GRASSLAND EARLESS DRAGON

TYMPANOCRYPTIS PINGUICOLLA

ACTION PLAN

PREAMBLE

The Grassland Earless Dragon (*Tympanocryptis pinguicolla* Mitchell, 1948) was declared an endangered species on 15 April 1996 (Instrument No. DI1996-29 *Nature Conservation Act 1980*, under the former name Eastern Lined Earless Dragon *Tympanocryptis lineata* pinguicolla). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1997 (ACT Government 1997). This revised edition supersedes the earlier edition. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*) and the Golden Sun Moth (*Synemon plana*).

CONSERVATION STATUS

Tympanocryptis pinguicolla is recognised as a threatened species in the following sources:

International

Vulnerable – IUCN (2015).

National

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

Australian Capital Territory

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

New South Wales

Endangered – Threatened Species Conservation Act 1995.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988*.

CONSERVATION OBJECTIVES

The overall conservation objective of this action plan is to maintain in the long term, viable, wild populations of *T. pinguicolla* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve all ACT populations.
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Grassland Earless Dragon *Tympanocryptis pinguicolla* is a small lizard in the family Agamidae. It was originally described as a subspecies of the more widespread and variable *Tympanocryptis lineata* (Mitchell 1948) and later recognised as a distinct species (Smith *et al.* 1999). Nelson (2004) noted morphological differences between animals from the Cooma district and the Canberra area.

Further genetic research, including studies of nuclear DNA microsatellites and mitochondrial DNA, has shown a clear genetic division between the extant populations in the NSW Cooma–Monaro and ACT–Queanbeyan areas, and that the ACT–Queanbeyan populations are also highly genetically structured (Melville *et al.* 2007; Scott and Keogh 2000; Carlson 2013; Hoehn *et al.* 2013). *Tympanocryptis pinguicolla* is found at higher altitudes and in cooler regions than any other earless dragon (Robertson and Evans 2009).

Most members of the genus *Tympanocryptis*, including *T. pinguicolla*, lack an external ear opening and a functional tympanum (ear drum) (Greer 1989, Cogger 2014). *Tympanocryptis pinguicolla* is a small lizard with a stout body and short robust limbs (Mitchell 1948), and is diurnal and cryptic in its grassland habitat. Total adult body length is usually less than 150 mm (Robertson and Evans 2009) with average snout-vent length of 55 mm (Smith 1994) and weight of five to nine grams (Robertson and Evans 2009).

The dorsal markings are distinctive, with a pale vertebral stripe flanked by alternating fawn/grey and dark brown irregular blocks between two pale (or yellow) dorso-lateral stripes. The pattern of the dark blocks is unique to each individual and does not change with age, and can therefore be used to identify individual animals (Nelson *et al.* 1996; Dimond 2010). There is usually a narrow pale bar on the head, between the anterior corners of the eyes, and two pale lateral stripes and scattered dorsal spinous scales (Cogger 2014).

The ventral surface is either intricately patterned with dark brown or grey markings, or immaculate white or cream. During the breeding season subadults and adults often have yellow-orange or reddish coloration on the throat, sides of the head and flanks, and this may be more common or prominent in males.

DISTRIBUTION AND ABUNDANCE

Prior to European settlement, *T. pinguicolla* was most likely distributed broadly in south-eastern Australia wherever suitable habitat (native grassland) was present. Pryor (1938) described *T. pinguicolla* as more common than the Eastern Brown Snake (*Pseudonaja textilis*) in the ACT, and animals were captured adjacent to Northbourne Avenue in the 1950s (Young 1992). NSW records show the species occurred in grasslands near Cooma in the Southern Tablelands (Mitchell 1948) and at Bathurst (Osborne *et al.* 1993a).

Most former records of *T. pinguicolla* in Victoria are from the basalt plains in the south of the state (Brereton and Backhouse 1993). The species was not uncommon at Essendon and the plains near Sunbury to the north of Melbourne late last century (McCoy 1889). There are also records from Maryborough and Rutherglen in central Victoria (Lucas and Frost 1894).

Recent records indicate *T. pinguicolla* has experienced a severe decrease in its geographic range. There have been no confirmed Victorian sightings since the 1960s, and no recent records north of the ACT, but populations still occur between Cooma and Nimmitabel in the Monaro region of NSW and there are some small populations near Queanbeyan, NSW (Queanbeyan Nature Reserve, The Poplars) (Robertson and Evans 2009).

In the ACT, T. pinguicolla was rediscovered in 1991 after not being recorded in the area for 30 years (Osborne et al. 1993). It is now known to occur in the eastern Majura Valley (Majura Training Area, Canberra Airport), western Majura Valley (West Majura Grassland and Campbell Park Defence land) and the Jerrabomberra Valley (Harman/Bonshaw, Cookanalla, Callum Brae, Jerrabomberra West Grassland Nature Reserve and Jerrabomberra East Grasslands) (ACT Government 2005, Biosis 2012) (Table 1).

