

Victorian Grassland Earless Dragon Habitat Assessment

Long Forest Estate, Merrimu

03-Jul-2024
Flanagans Drive, Merrimu

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03-Jul-2024

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Quality Information

Document Victorian Grassland Earless Dragon Habitat Assessment
 Ref
 Date 03-Jul-2024
 Originator Megan Price
 Checker/s James Booth
 Verifier/s Chris White

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
A	03-May-2024	Draft for client review	Christopher White- Technical Director Australia	
B	03-July-2024	Final	Christopher White- Technical Director Australia	

Professional Registration

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Registration Scheme	Discipline / Area of Practice	Name of Registered Professional*	Signature	Registration No.	Date

* The registered professional must be the originator of this work or have provided direct supervision to the originator.

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Executive Summary

AECOM Australia Pty Ltd (AECOM) was engaged by the Long Forest Unit Trust to undertake an assessment of the presence of Victorian Grassland Earless Dragon *Tympanocryptis pinguicolla* (VGED) habitat within a proposed future residential development site located on Flanagans Drive, Merrimu known as the Long Forest Estate (the 'Study Area'). The VGED is listed as Critically Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) and the Victorian *Flora and Fauna Guarantee Act, 1988* (FFG Act).

Habitat requirements were compiled from the Australian Government's conservation advice and draft national recovery plan, and habitat preferences for closely related species Monaro Grassland Earless Dragon *T. osbornei* and Canberra Grassland Earless Dragon *T. lineata*. Consequently, this habitat assessment was based on the assumptions that VGED-suitable habitat should have the following parameters:

- Abundant empty arthropod burrows.
- Native vegetation cover with open patches of bare soil and/or naturally short open tussocks due to low-level disturbance (e.g. managed fire, grazing).
- Dominance of native grass species such as Slender Wallaby-grass *Rytidosperma penicillatum*, Grey Tussock Grass *Poa siebriana*, Common Tussock Grass *P. labillardierei*, Red-leg Grass *Bothriacloa macra*, Spear Grass *Austrostipa* spp., and Kangaroo Grass *Themeda triandra*.
- Undisturbed soil, loose surface stones and large deep soil cracks.
- Adequate invertebrate prey.
- Minimal weed cover.
- Not been de-rocked, ploughed or fertilised to improve pasture quality.

The species' current distribution is unknown in Victoria. Until recently, there had been no confirmed sightings since 1969 despite extensive surveys being undertaken across much of its former range. There are no historic records of the species within 20 km of the Study Area.

Quadrats (1 m²) were haphazardly thrown based on systematically assigned grid points and assessed for 13 parameters thought most likely to influence dragon presence and/or habitat use based on available literature. These were arthropod burrow presence, burrow occupancy, biomass, tussock height, crack length in soils, embedded rock cover, surface rock cover, cryptogam cover, total forb cover, total native species cover, total vegetation cover, inter-tussock space and dominant tussock grass species. Burrows greater than 1 cm in diameter and appearing well-maintained were counted along transects running east-west connecting all quadrats.

The Study Area is in a highly modified landscape dominated by exotic vegetation. Native vegetation has largely been cleared and degraded by a long history of grazing, agriculture and lack of weed control. However, the Study Area is located adjacent to Long Forest Nature Conservation Reserve that lies on the border of the Victorian Volcanic Plain and the Northern Inland Slopes bioregions. It is unknown if Victorian Grassland Earless Dragons could use woodlands or forested areas (as well as grasslands) and not grasslands to disperse.

Habitat within 92 quadrats was assessed but no dragons were detected while undertaking habitat assessments. Fifty-three well-maintained arthropod burrows were found within or adjacent to quadrats. Surveyors covered 15,012 m² of the Study Area while walking the burrow density transects and found 1,610 well-maintained burrows >10 mm in diameter. This equates to 0.11 burrows/m².

The Study Area's habitat was significantly different to a theoretical reference site and does not contain all the habitat parameters assumed to be necessary for Victorian Grassland Earless Dragons, suggesting it is unsuitable for the species given the suite of habitat parameters. The dominance of Needle-grass *Nassella* species and other invasive weeds likely decreases the suitability of the Study Area for VGED. However, native grasses (spear and wallaby grasses) were also common, and it is possible that unidentifiable native tussocks had been grazed low by the large mob of resident kangaroos. Tussock height was low, and it is assumed that the species requires moderate to high

tussock height. Arthropod activity was good, with many crickets calling and moving about the site. Therefore, there is possibly sufficient prey diversity for the VGED. Cryptogam cover was typically low to moderate, but in places it was moderate to high (>50%). This suggests that the soil has not been recently disturbed in those places. Little soil disturbance is a key requirement for Victorian Grassland Earless Dragon presence, since well-formed tussocks and burrows cannot exist where there is disturbed soil. Burrows observed ranged from 10 to 70 mm in width and 0.5 to 250 mm in depth and many burrows were well-maintained by wolf spiders (preferred by other dragon species). Consequently, burrow size and density may be sufficient for the Victorian Grassland Earless Dragon.

Arthropod burrows are one of the most influential features for habitat use by Canberra Grassland Earless Dragon and this species have been found in landscape features previously thought unsuitable. Therefore, it is possible there is adequate burrow type, density and soil cracks across a few areas within the Study Area to suggest that Victorian Grassland Earless Dragon habitat exists, despite the widespread cover of invasive tussock grass. It is considered however, that the long history of landscape disturbance and little connectivity would decrease the likelihood that the species could have persisted at the site.

Any areas that have high density of Sifton Bush and Artichoke Thistle are unlikely to be suitable for Victorian Grassland Earless Dragon and therefore there would be no impact on Victorian Grassland Earless Dragon if this vegetation was removed. Similarly, if vegetation in highly soil disturbed areas were to be removed, it would be anticipated there would be no impact on Victorian Grassland Earless Dragon as it is unlikely to occur in these areas.

Currently, there is insufficient information to determine if there would be an impact on Victorian Grassland Earless Dragon in grassland areas, since it is unclear if the species can occur in degraded grasslands. If the species cannot occur in degraded grasslands, it is highly unlikely there would be an impact on the species as no suitable habitat exists. If Victorian Grassland Earless Dragons can occur in degraded grasslands, there is potential for dragon presence and thus impacts would be possible.

Overall, there is a low likelihood that the habitat in the Study Area is suitable for Victorian Grassland Earless Dragon, but the presence of the species cannot be discounted due to its cryptic nature, low detectability and little information about its tolerance to degraded grasslands.

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by the Long Forest Unit Trust to undertake an assessment of the presence of Victorian Grassland Earless Dragon *Tympanocryptis pinguicolla* (VGED) habitat within a proposed future residential development site located on Flanagans Drive, Merrimu known as the Long Forest Estate (the 'Study Area'). The Long Forest Estate property is located within the Merrimu Precinct Structure Plan (PSP) that is an area identified for future urban development. The broader area is part of the expansion of Bacchus Marsh under the Bacchus Marsh Urban Growth Framework developed by Moorabool City Council and the Victorian Planning Authority (VPA).

The Long Forest Unit Trust has requested an assessment of the Study Area, to determine with the Project. The VGED is listed as Critically Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act). A population of the VGED was found in early 2023 in Victoria after not being seen for more than 50 years (since 1969) and until this sighting, had been presumed extinct in the State (DCCEEW 2023a). Given the rediscovery of the species in Victoria and the location of the Study Area within the modelled distribution for the species (Figure 1), AECOM has undertaken a habitat assessment of the Study Area.

1.1 Background

The VGED once occurred in native tussock grasslands with little or no trees and shrubs (DCCEEW 2023b). Current population distribution is unknown, as are the specific habitat details of the recently found population. Although some of the habitat characteristics have been provided anecdotally, habitat requirement information for the habitat survey was largely based on historic VGED populations (pre-1969) and similar species in the ACT and NSW.

