed using the software packages BIOSYS ver. 1.7 (Swofford and Selander, 1989), POPGENE ver. 1.21 (Yeh et al., 1997), FSTAT ver. 1.2 (Goudet, 1995) and GENEPOP ver. 3.1 (Raymond and Rousset, 1995).

3. Results

3.1. Population structure

Allele frequencies were calculated for each locus and population and are available from the senior author. Based on these frequencies, pairwise genetic distances, (D) (Nei, 1978) and genetic differentiation, (F_{ST})

Table 1
Site details for *Synemon plana* samples collected in 1997

Site name	Code	n[a]	Latitude	Longitude	Elevation (m)	Area (ha)[b]
ACT						
Campbell Pk	CPK	30	35.17.13S	149.10.16E	580	9
Majura	MFR	30	35.16.00S	149.13.00E	580	142
Mulanggary	MGY	24	35.11.42S	149.07.53E	620	3.3
Mulligans 1	MF1	30	35.09.02S	149.09.06E	680	5
Mulligans 2	MF2	33	35.09.58S	149.08.59E	660	5
Naval Station	NS	30	35.13.00S	149.05.00E	600	106
Wast Belconnen	WBC	30	35.11.25S	149.00.16E	580	20
Woden	WH	31	35.22.26S	149.09.44E	600	72
Yarralumla	YL	31	35.18.10S	149.06.09E	560	4
York Park	YP	30	35.18.50S	149.07.47E	560	0.4
NSW						
Bendenine Rd	BRD	30	34.40.08S	148.41.23E	520	2.5
Binalong	BIN	32	34.40.38S	148.37.20E	480	0.2
Ginninderra Rd	GRD	32	35.08.59S	149.10.32E	640	91
Gundaroo	GTC	31	35.01.51S	149.16.19E	590	1
Letchworth	LTH	30	35.22.12S	149.11.49E	600	55
Rye Park	RPK	20	34.31.05S	148.54.28E	530	0.5
Sutton	SUT	9	35.09.39S	149.15.25E	620	1
Tarengo TSR	TAR	30	34.28.19S	148.39.56E	580	10
VIC						
Dunkeld	DNK	30	37.41.50S	142.41.36E	240	2
Mount Piper	MTP	13	37.12.07S	145.12.36E	230	0.6

[a] *n*, sample size.
[b] Area estimes are based on the area believed to represent suitable habitat for *Synemon plana* and generally equates to the area of medium to high density *Austrodanthonia* at each site. This area does not necessarily represent the total area of the site.

Table 2
Enzyme and locus details

Enzyme name	Abbreviation	EC no.	# Loci	Buffer[a]
Aconitate hydratase	*Acon*	4.2.1.3	2	TC
Adenylate kinase	*Ak*	2.7.4.3	1	TC
Fumarate hydratase	*Fum*	4.2.1.2	1	TC
Glucose-6-phosphate dehydrogenase	*G6pd*	1.1.1.49	1	TC
Glucose-phosphate isomerase	*Gpi*	5.3.1.9	1	TC
Glutamic-oxaloacetic transaminase	*Got*	2.6.1.1	2	TM
Glycerol-3-phosphate dehydrogenase	*αGpd*	1.1.1.8	1	TC
β-Hydroxybutyrate dehydrogenase	*Hbdh*	1.1.1.30	1	TM
Isocitrate dehydrogenase	*Idh*	1.1.1.42	2	TC
Lactate dehydrogenase	*Ldh*	1.1.1.27	1	TC
Malate dehydrogenase	*Mdh*	1.1.1.37	2	TC
Malic enzyme	*Me*	1.1.1.40	1	TM
Phosphoglucomutase	*Pgm*	2.7.5.1	1	TM
6-Phosphogluconate dehydrogenase	*6pgd*	1.1.1.44	1	TM
Triose-phosphate isomerase	*Tpi*	5.3.1.1	1	TM
Xanthine dehydrogenase	*Xdh*	1.1.1.24	1	TC

[a] TC = 0.1 M Tris-citrate pH 6.0; TM = 0.05 M Tris-maleate pH 7.8.

(Wright, 1978) between populations were estimated (Table 3). These estimates were then used to construct the UPGMA (unweighted pair group method with arithmetic averages) (Sneath and Sokal, 1973) phenogram shown in Fig. 2.