Genetic analysis indicates the ACT populations are highly genetically structured with little interchange of individuals between sub-populations. In particular the Majura Training Area and Jerrabomberra West populations are apparently insular and unlikely to provide or receive immigrants from the other populations, having been separated from the other populations for some time by natural and artificial barriers such as a river, creek, arterial road and/or developed land (Hoehn *et al.* 2013).

Monitoring of two main *T. pinguicolla* populations by Conservation Research (ACT Government) and the University of Canberra indicates that ACT populations declined dramatically during the last decade (2005–2009), possibly as a result of lack of ground cover caused by drought and exacerbated by

overgrazing (Dimond 2010; Dimond *et al.* 2012). The suggested mechanisms driving the decline are:

- Low soil moisture, increased exposure and dry conditions causing low production of, and high mortality in, eggs.
- Reduced plant growth during drought combined with increased grazing pressure from kangaroos (Eastern Grey Kangaroos) or stock, reducing ground cover and increasing the exposure of lizards (particularly hatchlings and juveniles) to predation.

Other factors related to drought and lack of ground cover might also be involved in the recent decline of *T. pinguicolla*, such as low availability of food (small invertebrates) or low availability of burrows for shelter (which would arise if the drought and ground cover conditions were also unfavourable for burrow-forming arthropods such as Wolf Spiders (*Lycosa* spp.) and Canberra Raspy Crickets (*Cooraboorama canberrae*).

The estimated density of the largest known population of *T. pinguicolla* (Jerrabomberra West), collapsed from 19.8 animals per hectare (ha) in 2006 to 2.4 in 2008. A population viability analysis suggested the Jerrabomberra population had a very high probability of extinction within 10 years and the regional decline places the species at severe risk of extinction (Dimond 2010).

Tympanocryptis pinguicolla has not been detected at two Symonston sites for several years and may no longer be present. These are north-west of the intersection of Hindmarsh Drive and Canberra Avenue in Symonston (Amtech East site: Osborne and Dimond 2008; Biosis Research 2011), and south-west of the intersection of Jerrabomberra Avenue and Narrabundah Lane (Callum Brae north: Fletcher *et al.* 1995; Rowell 2008; Dimond *et al.* 2010; Biosis Research 2012). The Amtech East site is relatively small and separated from the Cookanalla population by a major road.

Tympanocryptis pinguicolla was found in moderate numbers in the northern part of Canberra Airport in the late 1990s (ACT Government 2000), but numbers declined and it was not detected between 2005 and 2010. Numbers were still very low by 2015 (Rowell 2011 and unpublished data). The habitat at the airport was excised from the adjacent Majura Training Area in 1970 for a runway extension, and is now separated from it by an unsealed road with mown, relatively disturbed verges and two fences. This road is likely to form at least a partial barrier to movement between the sites (IAE 2013).

The airport grasslands are mown several times each year except during drought, in contrast to the Majura Training Area which was overgrazed by kangaroos during the first part of the 2002–2010 drought, then protected from kangaroo grazing from 2007. There have been no genetic studies of the airport population, but it may be reliant on occasional immigration from Majura Training Area for maintenance (IAE 2013).

Protection and enhancement of this potential movement corridor and appropriate management of the airport grasslands is likely be important for the survival of this small semi-isolated population.

Monitoring of *T. pinguicolla* populations at the Majura Training Area, Jerrabomberra West Nature Reserve and Jerrabomberra East grasslands suggests there is some post-drought recovery occurring in these populations (Cook *et al.* 2015).

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

HABITAT AND ECOLOGY

In the ACT and nearby NSW, *T. pinguicolla* is found in Natural Temperate Grassland and native pastures, usually on well-drained sites dominated by Tall Speargrass (*Austrostipa bigeniculata*) and shorter Wallaby Grasses (*Rytidosperma* spp.), with patches of tussocks and open spaces between them (Osborne *et al.* 1993a; Robertson and Evans 2009). In the ACT these sites are frost-hollow grasslands and have usually had little or no ploughing or pasture improvement (Osborne *et al.* 1993a). At one ACT site, *T. pinguicolla* has been shown to use a broader range of grassland types, including denser and moderately degraded grassland (Langston 1996; Stevens *et al.* 2010).

Recent studies have found higher trapping rates of *T. pinguicolla* at artificial burrows set in areas where herbage biomass is naturally lower compared to adjacent grassland, or in patches

where biomass is lower due to recent burning or grazing (Osborne et al. 2013; Cook et al. 2015; Osborne 2015). While it is not yet known whether this is due to differences in detectability or habitat preference of *T. pinguicolla*, maintaining a varied grassland structure and avoiding herbage biomass extremes is a management aim in order to maximise the range of shelter and thermal niches, and of prey types (Stevens et al. 2010; Taylor 2014; M. Evans pers comm.).