Habitat requirements were compiled from the Australian Government's conservation advice (DCCEEW, 2023a) and draft national recovery plan (DCCEEW, 2023b), and habitat preferences for closely related species', Monaro Grassland Earless Dragon (*T. osbornei* MGED and Canberra Grassland Earless Dragon *T. lineata* CGED. Melville et al. (2019) state that VGED is likely to have similar habits to these closely related species. CGED and MGED have been found to prefer burrows in paddocks with abundant small rocks, moderate tussock height of native grassland (20 -30 cm) dominated by *Poa siebriana*, *Bothriacloa macra*, *Austrostipa* and/or *Rytidosperma* spp., with *Themeda triandra* dominated grassland being the least preferred native grassland (McGrath, 2015). However, *Th. triandra* was the dominant species in natural grasslands on volcanic soils in southern Victoria and the extent of these once widespread grasslands overlapped with the historic distribution of the VGED (Morgan & Lunt, 1999). Consequently, areas with dominance and good coverage of *Th. triandra* are likely not avoided by VGED.

McGrath (2015) and Stevens et al. (2010) found that the presence and dimensions of empty arthropod burrows was a crucial factor in their habitat use and many Grassland Earless Dragons preferred burrows excavated by wolf spiders (Lycosidae spp.), particularly in over-wintering sites. Stevens et al. (2010) found that vegetation/tussock structure did not influence dragon habitat use in Canberra (ACT). However, McGrath (2015) and other studies based on trapping results (Langston, 1996; Osborne et al., 1993) found that grassland structural features (i.e. short grass) had an influence on habitat and burrow use. Thus, burrow presence is also likely to highly influence VGED presence as they are used for predator avoidance and possibly for nesting akin to CGED (DCCEEW, 2023a). VGED, like CGED and MGED, is believed to be found in grazing native grassland with low soil disturbance.

Consequently, this habitat assessment was based on the assumptions that VGED-suitable habitat should have the following parameters:

- Abundant empty arthropod burrows.
- Native vegetation cover with open patches of bare soil and/or naturally short open tussocks due to low-level disturbance (e.g. managed fire, grazing).
- Dominance of native grass species such as *Rytidosperma penicillatum* (Slender Wallaby-grass), *Poa siebriana* (Grey Tussock Grass), *P. labillardierei* (Common Tussock Grass), *Bothriacloa macra* (Red-leg Grass), *Austrostipa* spp. (Spear Grass), and *Themeda triandra* (Kangaroo Grass).
- Undisturbed soil, loose surface stones and large deep soil cracks.
- Adequate invertebrate prey.

- Minimal weed cover.
- Not been de-rocked, ploughed or fertilised to improve pasture quality.

The species is also very cryptic and hard to detect. The MGED has a detectability of 0.0098 (probability of detection per detection effort) and that McGrath (2015) needed to search 2,400 rocks at 60 known sites to have a 90% chance of detecting of MGED or 5,400 rocks to increase confidence to 99%. Consequently, targeted surveys for individuals may always be limited and unsuitable.

1.2 Scope of Work

AECOM has undertaken a review of existing information from key documents related to the VGED for the Study Area. The review involved:

- Review of key reference documents for the Victorian Grassland Earless Dragon:
 - *Draft National Recovery Plan for Four Grassland Earless Dragons (Tympanocryptis spp.) of Southeastern Australia (Draft National Recovery Plan)* developed by the Department of Climate Change Energy and Environment and Water (DCCEEW) in July 2023 which outlines research and management actions for four species of threatened grassland earless dragons, including the Victorian Grassland Earless Dragon (DCCEEW 2023b)
 - *Conservation Advice for Tympanocryptis punguicilla (Victorian grassland earless dragon)* in effect under the EPBC Act from 1 June 2023 which combines the approved conservation advice and listing assessment for the species (DCCEEW 2023a)
- Assessing the likelihood of the Study Area containing potential habitat for VGED and assigning a rating of likely, unlikely or unknown.
- Identifying whether the project requires further investigation in relation to potential impacts to VGED.

1.3 Study Area

The Study Area is approximately 98 ha in size and is located within the Long Forest Estate, Merrimu, approximately 5 km northeast of the township of Bacchus Marsh and 60 km northwest of the Melbourne CBD (Figure 1). The site is immediately adjacent to the Long Forest Nature Conservation Reserve (NCR) (managed by Parks Victoria), north of Bacchus Marsh Road between Melton and Bacchus Marsh. Long Forest Estate is within the Victorian Volcanic Plains (VVP) Bioregion and the Port Phillip and Westernport Catchment Management Authority (PPWCMA) region. The relevant local government planning scheme is the Moorabool Shire Council Planning Scheme. The Study Area is within the 2 km of the north-eastern boundary of the modelled distribution of VGED (Figure 2, Figure 3).

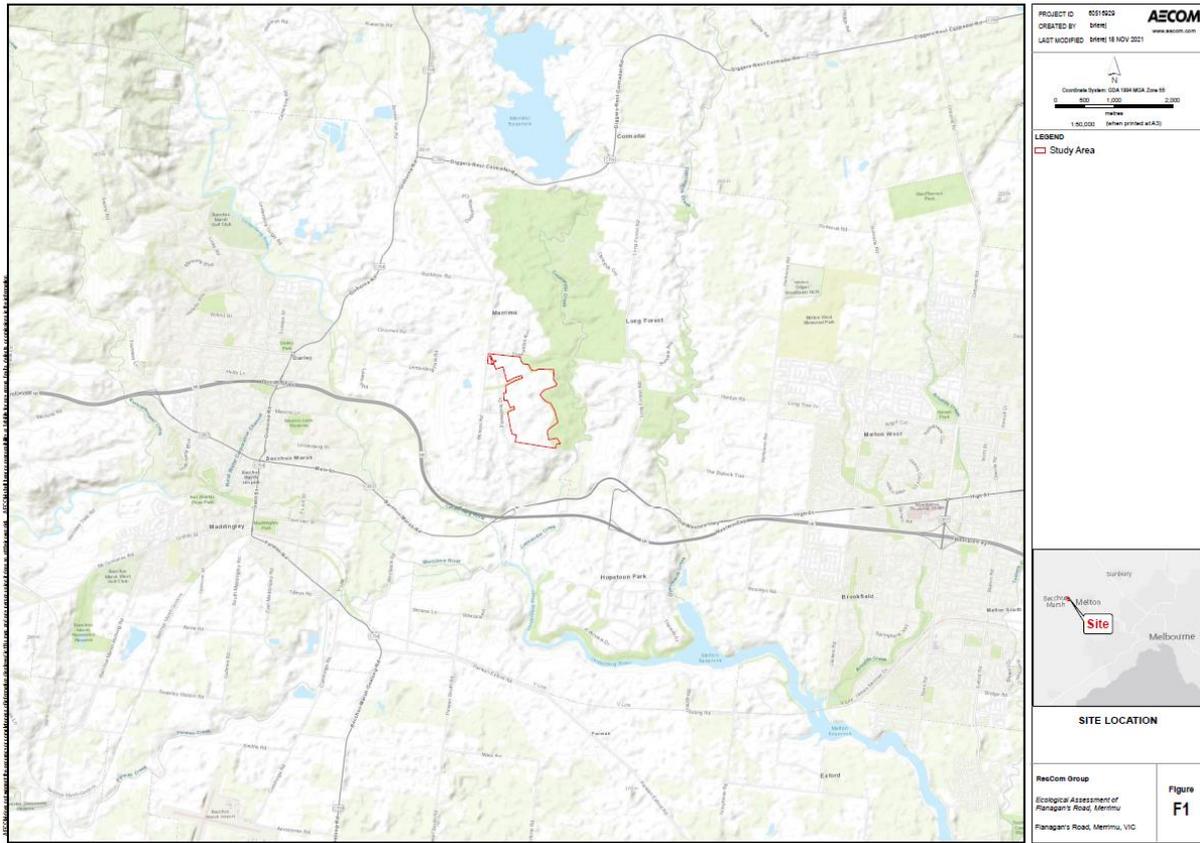


Figure 1 Long Forest Estate Study Area

2.0 Species Profile

2.1 Taxonomy

The VGED is one of four species of threatened Grassland Earless Dragon in south-eastern Australia (Melville et al. 2019):

- *Tympanocryptis pinguicolla* (Victorian Grassland Earless Dragon)
- *T. lineata* (Canberra Grassland Earless Dragon)
- *T. mccartneyi* (Bathurst Grassland Earless Dragon)
- *T. osbornei* (Monaro Grassland Earless Dragon)

The four species were a single species prior to recent taxonomic revisions and the Grassland Earless Dragon *T. pinguicolla* that was listed under the EPBC Act in July 2000 was regarded as four disjunct populations (Melville et al. 2019). All four species were individually listed as threatened under the EPBC Act in May 2023. The VGED is identified as Australia’s most imperilled of the four species having not been recorded for over 50 years (DCCEE 2023b).