Genetically the populations cluster into five major groupings, which correspond to geographic location of the populations. Group 1 (Victoria) comprises the two Victorian populations; Group 2 (Nth NSW) comprises four populations located approximately 80–100 km northeast of the ACT; Group 3 (Border) comprises five populations located in the area of the ACT/NSW north-northeastern border; Group 4 (Nth ACT) comprises three populations located in the northern region of the ACT and Group 5 (Sth ACT) contains the remaining six populations. Statistically these groupings are reasonably well supported ($\geqslant$75% support from 1000 bootstrap samples), particularly Groups 1–4. Group 5 is less well supported, which is not surprising given the very low genetic distances among populations. The average pairwise genetic distances and F_{ST} values between these groups are given in Table 4.

Statistical analysis of this population structuring [using Nei's (1987) gene diversity estimates and Wright's (1978) *F*-statistics] reveals significant population differentiation, with approximately 20% of the total genetic variation observed due to differences among populations ($P < 0.005$). In addition, exact tests for population

Table 3
Pairwise matrix of Nei's (1978) genetic distance, D (below diagonal) and Wright's (1978) F_{ST} (above diagonal)[a]

Pop	BIN	BRD	CPK	DNK	GRD	GTC	LTH	MF1	MF2	MFR	MGY	MTP	NS	RPK	SUT	TAR	WBC	WH	YL	YP
BIN		0.0081	**0.0538**	**0.3984**	0.0301	**0.0353**	**0.0347**	0.0278	**0.0462**	**0.0486**	0.0357	**0.3653**	**0.0340**	0.0078	0.0071	0.0021	**0.0399**	**0.0327**	**0.0418**	**0.0405**
BRD	0.0006		**0.0685**	**0.4027**	**0.0410**	**0.0432**	**0.0429**	**0.0414**	**0.0560**	**0.0689**	**0.0521**	**0.3816**	**0.0427**	0.0068	0.0127	0.0083	**0.0461**	**0.0358**	**0.0468**	**0.0566**
CPK	**0.0095**	**0.0115**		**0.4723**	0.0375	0.0496	0.0124	0.0373	0.0189	0.0087	0.0150	**0.5038**	0.0205	**0.0946**	0.0384	**0.0697**	0.0160	0.0068	0.0008	0.0058
DNK	**0.1380**	**0.1351**	**0.1553**		**0.4975**	**0.4484**	**0.4716**	**0.4840**	**0.5067**	**0.4783**	**0.4646**	**0.2732**	**0.4806**	**0.4365**	**0.4379**	**0.3728**	**0.5058**	**0.4790**	**0.4793**	**0.4740**
GRD	0.0050	**0.0065**	0.0052	**0.1598**		0.0002	0.0347	0.0044	0.0034	0.0485	0.0224	**0.5259**	0.0036	0.0511	0.0005	**0.0476**	0.0024	0.0072	0.0147	0.0275
GTC	**0.0063**	**0.0073**	0.0070	**0.1627**	0.0011		0.0231	0.0129	0.0114	0.0443	0.0348	**0.5148**	0.0008	0.0471	0.0210	**0.0433**	0.0028	0.0033	0.0165	0.0232
LTH	**0.0063**	**0.0074**	0.0027	**0.1521**	0.0048	0.038		0.0182	0.0005	0.0035	0.0029	**0.5055**	0.0016	0.0540	0.0101	**0.0377**	0.0204	0.0073	0.0069	0.0117
MF1	0.0051	**0.0070**	0.0054	**0.1598**	0.0006	0.0025	0.0031		0.0036	0.0452	0.0174	**0.5049**	0.0019	0.0528	0.0082	**0.0415**	0.0158	0.0093	0.0133	0.0127
MF2	**0.0069**	**0.0080**	0.0029	**0.1584**	0.0013	0.0021	0.0010	0.0006		0.0244	0.0017	**0.5518**	0.0119	**0.0729**	0.0103	**0.0604**	0.0056	0.0070	0.0060	0.0044
MFR	**0.0084**	**0.0113**	0.0003	**0.1569**	0.0063	0.0062	0.0017	0.0062	0.0035		0.0105	**0.5085**	0.0197	**0.0873**	0.0276	**0.0640**	0.0212	0.0092	0.0039	0.0006
MGY	0.0068	**0.0092**	0.0000	**0.1538**	0.0035	0.0052	0.0011	0.0031	0.0013	0.0002		**0.4954**	0.0039	0.0689	0.0167	**0.0512**	0.0077	0.0021	0.0087	0.0073
MTP	**0.1108**	**0.118**	**0.1472**	**0.0825**	**0.1446**	**0.1500**	**0.1450**	**0.1431**	**0.1497**	**0.1470**	**0.1431**		**0.5100**	**0.4300**	**0.4643**	**0.3618**	**0.5395**	**0.5142**	**0.5117**	**0.5099**
NS	**0.0061**	**0.0072**	0.0035	**0.1580**	0.0014	0.0012	0.0010	0.0008	0.0000	0.0033	0.0016	**0.1472**		0.0533	0.0170	**0.0474**	0.0053	0.0080	0.0039	0.0064
RPK	0.0009	0.0013	**0.0138**	**0.1439**	0.0071	0.0072	0.0081	0.0077	**0.0090**	**0.0125**	0.0102	**0.1161**	0.0079		0.0202	0.0047	0.0609	0.0485	0.0630	0.0723
SUT	0.0052	0.0062	0.0074	**0.1598**	0.0023	0.0005	0.0018	0.0014	0.0012	0.0059	0.0046	**0.1460**	0.0006	0.0062		0.0187	0.0002	0.0104	0.0053	0.0003
TAR	0.0016	0.0035	**0.0125**	**0.1291**	**0.0077**	**0.0077**	**0.0069**	**0.0073**	**0.0090**	**0.0112**	**0.0096**	**0.1158**	**0.0084**	0.0028	0.0077		**0.0618**	**0.0404**	**0.0521**	**0.0478**
WBC	**0.0063**	**0.0071**	0.0028	**0.1644**	0.0008	0.0013	0.0032	0.0026	0.0015	0.0033	0.0019	**0.1498**	0.0015	0.0080	0.0022	**0.0098**		0.0034	0.0038	0.0232
WH	**0.0058**	**0.0061**	0.0019	**0.1546**	0.0018	0.0015	0.0004	0.0020	0.0003	0.0021	0.0010	**0.1473**	0.0002	0.0072	0.0014	**0.0071**	0.0007		0.0129	0.0033
YL	**0.0075**	**0.0081**	0.0013	**0.1585**	0.0027	0.0031	0.0006	0.0027	0.0005	0.0017	0.0005	**0.1511**	0.0008	**0.0095**	0.0025	**0.0094**	0.0008	0.0000		0.0014
YP	**0.0070**	**0.0092**	0.0018	**0.1525**	0.0039	0.0037	0.0000	0.0024	0.0006	0.0011	0.0005	**0.1456**	0.0004	0.0103	0.0025	**0.0084**	0.0034	0.0007	0.0011	