Table 1. Sites supporting *Tympanocryptis pinguicolla* in the ACT

Site Name	Habitat area (ha)	Land Jurisdiction	Land use policy
Majura Training Area (north of Airport)	139	Commonwealth	Military training area, includes Air-services Beacon paddock.
Majura Training Area (former grazing properties east of Airport)	90	Commonwealth	Military training area
Airport	22	Commonwealth	Airport, office accommodation and retail outlet
West Majura Grassland	104	Territory	Broadacre*, managed for conservation
Campbell Park	35	Commonwealth	Land attached to Defence offices
Jerrabomberra West Grasslands Reserve	180	Territory	Nature Reserve
Callum Brae (west of Monaro highway)	68	Territory	Grazing lease
Amtech East	12	Territory	Unleased land
Bonshaw	158	Territory	Grazing lease
Jerrabomberra East Grasslands	71	Territory	Conservation Area
Cookanalla (east of Monaro highway)	164	Territory	Grazing lease

*Broadacre refers to agriculture and certain other 'large area' uses under Territory planning legislation.

Abandoned burrows of large arthropods appear to be an important feature of *T. pinguicolla* habitat in the ACT region. The species is known to use arthropod burrows as diurnal and nocturnal shelter sites in this region (Jenkins and Bartell 1980; Osborne *et al.* 1993b; Smith 1994; Langston 1996; Benson 1999; Rowell 2001; Stevens *et al.* 2010), and to shelter in tussocks (Langston 1996; Stevens *et al.* 2010). *Tympanocryptis pinguicolla* also shelters under rocks in NSW (Osborne *et al*. 1993b; McGrath *et al.* 2015), but rocks do not appear to be an essential component of the habitat for this species in the ACT (Langston 1996).

Capture data is characterised by a dominance of young animals and low recaptures of previous-year adults (Smith 1994; Langston 1996; Nelson *et al.* 1996; Dimond 2010), suggesting a predominantly annual turnover of adults with females able to breed in their first year. Some females survive into their second year, but most apparently only survive long enough to produce one clutch of eggs (Langston 1996; Nelson 2004). None have been found to be gravid in two consecutive years (Dimond 2010). As for many species, longevity of *T. pinguicolla* in captivity appears to be greater than in the wild,

with one male held at Tidbinbilla Nature Reserve living for five years (Evans pers comm).

The female lays a clutch of three to seven (typically six) eggs in an arthropod burrow 10–13 cm deep in November–January, and backfills the burrow with soil and litter (Dimond 2010; Doucette unpublished data).

The burrows are created by large arthropods such as the Common Wolf Spider (*Lycosa godeffroyi*) and the Canberra Raspy Cricket (*Cooraboorama canberrae*) (Osborne *et al.* 1993b, Benson 1999). Females have been observed to visit nest sites daily during incubation (Doucette unpublished data).

Arthropod burrows are also used as mating sites (Nelson 2004) and appear to be important as thermal refuges for the animals from high and low daily ambient temperatures and during winter (Benson 1999; Nelson 2004; Doucette unpublished data), and as refuge from predators.

Hatching occurs in January–March (Langston 1996; Dimond 2010; Doucette unpublished data), and high abundance of invertebrate prey coincides with the juvenile recruitment period (Benson 1999; Nelson 2004). Juveniles grow rapidly and males mature earlier than females (Langston 1996; Nelson 2004). Nelson (2004) found seasonal and annual variability in population structure, and suggested that cool weather conditions in spring/summer may affect basking opportunities and food availability, and hence the rate of growth and maturation.

The relatively low fecundity and short life span of *T. pinguicolla* makes local populations vulnerable to the effects of wildfire, drought and other environmental changes on their habitat. This vulnerability is increased where fragmentation of habitat prevents recolonisation from surrounding areas.

A radio-tracking study of 10 adult lizards showed that they mostly occupied one or two natural burrows within a home range of 925–4768 m^2, and that there was some overlap in home ranges (Stevens *et al.* 2010). Adults and juveniles frequently move from one natural or artificial burrow to another (Benson 1996; Langston 1996; Nelson 2004; Stevens *et al.* 2010; AECOM 2014; Doucette unpublished data), with some movements of at least 230 m over longer periods (ACT Government 2000).

Tympanocryptis pinguicolla takes shelter in burrows or tussocks when disturbed, so both of these features are likely to be important as refuge from predators.

The species relies on burrows as winter refuge sites, though animals can be active on cool sunny days and can move between burrows during winter (Benson 1996; Nelson 2004; Stevens *et al.* 2010).

Tympanocryptis pinguicolla is a sit-and-wait predator and eats a variety of small invertebrates, especially ants, beetles, spiders and moths (including larvae) (Howe 1995; Benson 1999; Dimond 2010).

Dimond (2010) found that although ants were frequently eaten, they were only taken in

Grassland Earless Dragon (photo M. Evans)

proportion to their abundance (i.e. were not selected for) and that beetles were preferred food items at three sites in 2007. Captive *T. pinguicolla* have been reported to eat crickets in preference to ants when both were offered, suggesting that the animals may have been selecting prey with a higher caloric value (Taylor 2014).