2.2 Description

The VGED is a small pale grey-brown to red-brown lizard of the dragon (Agamidae) family (Plate 1). A key feature that separates the *Tympanocryptis* genus from other members of the Agamidae is the lack of an external ear opening and functional tympanum (ear drum) (DCCEE 2023b). Adult VGED are approximately 50-70 mm snout-vent length (SVL) with a head to tail length generally less than 150 mm (DCCEE 2023b).



Plate 1 Victorian Grassland Earless Dragon (*Tymanocryptis pinguicollis*), sourced from “Zoos Victoria’s Fighting Extinction Species GRASSLAND EARLESS DRAGON”
<https://www.zoo.org.au/media/3070/grassland-earless-dragon.pdf>

2.3 Distribution

The species’ current distribution is unknown in Victoria. Until recently, there had been no confirmed sightings since 1969 despite extensive surveys being undertaken across much of its former range (DCCEEW 2023a). Multiple, but not all, extinction risk analyses showed a high probability that this species was extinct and the chance of undetected occurrences of the species in unsurveyed patches were considered slim (DCCEEW 2023a). However, in early 2023 a population of the species was discovered at a location currently undisclosed (DCCEEW 2023a) approximately 50 km west of Melbourne. This discovery has led to reassessment of the species’ potential presence in the region.

The VGED was formerly common on the plains near Sunbury and around the Melbourne CBD prior to development, with specimens and validated records from Sunbury, Maribyrnong River, the mouth of the Yarra River and Coode Island, Essendon and Moonee Ponds, and Prahran (DCCEEW 2023a). All specimens, and confirmed and unconfirmed records, are from temperate grasslands within a 100 km radius of the Melbourne CBD (Figure 2) in an area formerly known as the Keilor Plains, a subset of the Victorian Volcanic Plains (DCCEEW 2023a).

The Draft National Recovery Plan (DCCEEW 2023b) provides a modelled distribution that identifies the potential geographic range of the VGED based on known records and habitat attributes (Figure 2). The modelled distribution map is intended as initial guidance to instigate further investigation as the map is not the outcome of a species-specific assessment.

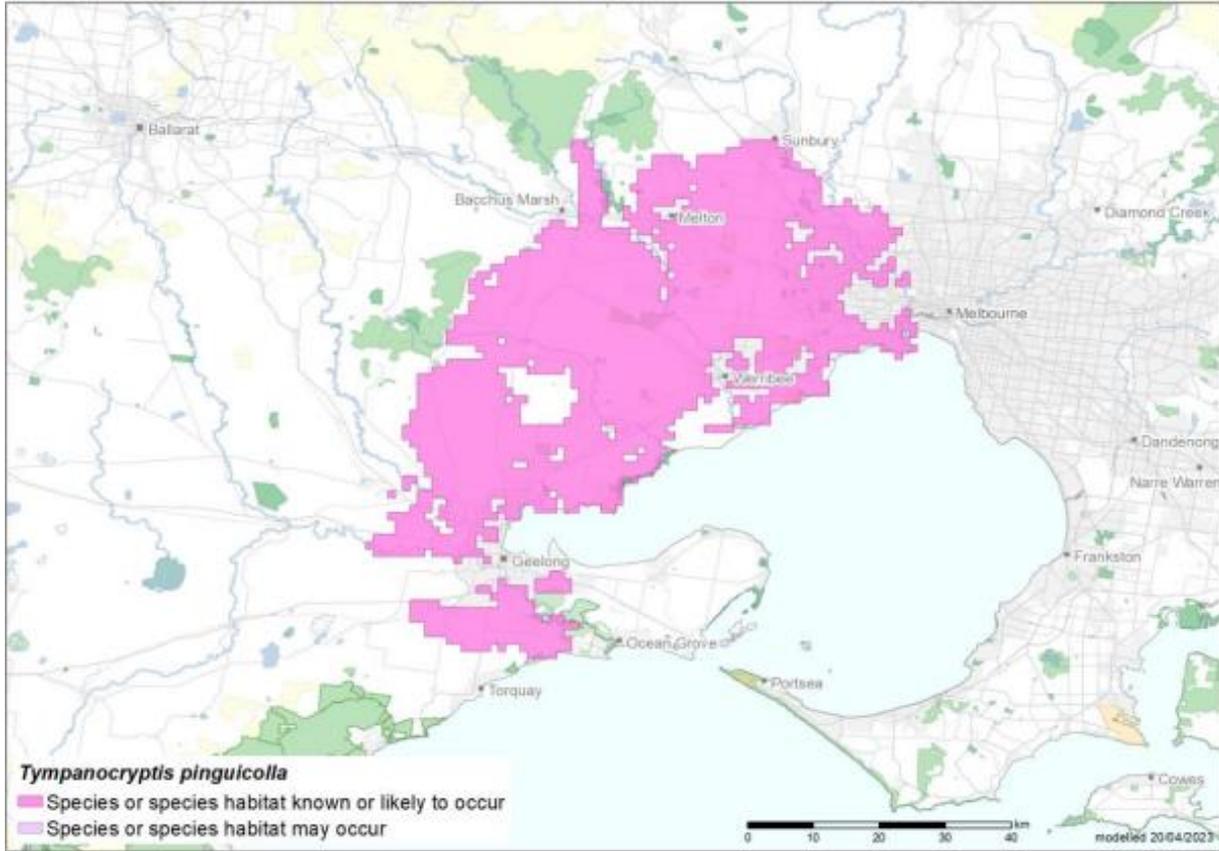


Figure 2 Modelled distribution of the Victorian Grassland Earless Dragon (DCCEEW 2023a)