[a] Significant values (following exact tests) shown in bold.

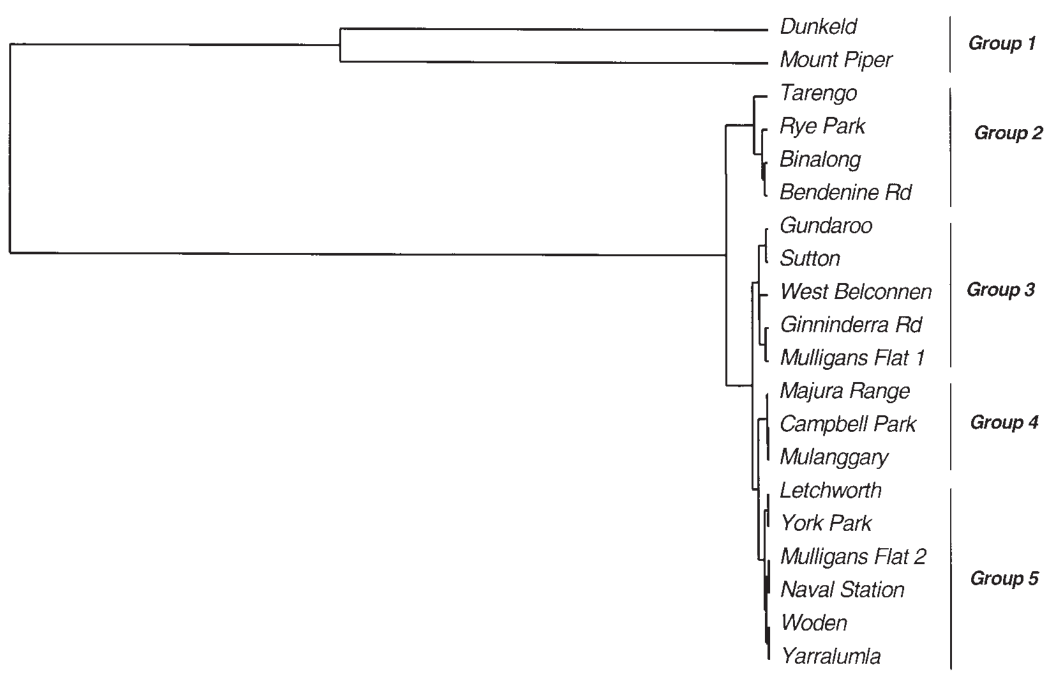

Fig. 2. UPGMA phenogram based on Nei's (1978) genetic distance. Branch lengths represent relative genetic distance.