PREVIOUS AND CURRENT MANAGEMENT

In the ACT *T. pinguicolla* occurs on land under a range of tenures and land management regimes.

The Jerrabomberra Valley, including sites where *T. pinguicolla* occurs, has a history of grazing by stock (mostly sheep, less so cattle and horses) and kangaroos. These areas include:

- Land previously owned and managed by the Commonwealth Government (Bonshaw Defence areas), now owned and managed by the ACT Government, which is generally lightly grazed by sheep and kangaroos.
- Broadacre Territory land (Amtech East Estate) with grazing agistment.
- Territory rural land leased for grazing (e.g. Cookanalla, North Callum Brae), which are grazed by stock (mostly sheep) and kangaroos.
- Land formerly leased (sheep grazing), that is now in nature reserve (Jerrabomberra West Grasslands), or set aside as a conservation area (Jerrabomberra East Grasslands), and are grazed by kangaroos. Management of the Jerrabomberra West Grassland Reserve and Jerrabomberra East Grassland conservation area is aimed at maintaining a heterogeneous grass sward mostly between 10 and 20 cm high, and includes grazing by kangaroos (with fencing to protect some areas from overgrazing), slashing along tracks and fence lines and, more recently, small-scale patchy burns to promote heterogeneity in the height and density of the grass sward.

In the Majura Valley *T. pinguicolla* occurs on the Majura Training Area (MTA) (Department of Defence land), where the species' habitat is managed for conservation and is generally only lightly grazed by kangaroos. A large area of habitat was fenced to prevent continued overgrazing by kangaroos in the 2002–2010 drought. Following the drought this area was opened to allow grazing by kangaroos. *Tympanocryptis pinguicolla* also occurs in the Airport Services Beacon paddock, a fenced area of about 10 ha that is contiguous with habitat on the MTA and has not been grazed for at least three decades. The species has been recorded intermittently in the northern section of Canberra Airport, which is subject to a slashing regime to maintain a moderately short grass sward. The grassland at Majura West is grazed by kangaroos and, in the past, has been grazed by sheep.

During the 2002–09 drought, some *T. pinguicolla* sites in the ACT were overgrazed by kangaroos and some by stock. Overgrazing was particularly severe in the Majura Valley at the MTA (kangaroos), West Majura (kangaroos and sheep), Cookanalla and Jerrabomberra East Grasslands. Sheep were removed from Majura West during the drought when overgrazing became evident, and stock numbers were reduced at Cookanalla. The height and biomass of the grass sward has since largely recovered at overgrazed sites.

Grasslands in the ACT, including *T. pinguicolla* habitat, are subject to planned and unplanned fire. An unplanned fire in the MTA in 1998 (Nelson *et al.* 1998b) resulted in several hectares of *T. pinguicolla* habitat being burnt. *Tympanocryptis pinguicolla* has been observed to use this and other burnt areas one year post-fire and in subsequent years, suggesting the species is capable of using grassland at least one year following fire if animals are able to disperse into the area from adjacent unburnt areas (Nelson *et al.* 1998b; Evans and Ormay 2002; Osborne *et al.* 2013; Cook *et al.* 2015).

Planned fire is used in grassland for ecological purposes and for fuel reduction. Recently, small-scale patch burning has been trialled in Jerrabomberra West Grasslands by the ACT Government with the aim of promoting heterogeneity of the grass sward to improve habitat for *T. pinguicolla*. Multiple burn patches (each several metres across) were used to create a mosaic of unburnt and recently burnt areas that differ in the density and height of the grass sward.

The small size of burnt areas means *T. pinguicolla* should be able to move a few metres to an unburnt area during the 'cool', slow burn. After the burn *T. pinguicolla* can forage in burnt

areas and seek shelter in the unburnt habitat. Each burn patch was raked and closely examined immediately after burning for signs of dead lizards, but none were detected, suggesting no mortality of *T. pinguicolla* has resulted from this habitat management action.

THREATS

Tympanocryptis pinguicolla is a grassland specialist, being restricted to remaining fragments of native grassland. Approximately 99.5% of Natural Temperate Grassland (a nationally critically endangered ecological community, *EPBC Act 1999*) in Australia has been destroyed or drastically altered since European settlement (Kirkpatrick *et al.* 1995).

The major perceived threats to the continued survival of *T. pinguicolla* are:

- Loss and fragmentation of habitat through clearing of native grasslands for urban, industrial and infrastructure development and for agricultural purposes.
- Modification and degradation of native grassland habitat through incompatible and inadequate land management practices and weed invasion.
- Major ecological disturbances to grassland habitat such as widespread (unplanned) fire, drought and climate change.

Proposed future developments that may cause further loss and fragmentation of habitat for *T. pinguicolla* include:

- New roads through or adjoining habitat in the Majura and Jerrabomberra Valleys.
- Construction of a new taxiway at Canberra Airport.
- Very Fast Train in the Majura Valley.
- Urban or commercial development in the Jerrabomberra Valley.