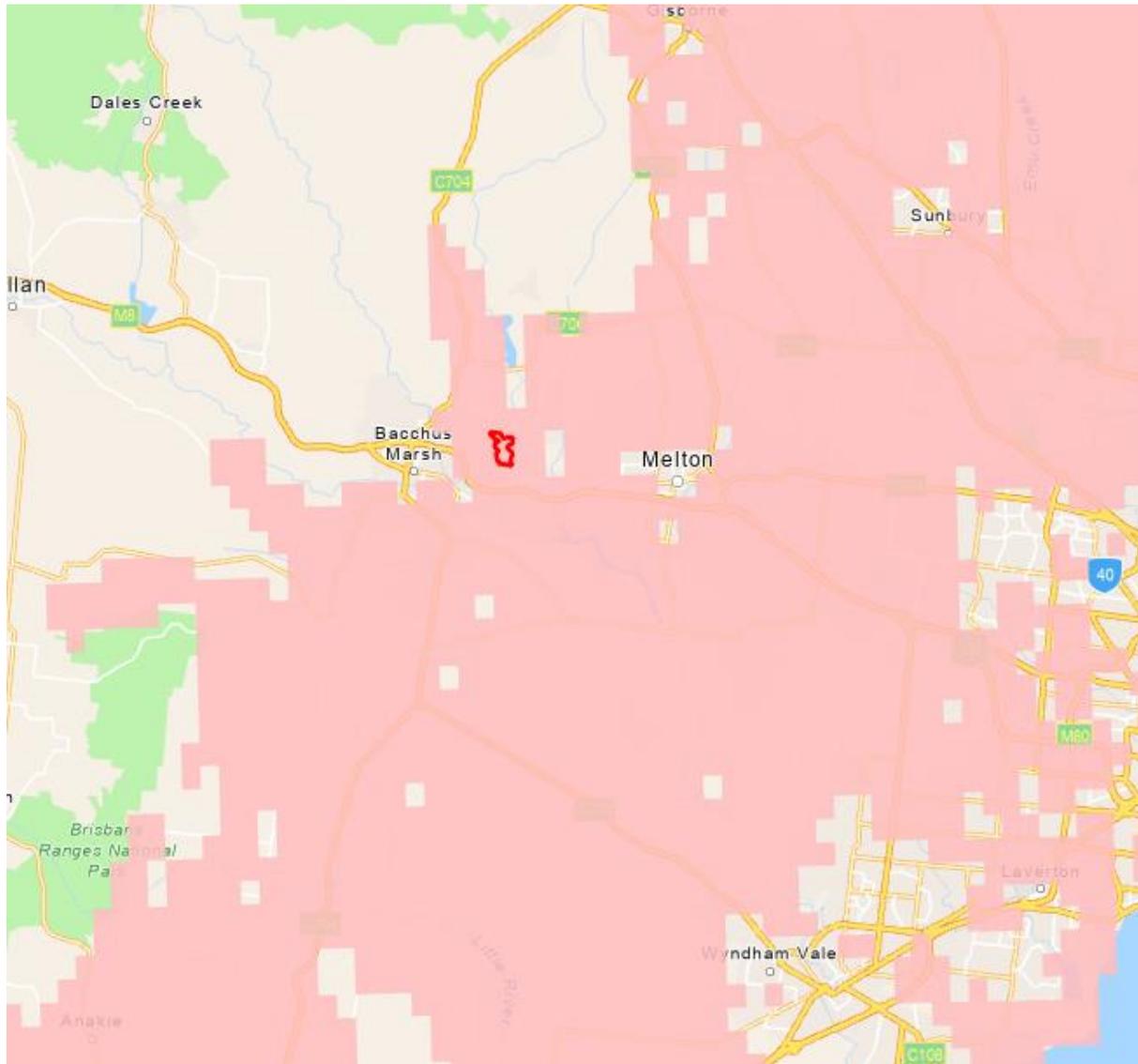


Figure 3 Location of Study Area (red polygon) within the modelled distribution of the Victorian Grassland Earless Dragon (Australia – Species of National Environmental Significance Distributions data, <https://fed.dcceew.gov.au/datasets/erin::australia-species-of-national-environmental-significance-distributions-public-grids/about>)

Prior to the draft National Recovery Plan for Four Grassland Earless Dragons (DCCEEW 2023b), the National Recovery Plan for Grassland Earless Dragon (i.e. the single species) identified the known populations in Victoria. While no populations were known to be extant in Victoria, the plan identified unconfirmed sightings that had been made since the 1960s at:

- Craigueburn Grassland (1990)
- Little River (1990)
- Holden Flora Reserve (1990)
- Donnybrook (Bald Hill) (1988)
- Cooper Street Grasslands (1985).

Other records from >30 years prior to 2012 were noted from:

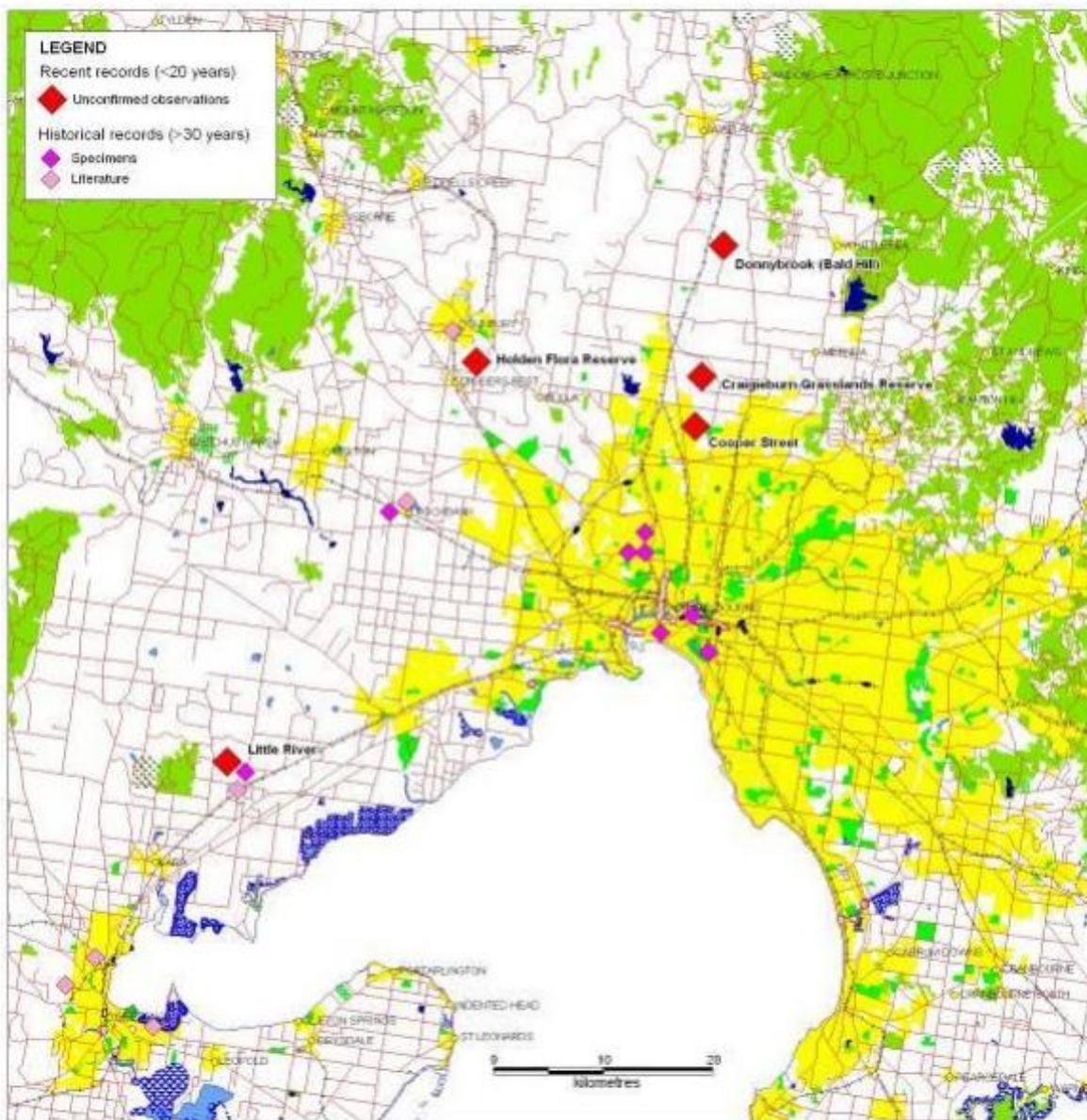
- Geelong area – North Geelong (1969), Newcomb (1968), Hamlyn Heights (1964)
- Rockbank area (1968)
- Little River (1967)

- Port Melbourne, Coode Island, Prahran, Essendon, Moonee Ponds, Sunbury (late 1800s and early 1900s).

The last confirmed sightings were from the Laverton area in 1960, Little River in 1967, Rockbank area in 1968 and Geelong area in 1969. An extract of the map of localities of Grassland Earless Dragon in Victoria (including unconfirmed observations) from Robertson and Evans (2009/2012) is provided in Figure 4 below for reference.

Surveys for this species were conducted to the north and west of Melbourne in the 1990s and early 2000s with the species not detected (Robertson and Evans 2009/2012). Up until recently it had largely been accepted that the species was likely extinct within northern Melbourne and potentially within Victoria with no confirmed sightings since 1969 (Melville et al. 2019; DCCEE 2023a). Even within the modelled distribution area, areas of high disturbance and development are unlikely to support the species.

Map of localities of Grassland Earless Dragons in Victoria.



Source: Robertson and Evans (2009/2012) page 51

Figure 4 Map of localities for Grassland Earless Dragon in Victoria prior to 2012

2.4 Habitat

The VGED was known from native tussock grasslands with little or no trees and shrubs (DCCEE 2023b). Habitat can include the EPBC Act-listed *Natural Temperate Grasslands of the Victorian*

Volcanic Plains (NTGVVP) and native grasslands and pastures with low floristic diversity that fall below the condition threshold for the ecological community. Soil type and substrate are important habitat attributes with those attributes varying between the four earless dragon species (DCCEEW 2023b). Soils at the known locations of the four species vary from limestone, granite or basalt devoid of loose or partially embedded surface rock to heavy basalt-derived clay with an abundance of surface rock and/or deep cracks (DCCEEW 2023b).

Low-lying areas that become waterlogged in winter and continue to be wet in spring are likely to be avoided as overwintering sites (Stevens et al. 2010). In Victoria, the heavy clay soils of the Keilor Plains dry and crack in summer and are waterlogged in winter (DCCEEW 2023a). During prolonged dry periods, areas such as low-lying swales previously deemed unsuitable may be utilised by the species (Stevens et al. 2010).