differentiation revealed significant differences (results not shown) in both allele and genotype frequencies for a range of loci among populations.

Group 1 is significantly different from all the remaining groups (Fig. 2 and Table 4). This is based on both the presence of different alleles and significant differences in allele frequency across a number of loci. In particular, these two Victorian populations show significant differentiation at *Acon*-1, *Mdh*-1, *Mdh*-2, *Got*-1, *Gpi*, and *Hbdh*. In addition, the two Victorian populations themselves are very different from each other ($D = 0.083$, $F_{ST} = 0.273$). This is primarily caused by large allele frequency differences at *Acon*-1, *Mdh*-1, *Pgm*, and *Hbdh* loci. Such genetic differentiation is perhaps not surprising given that a distance of 220 km separates these two populations.

By removing the Victorian populations and rescaling Fig. 2, the genetic interrelationships between the remaining populations are made clearer (Fig. 3). Group

2 is significantly different from the three other groups, with an average genetic distance of 0.007 (Table 4). The level of population differentiation remains significant after removal of the Victorian populations, with approximately 4% of total variation attributable to among population differences ($P < 0.005$).

Group 3 is likewise significantly different from the remaining two groups, which are in turn significantly different from each other (Table 4). The average genetic distances in the range of 0.001–0.004 are typical of intraspecific population differences (Avise, 1994).

On a pairwise population basis, it can be seen (Table 3) that the Dunkeld and Mt Piper populations are significantly different from all others (including each other). Three of the four Nth NSW populations (Binalong, Bendenine Rd and Tarengo) are similarly different from almost all other populations, with the Rye Park population not showing as many pairwise differences. However, these four populations show no significant differences among themselves. All other pairwise comparisons are not significant, although the differences between all groups are significant (Table 4).

Table 4
Pairwise average genetic distances (below diagonal) and F_{ST} (above diagonal) between groups of *Synemon plana* populations[a]

Group	# Pops	1	2	3	4	5
1 Victoria	2		0.3589	0.4895	0.4321	0.4398
2 Nth NSW	4	0.123		0.0423	0.0639	0.0518
3 Border	5	0.152	0.006		0.0362	0.0116
4 Nth ACT	3	0.149	0.009	0.004		0.0131
5 Sth ACT	6	0.150	0.007	0.001	0.001	

[a] All values are significant at $p < 0.05$.

Overall these populations conform to an isolation by distance model, in which genetic distance is correlated with geographical distance (Mantel test $R^2 = 0.943$, $P < 0.001$) (Fig. 4). Up to distances of approximately 100 km there appears to be little genetic differentiation or structuring among populations. Significant genetic differentiation occurs at distances around 200 km continuing to increase up to distances of 400 km.

3.2. Genetic variability

Estimates of genetic diversity and variability are given in Table 5. Populations within Groups 1 and 2 show consistently higher levels of variability for all parameters than populations within the remaining three groups, which are all very similar to each other. All populations show a reduction in observed heterozygosity compared with that expected under random mating (i.e. positive F values) with populations within Groups 1 and 2 displaying greater reduction, on average, than populations from the other three Groups.

4. Discussion

In summary, the results have revealed five genetically distinct groups of *S. plana* populations which correspond closely with geographic location. The level of