Habitat fragmentation and degradation will exacerbate any effects on populations from climate change (Hoehn *et al.* 2013). Fragmentation increases the risk of extinction of isolated populations which suffer declines due to environmental disturbances such as wildfire and drought and can no longer be re-colonised by immigration from other populations. Fragmentation also exacerbates the loss of genetic diversity and increased inbreeding in isolated populations, which may compromise both short and long-term population viability by reducing individual fitness and limiting the gene pool on which selection can act in the future. Recent genetic research suggests:

- Majura and Jerrabomberra West populations are each genetically isolated from all other populations.
- There is limited gene flow between the Jerrabomberra East, Bonshaw and Queanbeyan Nature Reserve populations (Hoehn *et al.* 2013).
- Animals from Cookanalla show a high degree of relatedness, and the population may be at risk of inbreeding depression (Carlson 2013).
- The Monaro and ACT/Queanbeyan populations are genetically distinct and translocation and/or interbreeding should not be undertaken between these populations unless justified by rigorous research.

Degradation of ACT habitat may occur due to:

- **Weed invasion:** Weeds of most concern are African Lovegrass (*Eragrostis curvula*), Chilean Needlegrass (*Nassella neesiana*), Capeweed (*Arctotheca calendula*), Saffron Thistle (*Carthamus lanatus*), Paterson's Curse (*Echium plantagineum*) and St John's Wort (*Hypericum perforatum*) (Walker and Osborne 2010). These plants are aggressive colonisers and the grasses can form a monoculture by outcompeting native species for water, light and nutrients. The young forbs have rosettes that can fill inter-tussock spaces and obscure burrows, and the mature plants can shade the ground and release excess nutrients into the soil when they die at the end of the season. All may reduce the density of prey species and some of these plants can increase in abundance under grazing as they are avoided by kangaroos and/or stock (as they are unpalatable, toxic or spiny).
- **Cultivation and pasture improvement:** Ploughing is likely to destroy the arthropods that *T. pinguicolla* relies on to form burrows (Nelson 2004), and pasture improvement leads to damage similar to that described for weed invasion.

- **Overgrazing by kangaroos, rabbits or stock, or close mowing** leads to loss of tussock structure and excessive bare ground. A local study of ground-dwelling reptiles in grassy habitats showed that no species was more likely to occur at high grazing intensities (Howland *et al.* 2014), however, this study did not include *T. pinguicolla*. High soil surface temperatures in summer require *T. pinguicolla* to retreat to burrows instead of feeding, and may contribute to loss of eggs and juveniles though overheating or desiccation (Nelson 2004; Dimond 2010; Doucette unpublished data). Excessive reduction in vegetation is also likely to lead to a reduction in prey (food) density and exposure of *T. pinguicolla* to increased predation. Overgrazing may reduce the number of burrowing arthropods that can be supported and burrow availability may then become a limiting factor for *T. pinguicolla*. Parts of three local *T. pinguicolla* populations were fenced to protect them from overgrazing by kangaroos late in the drought that ended in 2010.
- **Development of excessive vegetation biomass** due to insufficient grazing leads to a reduction in inter-tussock spaces for hunting and basking, a reduction in soil surface temperatures, and may increase the risk of wildfire. Recent analysis of kangaroo density and vegetation condition at many ACT grassy sites showed increased floristic diversity in moderately grazed grasslands due to the reduction in herbage biomass of more competitive plant species (Armstrong 2013). Moderate levels of kangaroo grazing are therefore required to maintain structural heterogeneity by preventing a few grass species from dominating the sward. Kangaroos have been allowed into the fenced Majura Training Area site since the drought ended, part of the Jerrabomberra East site is grazed by kangaroos, and monitored light sheep grazing is being trialled on part of Jerrabomberra West to keep herbage biomass within desirable limits (Cook *et al.* 2015).
- **Wildfire or inappropriate fire regimes:** Fire can be used to rejuvenate native grasslands and to maintain diversity in grassland structure, but widespread fire can also kill *T. pinguicolla*, reduce or alter habitat and temporarily reduce their food supply. There is a local record of *T. pinguicolla* both fleeing from and being killed by an unplanned fire (Osborne *et al.* 2009). Individuals have been recorded using an area in the year following a fire (Nelson *et al.* 1998b, Osborne *et al.* 2013) and in subsequent years (Evans and Ormay 2002, Cook *et al.* 2015). Small patch burning is being trialled at Jerrabomberra West Nature Reserve to promote structural heterogeneity in the sward.
- **Predation by cats, dogs and foxes:** Foxes are likely to be more numerous on the rural sites, and predation by domestic pets might cause increased predation rates where housing is developed close to *T. pinguicolla* sites.
- **Increased predation by native animals** due to: an increase in artificial perches (posts, fences, buildings) for birds such as magpies, ravens and raptors; exposure due to loss of groundcover; or enhanced shelter for snakes (e.g. through dumped materials or added logs/woody debris near *T. pinguicolla* habitat). Eastern Brown Snakes have been found to be efficient predators of *T. pinguicolla* (Doucette, unpublished data).