The presence, but not necessarily dominance, of native grass tussocks is an important habitat attribute. For the VGED historical records are from areas dominated by tufted grasses such as *Rytidosperma penicillatum*, *Themeda triandra* and *Poa labillardierei* (DCCEEW 2023b). Their habitat preference includes grasslands with undisturbed soil, containing arthropod burrows, loose surface stones and large deep soil cracks for refuge. The VGED is reported to primarily occur on open basalt stony plains and along riverbanks (DCCEEW 2023a). The Conservation Advice (DCCEEW 2023a) for the species reports that:

- *Victorian volcanic and coastal grasslands with the greatest likelihood of harbouring a remnant Victorian Grassland Earless Dragon population are likely to have:*
 - *native vegetation cover with open patches of bare earth and/or naturally short open swards due to low-level disturbance (e.g. managed fire, grazing);*
 - *invertebrate burrows and/or rock cover and/or cracking vertisol (also known as vertosol) soils;*
 - *adequate invertebrate prey;*
 - *minimal weed cover;*
 - *not been de-rocked, ploughed or fertilised to improve pasture quality.*
- *Grasslands with these attributes, and that are located broadly within the recorded historical range of the Victorian Grassland Earless Dragon (see Map 1: 'may' and 'likely' to occur) are likely to have been occupied by this species prior to European colonisation and may retain a remnant population. (p7 DCCEEW 2023c)*

Representative photos of habitat for the VGED are provided in the Draft National Recovery Plan (DCCEEW 2023b). An extract of images showing examples of known habitat for the other Grassland Earless Dragon species are provided in Figure 5 and Figure 6 for reference. Optimal biomass/structure has been presented diagrammatically in Figure 9 in the draft National Recovery Plan (DCCEEW 2023b, sourced from NSW DPE and modified from ACT Government 2017) and is extracted here as Figure 7 for reference.

Grassland Earless Dragons shelter and lay their eggs in burrows that are either existing burrows created by arthropods or burrows they dig themselves. The species shows site fidelity to one or two burrows and usually remain within 1 m of a burrow (DCCEEW 2023b). Individual adults rarely move more than 40 m over days or weeks but are capable of longer movements over time with distances of 67 m over three days, 110 m over summer and 80 m in a week reported for Monaro and Canberra earless dragons (DCCEEW 2023b).

Photograph 23. Example of grassland condition and structure found to be supporting the Victorian GED.



Photographer and source: Garry Peterson

Figure 5 Known habitat for Victorian Grassland Earless Dragon (Source: DCCEEW 2023b p20 & 59)

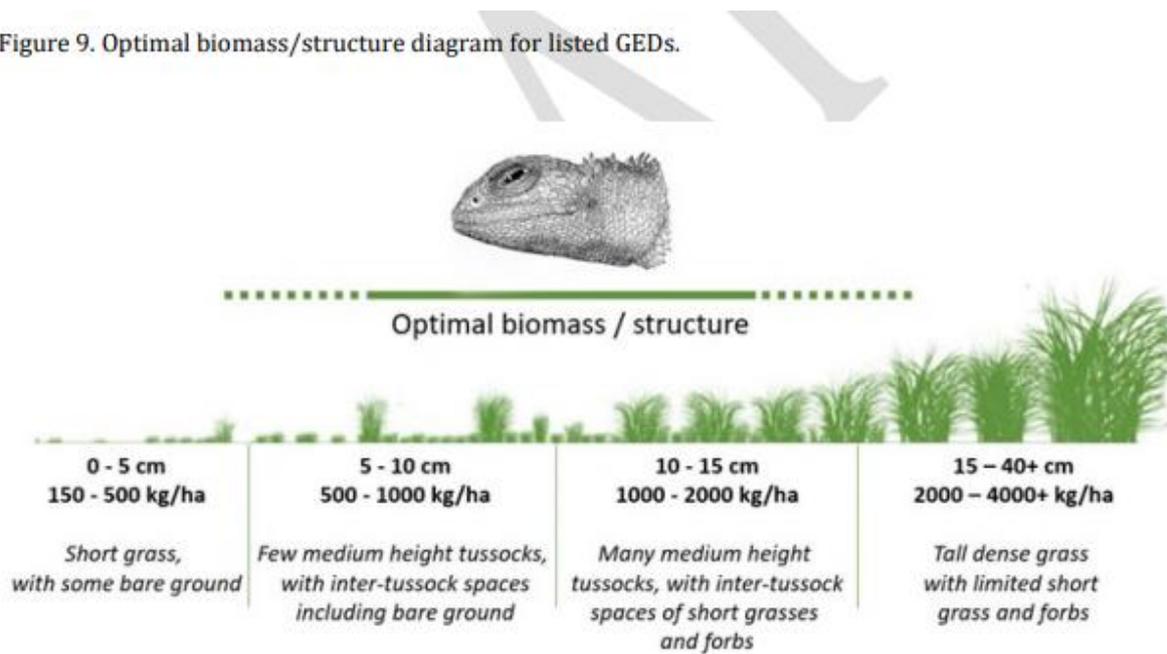
Photograph 10 Examples of known habitat for the Victorian GED habitat on the Keilor plains during summer (top left and right) and in early autumn (bottom left) and late autumn (bottom right).



Photographed and supplied by Nick Clemann.

Figure 6 Known habitat for Victorian Grassland Earless Dragon (Source: DCCEEW 2023b p20 & 59)

Figure 9. Optimal biomass/structure diagram for listed GEDs.



Source: NSW DPE, modified from ACT Government (2017).

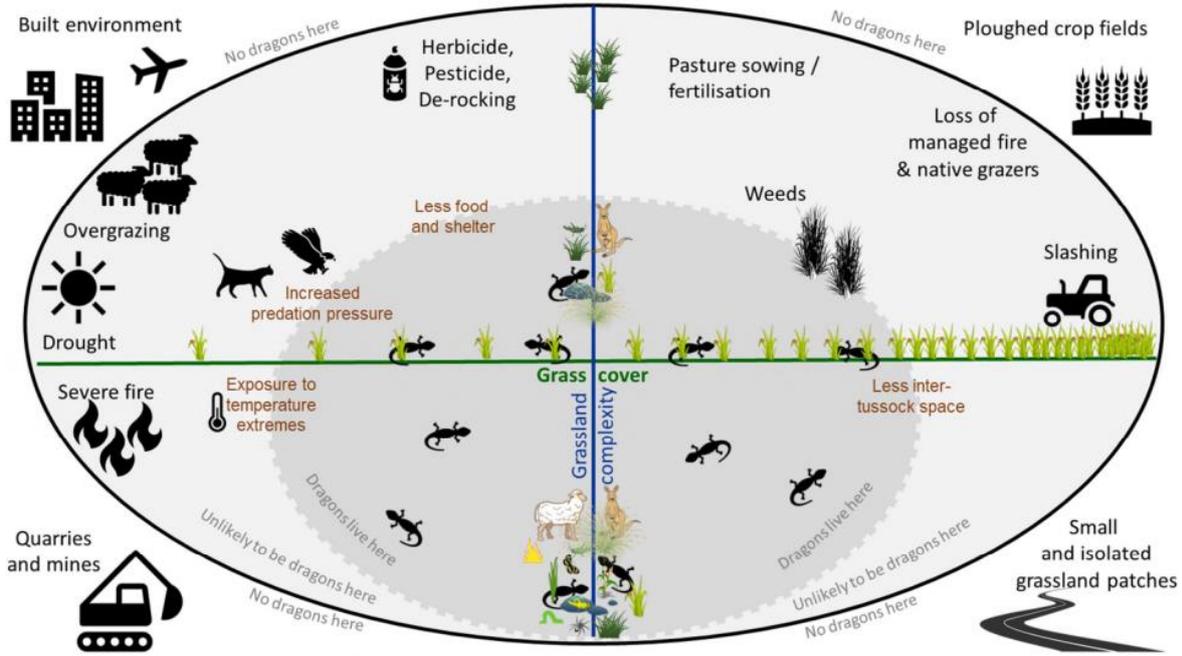
Figure 7 Optimal biomass/structure diagram (extract from DCCEEW 2023b p 57)

2.5 Threats

Historical causes of decline and local extirpation of Grassland Earless Dragons has been the loss, degradation, and fragmentation of their habitat by development (agricultural and urban). Current threats to Grassland Earless Dragons are identified in DCCEEW (2023b) and include:

- Development, particularly ongoing urban expansion and renewable energy programs, quarries and mines
- Agricultural activities (cropping and pasture supplementation)
- Grazing
- Weeds
- Fire
- Drought
- Climate change
- Predation.