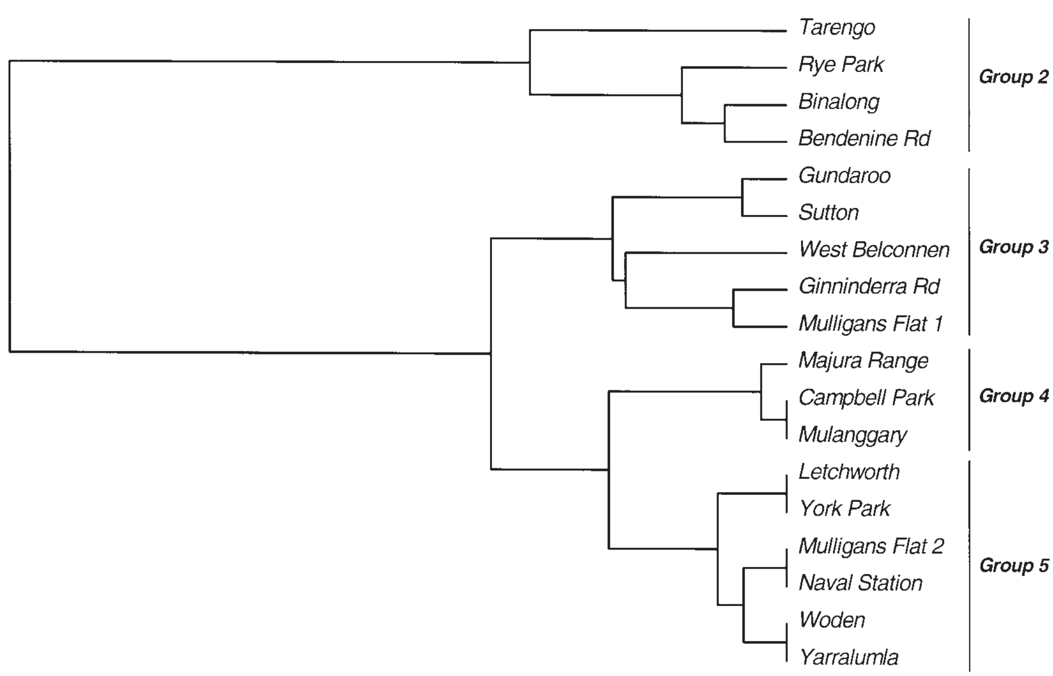

Fig. 3. UPGMA phenogram based on Nei's (1978) genetic distance following removal of Victorian populations and rescaling. Branch lengths represent relative genetic distance.

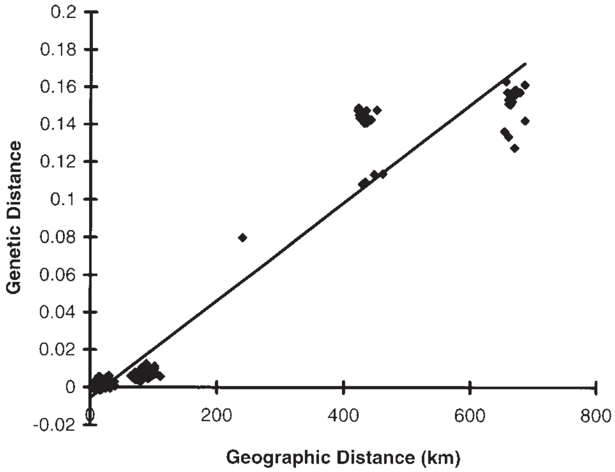

Fig. 4. Scatterplot of genetic distance against geographic distance.

genetic differentiation among groups may be sufficient for each group to be subject to separate conservation management in an effort to conserve as much genetic diversity in this species. In addition the levels of genetic diversity within individual *S. plana* populations are lower than that observed in other lepidopteran species.

4.1. Population structure

The isolation by distance pattern of population structuring conforms to that expected for a species with limited flying capability. For most mobile organisms the lack of significant genetic differentiation over relatively short distances observed for these populations would primarily be due to migration of individuals between populations, thus maintaining gene flow and increasing

Table 5
Estimates of gene diversity and variation (SE in parentheses)[a]