CHANGING CLIMATE

In addition to the above threats, the severe decline of *T. pinguicolla* during the 2002–10 drought suggests the species may be sensitive to the predicted effects of climate change. Recent modelling of the effect of climate change on reptiles predicts that by 2080 local reptile population extinctions could reach 39% worldwide, and reptile species extinctions may reach 20% (Sinervo *et al.* 2010). Warmer year-round temperatures are predicted for south-eastern Australia by the end of the century, with fewer frosts, more hot days and warm spells, and declining rainfall (especially in winter). These changes have the potential to affect reproduction and survival of *T. pinguicolla* as the structure of their habitat is sensitive to drought, and sparser ground cover will lead to higher ground temperatures.

Higher ground temperatures combined with drier soil may increase mortality of eggs and hatchlings through desiccation (Dimond 2010), thermal refuges may be less effective, and at high temperatures the daily activity period of *T. pinguicolla* is shorter, reducing foraging time

(Doucette, unpublished data). The predicted temperature increase of 3–5 °C by 2080 could restrict activity sufficiently to prevent *T. pinguicolla* from obtaining adequate food to meet increased metabolic requirements during summer months (Doucette, unpublished data).

The temperatures experienced during embryonic development can determine the sex of some reptiles, but there is so far no evidence of this occurring when *T. pinguicolla* eggs are incubated at different temperatures in the laboratory (Doucette, unpublished data). There is a recent report of temperature-related sex reversal in females of another Australian Agamid (Bearded Dragon) in the wild, and subsequent controlled mating of normal males with sex-reversed females produced fertile offspring whose phenotypic sex was determined solely by temperature rather than chromosomes (Holleley *et al.* 2015).

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

The known extant *T. pinguicolla* populations occur on land under a variety of tenures including nature reserve (Territory Land), rural leasehold Territory Land, Commonwealth owned and managed land (National Land) and unleased Territory Land. These sites are separated from one another by unsuitable habitat, roads and urban development.

Conservation effort for *T. pinguicolla* in the ACT is focused on protecting viable populations in functional native grassland habitat within two clusters of sites across its geographical range—the Majura Valley and the Jerrabomberra Valley. Both provide the opportunity to also protect the endangered Natural Temperate Grassland community and associated threatened species. Parts of a number of the ACT's *T. pinguicolla* sites are the subject of development proposals including an airport taxiway extension, the Very High Speed Train route, roads, and urban development.

In the Majura Valley *T. pinguicolla* occurs on a relatively large patch (around 100 ha) of native grassland north of Canberra Airport on the Majura Training Area, which is Defence (Commonwealth) land. This area of high quality grassland is managed for conservation but is not formally protected.

The species has been recorded on the Majura Training Area to the east of the airport, which was a former property (Malcolm Vale) that was grazed. The species also occurs (at least intermittently) in grassland on Canberra Airport, which is not formally protected. Habitat on the airport is contiguous with habitat on the Majura Training Area. It is possible that the high quality grassland on the Majura Training Area north of the airport forms the core of the species' habitat on the eastern side of the Majura Valley and individuals disperse onto the airport during favourable years.

On the western side of the Majura Valley *T. pinguicolla* occurs in a large patch of native grassland (West Majura grassland) that adjoins woodland in the Mt Majura Nature Reserve. While not currently protected in reserve, this area is managed for conservation by the ACT Government and has been proposed for future formal protection. The species also occurs in adjacent grassland (Campbell Park) that is Defence (Commonwealth) land, which is not formally protected.

In the Jerrabomberra Valley some of the habitat is protected in nature reserve (Jerrabomberra West Grassland Reserve) and in a conservation area (Jerrabomberra East Grasslands). The species also occurs on Territory rural lands leased for grazing (Cookanalla), and on Territory land previously owned and managed by Defence (Bonshaw) that is not formally protected. The species has apparently become locally extinct from an area (about 20 ha) of unleased Territory land (Amtech East Estate).

Protecting existing *T. pinguicolla* habitat in the ACT and preventing further fragmentation is important due to the limited known habitat for the species in the ACT and NSW, the genetic distinctness between the ACT/Queanbeyan and Monaro populations, and the recent rapid drought-associated decline in ACT and NSW populations.

The highest level of protection is in nature reserve, though populations of the species have been maintained on leased Territory land used for stock grazing, providing the grazing regime is compatible with maintaining suitable habitat. Where the species occurs on grazing land, an appropriate legislative mechanism should be applied to prevent habitat from being overgrazed or degraded. The ACT Government will liaise with the Department of Defence to encourage continued protection and management of *T. pinguicolla* populations on their land.