Figure 8 provides a generalised overview of threats and impacts on Grassland Earless Dragons (extract of Figure 7 from DCCEEW 2023b p 30). Table 1 provides a description of the current threats based on the Conservation Advice and Action Plan (DCCEEW 2023a p217-218, ACT Government 2017b).



Source: Symbols courtesy of Creative Commons licencing and the NESP Resilient Landscapes Hub: www.nesplandscapes.edu.au

Figure 8 Generalised overview of threats and impacts on Grassland Earless Dragons (extract of Figure 7 from DCCEEW 2023b p 30)

Table 1 Threats to the Victorian Grassland Earless Dragon

Threat	Description (based on DCCEEW 2023c and ACT Government 2017b)
Urbanisation	Loss and fragmentation of habitat through clearing of native grasslands for agricultural purposes and urban, industrial and infrastructure development has been, and continues to be, a major threat to the survival of Victorian Grassland Earless Dragon. Less than 2 % of the Victorian volcanic grasslands remain and most of the higher quality remnants that remain within the modelled distribution of the VGED occur in small and isolated areas on public land (DCCEEW 2023a). Larger remnants occur on private land and are mostly degraded; this includes the Western Grasslands Nature Conservation Reserve that was proposed to offset actions arising from the Melbourne Strategic Assessment urban growth areas. The Western Grasslands Nature Conservation Reserve has a high proportion of de-rocked, fertilised or weed invaded areas and only 10% of the reserve area has been purchased in the 10-year timeframe for establishing the reserve (DCCEEW 2023a).
Agricultural land modification	Ploughing, the use of fertilisers, and de-rocking to improve agricultural land are actions that are incompatible with grassland earless dragon occurrence and are likely to have caused significant loss of habitat for the species (DCCEEW 2023a). Ploughing and rock removal destroy spider burrows, soil cracks and rock cover which are critical shelter resources for the grassland earless dragons (DCCEEW 2023a). Pasture improvement leads to damage like weed invasion (ACT Government 2017b).
Overgrazing	Overgrazing by kangaroos, rabbits or stock (or close mowing) leads to soil compaction, loss of tussock structure and increase in bare ground. Reductions in vegetation cover are likely to reduce availability of invertebrates (as prey and creators of shelter burrows) and increase exposure to predation and/or overheating. Impacts of overgrazing are exacerbated during drought conditions (DCCEEW 2023a; ACT Government 2017b). Grassland Earless Dragons in other states (ACT and NSW) occur in areas with intermittent or light levels of managed grazing (DCCEEW 2023a).
Weed invasion	Weeds which are aggressive colonisers that form monocultures by outcompeting native species are of particular concern as they can obscure invertebrate burrows and fill inter-tussock spaces (DCCEEW 2023a). Those weeds include African Lovegrass (<i>Eragrostis curvula</i>), Chilean Needlegrass (<i>Nassella neesiana</i>), Capeweed (<i>Arctotheca calendula</i>),

Threat	Description (based on DCCEEW 2023c and ACT Government 2017b)
	Saffron Thistle (<i>Carthamus lanatus</i>), Paterson's Curse (<i>Echium plantagineum</i>) and St John's Wort (<i>Hypericum perforatum</i>) (ACT Government 2017b). The young forbs have rosettes that can fill inter-tussock spaces and obscure burrows. The mature plants can shade the ground and release excess nutrients into the soil when they die at the end of the season. Weeds may reduce the density of prey species (ACT Government 2017b). Invasive weeds are often unpalatable to grazers leading to their dominance where heavy grazing occurs (DCCEEW 2023a).
Biomass	Excessive vegetation biomass that can develop due to insufficient grazing leads to a reduction in inter-tussock spaces for hunting and basking, a reduction in soil surface temperatures, and may also increase the risk of wildfire. A study of kangaroo density and vegetation condition at ACT sites showed moderate levels of kangaroo grazing (or light sheep grazing) are required to maintain structural heterogeneity by preventing a few grass species from dominating the sward (ACT Government 2017a).
Slashing	Urbanisation has resulted in a change in management approach in fragmented grassland remnants in the greater Melbourne area. Those grassland remnants are typically managed through slashing and spraying of herbicides rather than through grazing animals and/or fire. Slashing creates a homogenous structure with reduced availability of inter-tussock spaces (DCCEEW 2023a). Slashing also creates mats of cut grass that increase nutrient release which promotes weed growth and increase the risk of severe fire (DCCEEW 2023a).
Pesticide use	Pesticides to control insects is likely to constrain the availability of invertebrate prey and burrows for VGED (DCCEEW 2023a).
Fire	Fire can be used to rejuvenate native grasslands by reducing biomass and maintaining diversity in the grassland structure (structural heterogeneity). However, although arthropod burrows may protect VGED, fire could still result in direct mortality of VGEDs. Fire could also result in reduced body condition post-fire of any individuals that persist by temporarily reducing availability of food and shelter. Predation risk also increases in open areas when ground cover has been removed by fire (DCCEEW 2023a). A small-scale patch burning trial in grasslands in the ACT suggests grassland earless dragons may be resilient to patchy fires of low severity but suffer declines following large-scale high-severity fires (DCCEEW 2023a).
Predation	Predation by cats, dogs and foxes may impact populations particularly in areas in proximity to urban areas and/or where vegetation cover has been reduced by grazing or unmanaged fire. Foxes are likely to be more numerous on the rural sites. Predation by domestic pets might cause increased predation rates where housing is developed close to VGED sites (DCCEEW 2023a; ACT Government 2017b). Predation by native animals is another potential threat to the species. Increase predation may occur due to an increase in artificial perches for birds such as magpies, ravens and raptors (posts, fences, buildings); exposure due to loss of groundcover (grazing and/or unmanaged fire); or enhanced shelter for snakes (e.g. dumped materials or added logs/woody debris near habitat) (ACT Government 2017b).

3.0 Method

Consideration of the potential for the Study Area to support habitat for VGED has been based on desktop information (reference material and findings of flora and fauna assessments undertaken for the Project) and a species-specific habitat assessment.

3.1 Desktop Information

Desktop information considered in the assessment:

- Searches of the Victorian Biodiversity Atlas (VBA) and Atlas of Living Australia (ALA) for records within 20 km of the study area.

- Searches of Victorian Government Maps and Spatial Data (Department of Transport and Planning, 2024) for land use history and barriers to movement.

All scientific literature publicly available relating to *Tympanocryptis* spp. was reviewed for information relevant to the Study Area.

3.2 Habitat Assessment

The Study Area was searched and habitat assessed for suitability for VGED on the 22nd and 23rd April, 2024.

Grassland Structure and Burrow Parameters

Quadrats (1 m²) were haphazardly thrown based on systematically assigned grid points. Quadrats were aligned in grids 100 m apart to cover the entire site using ArcGIS Pro. Surveyors attempted to locate the pre-assigned location when throwing quadrats, but with GPS accuracy of ± 10 m. Quadrats were assessed for 13 parameters thought most likely to influence dragon presence and/or habitat use (Table 2) based on available literature. Data was collected using ArcGIS Field Maps.

Biomass was assessed using the golf ball method developed to assess the biomass cover in south-eastern Australia grasslands (Schultz et al., 2017). South-eastern Australia grasslands are adapted to a disturbance regime (i.e. evolved with a fire regime, native herbivore grazing) and many native flora and fauna species rely on this disturbance. Victorian Volcanic Plains grasslands require a certain level of openness to reproduce and grow. Historic fire regimes cleared biomass to prevent smothering of seedlings and allow recruitment (Schultz et al., 2017). The golf ball method was devised to provide managers with a quantitative measure of biomass when managed fires would be necessary. Obscured golf balls lying in grass (from a bird's eye view) indicate that biomass has accumulated, and management is necessary. Schultz et al. (2017) recommends that in the more productive Victorian Volcanic Plains that the golf ball method be employed with other measures of grass structure, such as the parameters collected during this assessment.