Population	P	A	A_p	H_e	H_o	F
Victoria						
Dunkeld	80	1.9 (0.2)	2.31 (0.1)	0.173 (0.05)	0.122 (0.04)	0.297
Mt Piper	70	1.8 (0.2)	2.60 (0.2)	0.150 (0.05)	0.127 (0.05)	0.162
Group mean	75.0	1.85	2.46	0.162	0.125	0.229
Nth NSW						
Binalong	75	2.0 (0.2)	2.40 (0.1)	0.147 (0.04)	0.123 (0.04)	0.170
Benedine Rd	65	2.0 (0.2)	2.46 (0.1)	0.137 (0.04)	0.102 (0.03)	0.257
Rye Park	55	1.6 (0.2)	2.50 (0.3)	0.104 (0.04)	0.070 (0.03)	0.326
Tarengo	75	2.0 (0.2)	2.36 (0.2)	0.159 (0.04)	0.129 (0.04)	0.192
Group mean	67.5	1.90	2.43	0.137	0.107	0.236
Border						
Ginninderra Rd	50	1.5 (0.2)	2.29 (0.2)	0.087 (0.03)	0.071 (0.03)	0.191
Gundaroo	65	1.5 (0.1)	2.10 (0.1)	0.097 (0.03)	0.081 (0.03)	0.173
Mulligans 1	55	1.6 (0.2)	2.50 (0.2)	0.096 (0.04)	0.092 (0.04)	0.045
Sutton	50	1.4 (0.1)	2.14 (0.1)	0.101 (0.04)	0.078 (0.03)	0.238
West Belconnen	60	1.5 (0.1)	2.11 (0.1)	0.083 (0.03)	0.071 (0.03)	0.154
Group mean	56.0	1.50	2.23	0.093	0.078	0.160
Nth ACT						
Campbell Pk	70	1.6 (0.1)	2.00 (0.0)	0.101 (0.03)	0.082 (0.03)	0.175
Majura	50	1.5 (0.1)	2.13 (0.1)	0.098 (0.04)	0.081 (0.04)	0.175
Mulanggary	55	1.5 (0.2)	2.25 (0.2)	0.098 (0.04)	0.088 (0.04)	0.109
Group mean	58.3	1.53	2.13	0.099	0.084	0.153
Sth ACT						
Letchworth	60	1.6 (0.2)	2.44 (0.2)	0.097 (0.04)	0.077 (0.03)	0.213
Mulligans 2	50	1.4 (0.1)	2.14 (0.1)	0.078 (0.03)	0.058 (0.02)	0.256
Naval Station	60	1.6 (0.2)	2.20 (0.1)	0.098 (0.03)	0.092 (0.04)	0.057
Woden	65	1.5 (0.1)	2.00 (0.0)	0.096 (0.03)	0.04 (0.03)	0.124
Yarralumla	70	1.7 (0.2)	2.27 (0.1)	0.100 (0.04)	0.04 (0.03)	0.259
York Park	50	1.5 (0.2)	2.42 (0.2)	0.096 (0.04)	0.085 (0.04)	0.115
Group mean	59.2	1.55	2.25	0.094	0.0778	0.171
Overall mean	62.0	1.64	2.28	0.110	0.089	0.190

[a] P = % polymorphic loci; A = allelic richness (average number of alleles per locus); A_p = average number of alleles per polymorphic locus; H_e = gene diversity (average expected heterozygosity) (Nei, 1978); H_o = average observed heterozygosity per individual; F = fixation index (Wright, 1978).

genetic homogeneity among populations. However, in the case of *S. plana*, in which we assume that these populations are effectively genetically isolated, due to its restricted flying ability, this lack of differentiation between closely located populations, may indicate that these were all historically connected and have only recently undergone fragmentation. These results are in contrast with those reported for the winter moth (*Operophtera brumata*) in which significant genetic differentiation was observed between populations separated by as little as 3 km yet no differentiation was detected at scales of 10–40 km (Van Dongen et al., 1998).

The average genetic distances between Group 1 and the remaining groups (range 0.123–0.152) can be considered quite high, and are typical of values that distinguish subspecies or races in other species (Avise, 1994). For example, the average genetic distance between subspecies of *Drosophila willistoni* is 0.17. The pairwise genetic distances between each of these Victorian populations and the remaining populations again average 0.15, supporting the idea that the Victorian populations may represent a separate race or even a subspecies of *S. plana*. More research into the formal taxonomy of this group is now warranted, using both morphological and genetic approaches.

4.2. Genetic variability

The overall level of polymorphism of 62% in *S. plana* is higher than the average for insect species in general ($P=0.35$; Nevo et al., 1984). However, this parameter is subject to considerable bias as the choice of loci examined within allozyme studies is rarely random, with researchers actively choosing variable loci for examination.

Estimates of allelic diversity for insects are rare in the literature, however, three recent papers on rare and fragmented lepidoptera have provided estimates of 2.9 alleles per polymorphic locus for *Plebejus argus* (Brookes et al., 1997), 3.31 alleles for the winter moth *Operophtera brumata* in Belgium (Van Dongen et al., 1998) and 2.5 for the Karner Blue *Lycaeides melissa samuelis* (Packer et al., 1998). The estimates for *S. plana* (2.28) are somewhat less than these. However, inferences based on allele number are problematic, as the number of alleles observed in a population is dependent on sample size. Most outbreeding populations contain many rare alleles. The chances of detecting such alleles depend on the number of individuals sampled within each population. However, when sample sizes are relatively equal across sampled populations (as is the case here) allelic diversity can serve as a reliable parameter for among-population comparisons. Allelic richness is consistently higher in populations in Groups 1 and 2 than in the remaining groups, with few exceptions, viz. Mulligans 1, Letchworth and York Park (Table 5). Allelic diversity can be reduced by a number of population processes, the most important being either a drastic reduction in effective population size (bottleneck), or continually low effective population size. Under these circumstances genetic drift is the major evolutionary force at play and rare alleles are lost through chance sampling events during mating (Hartl and Clark, 1989).