Given *T. pinguicolla* recently declined to extremely low or undetectable levels at some ACT sites, and that some recovery appears to be occurring, it should be assumed the species is present at any site where it has previously occurred since 1991 unless this is disproved by rigorous survey or the habitat has been destroyed. As a guide, Dimond (2010) determined that where population density was very low, 26 artificial burrows (Fletcher *et al.* 2009) would need to be checked for six weeks (18 checks, February–March) to have 50% confidence of detecting the species, with 167 burrows checked over the same time period for 99% confidence of detection.

The protection of *T. pinguicolla* habitat in the Jerrabomberra West Grassland Nature Reserve and Jerrabomberra East Grasslands has given protection to endangered Natural Temperate Grasslands and other threatened species in this community (Golden Sun Moth *Synemon plana*, Striped Legless Lizard *Delma impar*, Perunga Grasshopper *Perunga ochracea*). Management

of all these species on the same site requires monitoring of their populations and their habitat, and integrated vegetation management strategies taking their different habitat needs into account.

While the Majura and Jerrabomberra populations of *T. pinguicolla* have a long history of separation by natural barriers, populations within each of the valleys have been fragmented into subpopulations by more recent anthropogenic land-use changes. Further fragmentation of habitat/populations is likely to increase the risk of localised extinctions and so should be avoided. There may be opportunities to promote expansion of *T. pinguicolla* populations into areas formerly occupied by the species. For example, appropriate management of grasslands (with the aim of restoring habitat) to the east of the airport, in north Callum Brae and in parts of Cookanalla might enable adjacent populations of *T. pinguicolla* to expand into these areas. There are currently significant technical and resource challenges to restoring native grasslands.

Even restoring grasslands to low or marginal quality habitat might enable *T. pingiuicolla* to colonise and occupy such areas during years when conditions are favourable for the species, and hence help maintain genetic diversity in the longer term.

There may also be opportunities to reconnect sub-populations. For example, maintaining a link between Jerrabomberra West Grassland Reserve and North Callum Brae, and linking populations on Cookanalla to Bonshaw. Habitat corridors linking sub-populations must be sufficiently large (wide) to enable movement between sub-populations and to not act as population 'sinks'.

Salvage, involving removal of animals from the wild, will be considered only as a last resort, and only in cases where the site is considered non-viable and an approved research project with identified facilities and appropriate research resources are available.

ENVIRONMENTAL OFFSET REQUIREMENTS

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

Tympanocryptis pingiuicolla has been determined to have a high risk of local extinction in the event of further habitat loss in the ACT so offsets are not appropriate. Habitat for *T. pingiuicolla* has been mapped and must be avoided for development. The map provided on the ACT Government website (ACTMAPi) should be used to determine whether the species occurs on the site.

SURVEY, MONITORING AND RESEARCH

Over the past two decades there have been numerous, extensive surveys of potential habitat to determine the distribution of *T. pinguicolla* in the ACT. There is now a good understanding of the species' distribution but the area of occupancy of all suitable habitat at most sites has not been fully determined.

Further surveys should be undertaken at ACT sites where the abundance of the species across the site is not well understood. These areas include Majura West Grasslands, grassland on Defence land to the east of the airport (former Malcolm Vale property), North Callum Brae and Bonshaw.

Past surveys in potential habitat at a number of sites in the ACT did not detect the species. These sites should be revisited and the habitat assessed for quality and potential for presence of *T. pinguicolla*, and surveyed if appropriate (i.e. the area appears to contain habitat suitable for the species). Sites where surveys in potential habitat have not detected the species are:

- Lawson Grasslands (former Belconnen Naval Transmission Station) (surveyed in summer 1996, summer 2001)
- "Avonley" (surveyed in summer 1998)
- adjacent to Pialligo Avenue (surveyed in summer 1998)
- opposite airport on Majura Road (surveyed in summer 1998)
- RAAF Fairbairn (surveyed in summer 1998)
- "Dundee" (southern part of Majura Training Area, east of Canberra Airport, surveyed in Summer 1998)

- southern part of HMAS Harman (surveyed in summer/autumn/spring 2004–2006)

Regular abundance monitoring of the larger ACT *T. pinguicolla* populations has been undertaken since 2001 using fixed grids of artificial burrows. The Majura Training Area population has been monitored annually since 2001, the Jerrabomberra West Grassland Nature Reserve has been monitored since 2006 and the Jerrabomberra East grasslands since 2009. The Canberra Airport population (adjoining Majura Training Area) has also been monitored by the airport since 2007 (Rowell 2011 and unpublished data) and four monitoring surveys have been undertaken since 2007 for the Department of Defence at Bonshaw (former Defence land adjoining Jerrabomberra Grassland Nature Reserve east) (Osborne *et al*. 2009, AECOM 2014). Monitoring has begun more recently at Cookanalla in the Jerrabomberra Valley.

This monitoring program has been undertaken by ACT Government staff from the Conservation Research section and, since 2005, has often been jointly undertaken with staff from ACT Parks and Conservation Service and researchers from the Institute of Applied Ecology at the University of Canberra. Prior to establishment of the monitoring program in 2001, these and other sites have been intermittently surveyed by ACT Government staff, and a number of university studies have been completed on the ecology of these populations.