Briefly the method involved photographs taken at approximately the same aspect and direction for every quadrat (e.g. North) before and after 18 golf balls were haphazardly thrown into the quadrat (see Schultz et al. (2017) for detailed methods). Photographs were later assessed for the visibility of each golf ball, within three categories (i.e. visible: >90% ball visible; partially obscured: between 33-90% visible; obscured: <33% visible). Visible scored 1, partially obscured scored 0.5 and obscured scored 0. The summed total was divided by 18 to determine a biomass proportion between 0 and 1, with 0 being high in biomass and 1 being low in biomass.

If well-maintained arthropod burrows (diameter >1 cm) were found in a quadrat, the width and approximate depth were recorded and the burrows were investigated using a camera and scope (5 mm camera head, Plate 2). Depth was often not recorded if burrows were occupied and taxon was recorded.

Burrow Density

Burrows greater than 1 cm in diameter and appearing well-maintained were counted along transects running east-west connecting quadrats. It was determined that such small burrows could reasonably be seen within 1 m of either side of each transect. Transects were walked slowly (2-3 km/hr) following pre-aligned transects but may have deviated due to terrain and obstacles, including dense vegetation. Points and the number of burrows were recorded every 10-20 m.



Plate 2 Use of scope to investigate arthropod burrows

Table 2 Vegetation and structural parameters for quadrat habitat assessment

Name	Description	Categories/variable
Arthropod burrow presence	Any likely invertebrate burrows If "Yes" also collected burrow data separately	No Yes
Burrow occupancy	Use scope and/or torch	No Yes
Biomass	Using golf ball method to approximate biomass score within quadrat, calculated as a proportion between 0 and 1	0 to 1 (High to Low)
Tussock height	Average height of tussocks	Absent Low (1-15 cm) Medium (15-30 cm) High (30+ cm)
Crack length in soils	Estimate the length of cracks	0 (absent) 1-50 cm 50-100 cm 100-200 cm 200+ cm
Embedded rock cover	Approximate percentage cover of embedded rocks	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Surface rock cover	Approximate percentage cover of embedded rocks	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Cryptogam cover	Plants or non-plants that have no true flowers or seeds, including ferns, mosses, liverworts, lichens, algae, and fungi. Approximate cover on soil	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Total forb cover	Approximate percentage cover of forbs	Absent

Name	Description	Categories/variable
		<1% 1-5% 5-25% 25-50% 50-75% 75-100%
Total native species cover	Approximate percentage cover of native species – this was total cover, not a proportion of total vegetation If all vegetation is native, but it only covers 70% of the quadrat, this would be 50-75% and total cover would be 50-75%	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Total vegetation cover	Approximate percentage cover of all living vegetation (i.e. excludes dead vegetation)	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Inter-tussock space	Approximate percentage cover between tussocks, excluding rocks, i.e. bare soil	Absent <1% 1-5% 5-25% 25-50% 50-75% 75-100%
Dominant tussock grass species	Preferably to species, but genus sufficient	Absent or Genera used for summary

Data Analysis

Averages were calculated for continuous biomass data, while medians were calculated for ordinal data (i.e. percentage cover) and mode for nominal categorical data (e.g. dominant species).

A PERMANOVA (permutational multivariate analysis of variance) was performed in PAST 4.15 comparing the Study Area's habitat parameters, using Bray Curtis distances and Bonferroni Probability Values to account for multiple testing. Given that there are no reference sites for this species, theoretical quadrat habitat data were randomly generated considering the species' preferred habitat conditions (as stated in Section 1.1, Table 3). Ninety-two 'reference' site data were randomly generated and another 92 fully randomised (all categories for each parameter) site data was generated to minimise statistical noise.

A PERMANOVA does not require continuous data nor many of the assumptions of an ANOVA but does produce an F and P values that can be interpreted in the same way. ANOVA with Tukey's Pairwise was used to test biomass between habitat assessment and controls.

Table 3 Theoretical preferred habitat categories for parameters based on Victorian Grassland Earless Dragon potential habitat conditions (DCCEE, 2023a, b)

Name	Description	Categories randomised
Arthropod burrow number	VGED require well-maintained arthropod burrows, other dragons prefer no additional burrows in 4 m ²	1
Burrow occupancy	VGED require well-maintained arthropod burrows, but other dragon species have been known to share burrows with arthropods	No Yes

Name	Description	Categories randomised
Biomass	Moderate biomass, not too open and not too closed	Between 0.39 and 0.83
Tussock height	Other dragon species reportedly prefer medium to high tussock height	Medium (15-30 cm) High (30+ cm)
Crack length	Moderate cracking, but not excessive to decrease biomass/vegetation growth	50-100 cm 100-200 cm
Embedded rock cover	Other dragons prefer a few to moderate rock cover, but not high cover of both surface and embedded	1-5% 5-25%
Surface rock cover	Other dragons prefer a few to moderate rock cover, but not high cover of both surface and embedded	1-5% 5-25%
Cryptogam cover	Moderate cryptogam cover demonstrates little recent soil disturbance, moderate grassland openness and other features preferable for VGED	5-25% 25-50% 50-75%
Total forb cover	Forb cover should not be high and dominate since VGED require tussock grass	1-5% 5-25%
Total native species cover	Other dragons can persist in degraded farmland pasture, therefore native species cover ranges from poor to excellent	5-25% 25-50% 50-75% 75-100%
Total vegetation cover	Dragons seemingly prefer moderate openness to full coverage	5-25% 25-50% 50-75% 75-100%
Inter-tussock space	VGED require moderately open swarths of grass tussocks	5-25% 25-50% 50-75%
Dominant tussock grass species	Other dragon species are known to prefer grasslands with these two species. Although other dragon species are known to prefer native <i>Poa</i> spp. none were identified on site and thus not included. Similarly, no <i>Themeda triandra</i> was identified on site (a possible preference for VGED)	<i>Rytidosperma</i> <i>Austrostipa</i>

4.0 Results and Discussion

4.1 Proximity to Historic Records

There are no records of VGED within 20 km of the Study Area on the VBA or ALA. Widening the search area to 50 km finds 19 records from the VBA and 27 on the ALA. Over half of these are museum specimens collected before 1900. The closest records are 24 km to the east (Sunbury) and approximately 28 km south (Little River). The location of VGEDs recently discovered has not been released however AECOM's understanding is that it is west of Melbourne, and relatively close to the Study Area.

4.2 Land Use

The Study Area is in a highly modified landscape dominated by exotic vegetation. Native vegetation has largely been cleared and degraded by a long history of grazing, agriculture and lack of weed management. Merrimu is historically a farming area dominated by agricultural land uses.

Native vegetation cover is now minimal but Plains Grassland (EVC 132), Grassy Woodland (EVC 175) and Rocky Chenopod Woodland (EVC 64) were probably widespread across the Study Area prior to European settlement. Changes to native vegetation quality between 2012 and 2021/2022 were evident when AECOM first assessed the Study Area in 2021 (AECOM 2023). There was an increase in the spread of woody weeds (both exotic and native) throughout the site, and a reduction in native vegetation extent and quality. Due to a lack of both woody weed management and grass and herb weed management the cover of invasive species including African Box-thorn *Lycium ferocissimum*, Serrated Tussock *Nassella trichotoma* and Artichoke Thistle *Cynara cardunculus* has increased throughout the site.

This was concurrent with other impacts such as overgrazing by kangaroos, and cumulatively, these impacts have resulted in a reduction in the extent and quality of Plains Grassland EVC. The establishment and proliferation of Sifton Bush *Cassinia sifton* has also played a role in reducing Plains Grassland EVC quality and extent in a similar way to African Boxthorn, Serrated Tussock and Artichoke Thistle.

Long Forest Estate was purchased in 2012 with an expired planning permit to subdivide the land into 84 residential lots (minimum lots size of 7,500 m²). Infrastructure including gas, water and wastewater was installed before the project ceased and the land was sold to the current landowner. Since being in its current ownership, the landowner has grazed the site with cattle in low numbers to address fire risk. Some weed control works were also prioritised from 2016 onwards to address weed control and spread as required by landowners under the Catchment and Land Protection Act 1994 (CaLP Act).