The average observed heterozygosity within individuals (H_o) across all populations of 8.9% (Table 5) is lower than that reported for other lepidopteran species (12.7%) (Nevo et al., 1984). Only the Victorian and Nth NSW populations approach this level of variation with the other populations showing up to 50% less variability.

A recent paper has summarised expected heterozygosities (H_e) for 56 lepidoptera species (Packer et al., 1998). The average was calculated as 0.105 and ranged from 0.324 for *Pectinophora gossypiella* to 0.000 for *Ecdytolopha mana*. In the three studies on rare and fragmented populations mentioned above, the estimates were 0.236 for *Plebejus argus* (Brookes et al., 1998), 0.46 for *Operophtera brumata* (Van Dongen et al., 1998) and 0.11 for *Lycaeides melissa* (Packer et al., 1998). The average of 0.11 for *S. plana* is comparable to that for *L. melissa* and the average for lepidoptera, but significantly lower than the other two species. Once again it can be seen that the Victorian and Nth NSW populations contain up to 50% more gene diversity than the remaining populations. However, low levels of heterozygosity cannot always be viewed as being problematic for individual fitness or population viability (Avise, 1994). Numerous examples exist of common and widespread species lacking significant levels of heterozygosity. In addition, although many rare and threatened species contain relatively low levels of heterozygosity (Frankham, 1995), in most cases this has been shown to be the outcome, rather than the cause of population bottlenecks (Avise, 1994).

Overall the levels of allelic diversity and observed heterozygosity within populations in Groups 3–5 can be considered lower than that within other lepidopteran species. This may be attributable to founder events (population bottlenecks) during the process of population fragmentation. Depending on the time scale over which any fragmentation events occurred, it is conceivable that relatively few "founder" individuals remained within the intact grassland fragment. Genetic variation, particularly allelic richness is known to be reduced following bottlenecks (Luikart et al., 1998). Any subsequent increase in variation depends on how long small population sizes persist within the newly created fragment. In the absence of migration from outside populations average heterozygosity will rebound more rapidly than allelic diversity (which relies on mutational events).

The relative differences in genetic diversity between populations within Groups 1, 2 and the remainder may represent different time scales for habitat fragmentation. The populations within Groups 1 and 2 lie within agricultural habitats that were cleared between 100 and 150 years ago. Although relatively recent in evolutionary terms, there has been considerable potential (>100 generations) for restoration of genetic diversity if any bottlenecks accompanied the fragmentation provided populations did not remain small for long periods. The populations within Groups 3–5 have only more recently been fragmented, primarily through the urban and agricultural expansion around the ACT over the last 70 years and in many cases the last 20 years. Thus, the chances for recovery of genetic diversity within these populations have been limited.

All the populations examined show a reduction in observed heterozygosity. Examination of the genotype frequency distributions for conformity to Hardy–Weinberg expectations (random mating) reveals that in all populations a number of loci (between 1 and 5) failed to comply. In most cases this involved loci with relatively rare alleles which were present as homozygotes rather than the expected heterozygotes. Given that this is the general pattern observed across all the *S. plana* populations examined, it is clear that they are not undergoing random mating.

Non-random mating can arise from a number of population processes — inbreeding, assortative mating, population subdivision and selection (Nei, 1987). As the loci examined within the current *S. plana* populations are selectively neutral (following Ewens–Watterson tests; Hartl and Clark, 1989), selection can be ruled out as a probable cause. Likewise assortative mating can be discounted as it is unlikely that the loci examined contribute significantly to phenotypic characteristics important for mate choice. It is not possible to detect the presence of Wahlund effects (population subdivision) without structured sampling within a population across spatial and temporal scales. However, in effect, any such population subdivision promotes inbreeding due to the reduction in effective population size within any subpopulation. In addition, unless these subpopulations are continuously isolated, a single generation of random mating between them will restore Hardy–Weinberg equilibrium.