Tympanocryptis pinguicolla populations can undergo major fluctuations in size, as evidenced by the severe decline to very low numbers towards the end of the 2002–10 drought, and subsequent increase. A representative set of sites with *T. pinguicolla* will need to be monitored to determine long-term population trends and to evaluate the effects of management. Key sites for population monitoring are those with an established long-term monitoring program (Majura Training Area, Jerrabomberra West Grassland Reserve, Jerrabomberra East Grasslands).

University research projects conducted on ACT *T. pinguicolla* populations and their habitat include undergraduate studies, honours projects, two PhD theses and post-doctoral research.

These studies have been undertaken in partnership with, or facilitated by, the ACT Government. Research projects have covered morphology, taxonomy, habitat investigations, population and species ecology (including thermal ecology), life history, population viability analysis, microhabitat use, diet, home ranges, genetic studies, captive breeding and studies of behaviour of wild and captive animals.

Research and adaptive management is required to better understand the habitat requirements for the species and techniques to maintain the species' habitat. Specific research priorities include:

- Optimal habitat requirements, particularly structure and biomass of the grass sward.
- Land management practices compatible with, or required for, maintaining suitable habitat (such as grazing, slashing, burning).
- Breeding requirements, oviposition sites, reproductive rates, and their relationship to habitat structure, seasonal conditions and predicted effects of climate change.
- Importance of availability and density of natural burrows, relationship between *T. pinguicolla* and burrowing arthropods, effect of burrow supplementation on sparse *T. pinguicolla* populations.
- Sensitivity of *T. pinguicolla* to weeds in its habitat, the weeds of major concern, and suitable control and revegetation methods.
- Techniques to maintain and breed the species in captivity (this knowledge will be required should captive insurance populations be required).
- Magnitude and significance of seasonal/annual *T. pinguicolla* population fluctuations (may require annual or biennial monitoring at key sites) and relationship to seasonal/annual conditions and habitat characteristics.

MANAGEMENT

Based on current knowledge of the habitat requirements of *T. pinguicolla*, management actions should aim to maintain grassland that has a well-defined tussock structure (i.e. tussocks with inter-tussock spaces). Tussock heights (i.e. the height of the bulk of the tussock

leaves, not including the often few higher leaves and seed bearing culms) of the grass sward should be mostly between 5 cm and 15 cm, with well-defined inter-tussock spaces composed of shorter grasses, forbs and bare ground.

This structure can be achieved by maintaining intermediate levels of herbage mass. Management actions should avoid creating a grass sward that is uniformly very short (<5 cm) or uniformly very tall and dense (>15 cm high with very few inter-tussock spaces).

A 'patchy' sward containing grass tussocks of mostly intermediate height interspersed with patches of taller and shorter height tussocks with linked inter-tussock areas containing shorter grass and forbs (and which might include some bare ground), is likely to provide *T. pinguicolla* with a greater range of sites for shelter and thermoregulation, and a wider range and/or density of prey (Melbourne 1993, Stevens *et al.* 2010, Barton *et al.* 2011, Taylor 2014).

The arthropods which form the burrows used by *T. pinguicolla* also prey on invertebrates and are also likely to benefit from diversity in habitat structure.

From an ecological community perspective, a heterogeneous grass sward structure is likely to provide a greater range of habitat niches and hence support a greater diversity of grassland flora and fauna.

Maintaining a heterogeneous habitat is also an appropriate goal given imperfect knowledge of the long-term habitat requirements for *T. pinguicolla*.

Extensive survey, monitoring and research has been carried out on ACT *T. pinguicolla* populations since 2005. An adaptive management approach is being implemented as results of this work become available. Recent analysis of kangaroo density and vegetation condition at many ACT grassy sites has found increased floristic diversity in moderately grazed grasslands due to the reduction in biomass of more competitive species (Armstrong 2013). This suggests that moderate kangaroo grazing is likely to preserve structural heterogeneity in grasslands by preventing a few vigorous species from dominating the sward.

IMPLEMENTATION

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

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

OBJECTIVES, ACTIONS AND INDICATORS

Table 2 Objectives, actions and indicators

Objective	Action	Indicator
1. Conserve all ACT populations.	Apply formal measures to protect all populations on Territory-owned land. Encourage formal protection of all populations on land owned by other jurisdictions.	All populations are protected by appropriate formal measures.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor abundance of key populations and the effects of management actions.	Trends in abundance are known for key populations. Management actions recorded.
	Manage habitat to maintain its suitability for the species, including implementing an appropriate grazing and fire regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and plant species composition). Potential threats (e.g. weeds) are avoided or managed. Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations, or to establish new populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity. If suitable habitat exists, re-establish populations where they have become locally extinct.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant species composition). If suitable habitat exists, research and trials have been undertaken to establish new populations.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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