Hence, inbreeding would appear to be the most probable cause of the observed deviation from random mating. There are a number of possible scenarios to explain the results observed in these *S. plana* populations. Most matings may be carried out by very few males (assuming that males mate more than once). Under this scenario progeny resulting from individual females mated by the same male will be half sibs. Alternatively, very few females may mate and oviposit, yet the majority of their eggs develop to adults. Under these conditions the majority of individuals within the population are related, (full sibs), thus increasing the chances of inbreeding. Another possibility is that the pattern of non-random mating may be due to either continuous spatial or temporal subdivision within populations. Further study on these possibilities is currently being undertaken.

It must be pointed out that inbreeding per se does not always lead to a reduction in fitness through the effects of inbreeding depression. The cost of inbreeding, in terms of reduction in survival following full sib mating, has been shown to vary across two orders of magnitude (Avise, 1994). It has been argued that populations which have been exposed to inbreeding for long periods of time have the ability to purge any deleterious recessive alleles responsible for inbreeding depression and fitness reduction (Templeton and Read, 1983). At this stage the potential for fitness decreases following inbreeding in *S. plana* is unknown.

Another possible explanation for the observed pattern of non-random mating may be the potential for some degree of parthenogenesis in this species. Parthenogenesis is rare within the Lepidoptera (White, 1973) although it is notable that a closely related species, *Synemon selene* has both bisexual (probably now extinct) and all-female (parthenogenetic) populations. Given that females are the heterogametic sex in Lepidoptera, any parthenogenetic mechanism must restore heterozygosity of the sex chromosomes, most probably through nuclear fusion (White, 1973). Such a breeding structure would generate closely related individuals and could explain the relatively high frequency of rare allele homozygotes.

4.3. Conservation implications

It must be stressed that genetic data in isolation do not provide all the answers for effective conservation management. The overly prescriptive use of genetically-derived information in planning can be fraught with danger. However, its careful use in conjunction with demographic, land use and resource management information has the potential for objective management decisions to be made.

From a genetics perspective, the primary conservation goals are to conserve as much genetic diversity and variability as possible. In addition, it is important to conserve those evolutionary processes responsible for the generation, maintenance and partitioning of that diversity within and among populations (Avise, 1994).

Given the significant degree of genetic differentiation among the five groups of populations it would seem reasonable to treat these as separate management units. Conservation planning needs to take into consideration that much of this differentiation (particularly that between Groups 1, 2 and the remainder) represents historic evolutionary processes rather than recent fragmentation events. Similarly, within Group 1 the two populations are significantly different from each other, and all other populations, that they will need separate management in order to conserve the underlying genetic diversity.

From the point of view of species (re)introduction programmes or translocation of individuals among populations for the purposes of population supplementation (in order to increase population size or genetic variability), it would be considered unwise to mix individuals between groups given this underlying significant level of population structuring and differentiation. The potential for outbreeding depression increases with increasing genetic separation between populations. However, given the relatively low levels of genetic differentiation among populations within groups, movement of individuals among these populations should not pose any genetic difficulties.

Within Groups 2–4, the lack of significant genetic differences among populations could be argued to display some degree of genetic or population redundancy, and thus afford the opportunity to focus on certain populations at the expense of others. For example, large populations may be viewed as being more viable in the long term than small ones, or alternately, several small populations may be preferable to one large. Populations with more secure land tenure may be 'easier' to manage than less secure ones etc. There are however dangers with this type of reasoning, and the ultimate aim must be to conserve and manage as many populations as possible, if nothing other than to safeguard against the loss of one or more populations through local 'catastrophes' such as fire or drought.

However, one of the realities of modern conservation management is that it is impossible to conserve or protect everything and priorities have to be decided upon. Given that our ultimate aim, from a genetic perspective, is to conserve as much allelic diversity and heterozygosity as possible, it is possible to rank populations based on these parameters in order to establish priority lists. Ideally such rankings need to be combined with similar site rankings based on patch size and quality, and land tenure. Such combined information can then be used to identify populations for focussing attention and resources.

The relatively high frequency of non-random mating observed in these populations may not be of great concern at this stage. The fact that the pattern was observed across all populations suggests that it is a normal feature of the breeding system of *S. plana*, rather than a consequence of fragmentation. However, until further research is conducted in this area, and the potential for spatial or temporal subdivision within populations and fitness reduction through inbreeding thoroughly investigated, we should remain cautious. Every attempt should be made to prevent further population size reduction.

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