4.3 Landscape Context

The Study Area located in a modified landscape with developed areas, infrastructure, agricultural, woodland remnants and reserve environments that may influence the ability for the species to persist due to isolation. It is clear from aerial imagery that wildlife corridors (e.g. vegetated creeks, green wedges) are somewhat fragmented and may provide little cover and connectivity for a small reptile (Figure 9). However, the Study Area is located adjacent to Long Forest Nature Conservation Reserve (NCR) that lies on the border of the Victorian Volcanic Plain and the Northern Inland Slopes bioregions. Long Forest NCR protects ~600 ha of remnant vegetation dominated by Rocky Chenopod Woodland and Grassy Woodland. To the north, the Long Forest NCR joins the larger Lerderderg State Park. It is unknown if VGEDs could use woodlands or forested areas and not grasslands to disperse.

There is largely ploughed fields and Bacchus Marsh township to the west and grazed pasture to the north. Ploughed fields and other forms of agriculture, and residential areas are unsuitable for VGED. It is unknown if VGED can use pastureland. The Western Freeway to the south (M8) would have reduced or ceased connectivity the landscape had to southern grasslands (e.g. Melton South, Werribee). Canberra Grassland Earless Dragon populations are isolated by disturbance and Hoehn et al. (2013) found that human activities present significant barriers to dispersal, increasing genetic isolation and likelihood of a population crash. It is likely that VGED would also find human land use (e.g. roads, Bacchus Marsh) a barrier to dispersal.

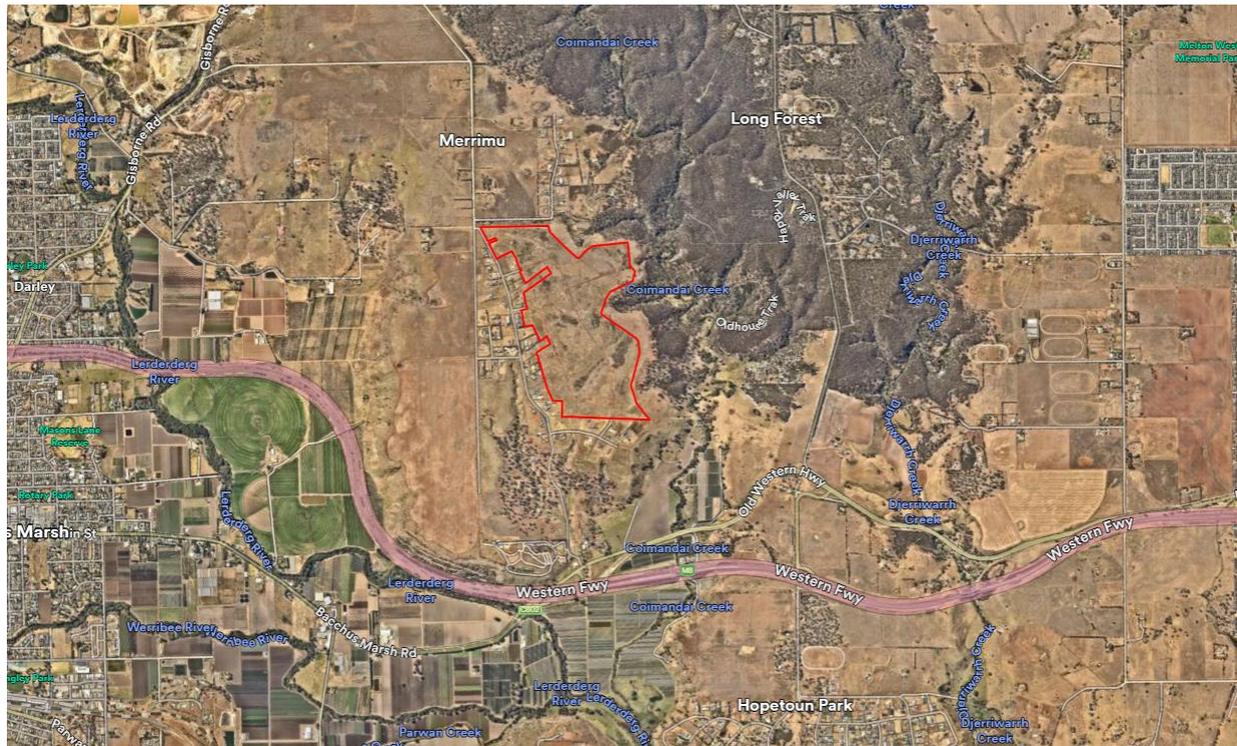


Figure 9 Study Area (red polygon) with ploughed fields and Bacchus Marsh to the west, grazed pastures and residences to the north, Long Forest NCR to the east and the Western Freeway (M8) to the south (NearMap 2024)

4.4 Habitat Features

4.4.1 Grassland Structure

Habitat within 92 quadrats was assessed for the 13 parameters that may influence VGED presence (Table 4). No VGED were detected while undertaking habitat assessments. The habitat parameters within the Study Area's quadrats were significantly different to randomly generated theoretically preferred ("reference site", $F=100.8$, $P<0.001$) and control quadrats ($F=49.4$, $P<0.001$, Table 4). The two randomly generated site groups were also significantly different ($F=26.71$, $P<0.001$). This suggests that the Study Area's habitat is different from a theoretical preferred reference and a randomly generated grassland.

The median number of burrows in Study Area quadrats was zero and were unoccupied (see Section 4.4.2 for more discussion of burrows). Tussocks had been largely grazed, minimising the height and therefore the median was Low (1-15 cm). Grazing also resulted in an open structure, with inter-tussock space being 75-100% and biomass being low (0.88). Native species cover was low to moderate, as was found during previous AECOM assessments. However, the surveys were conducted outside of the optimal season for grassland detection and thus species could have been missed.

Study Area quadrats were most frequently dominated by *Nassella* (38 quadrats), but much of the grass was grazed in areas and therefore species could not be identified (Plate 3-Plate 9). Together, the two native grasses *Austrostipa* (2) and *Rytidosperma* (36) were as frequently dominant as *Nassella*. Soil cracking was minimal, but occasionally cracks were observed and were of sufficient diameter and depth (Plate 7). Forb cover was low to moderate as is normal in grasslands, but invasive forbs were common (e.g Artichoke Thistle). Cryptogam cover was low to moderate, suggesting that recent soil disturbance was low to moderate across most of the site. However, there were nine quadrats with over 50% cryptogam cover, and five of these over 75%. Most of the soil disturbance observed across the Study Area appeared to be restricted to certain areas as it was caused by cattle hooves, vehicle access tracks and cable/pipe works. Embedded and surface rock was good in places, but many areas had been derocked and were sitting in piles. Overall, rock cover was lower than is preferable for dragons.

4.4.2 Burrows

Fifty-three well-maintained arthropod burrows were found within or adjacent to quadrats. The majority (37) were seemingly unoccupied, but if the burrows were deep and multi-channelled it is possible that many more were occupied than counted (16). The burrows ranged from 10 to 70 mm in width

(mean±s.d. = 15.8±9.3) and 0.5 to 250 mm in depth (mean±s.d. = 65.9±46.1). The burrows were mostly occupied by a wolf spider species (likely Garden Wolf Spider *Tasmanicosa godeffroyi*) and black crickets (likely Black Field Crickets *Teleogryllus commodus*). Arthropod presence was good across the site, with a number of cricket species seen and heard. The number of burrows within quadrats ranged from zero to five, with the median being zero (Table 4). Surveyors covered 15,012 m² of the Study Area while walking the burrow density transects and found 1,610 well-maintained burrows >10 mm in diameter (Figure 11). This equates to 0.11 burrows/m².

While investigating burrow density, a Tussock Skink (*Pseudemoia pagenstecheri*) was found emerging from a large crack/burrow (Plate 14). The Tussock Skink is listed as Endangered under the FFG Act.

Table 4 Summary of habitat parameters from Study Area quadrats, and randomly generated theoretically preferred ("reference site") and control quadrats for Victorian Grassland Earless Dragon habitat assessment at Flanagans Drive

Parameter (summary method)	Study Area Quadrats	Theoretical Preferred Reference	Control
Number of arthropod burrows (median)	0	2	2
Burrow occupied (mode)	No	No	Yes
Biomass (mean)	0.88	0.60	0.46
Tussock height (median)	Low	High	Low
Crack length (median)	1-50 cm	100-200 cm	50-100 cm
Embedded rock cover (median)	<1%	1-5%	5-25%
Surface rock cover (median)	<1%	1-5%	5-25%
Cryptogam cover (median)	5-25%	25-50%	5-25%
Total forb cover (median)	5-25%	5-25%	25-50%
Total native species cover (median)	5-25%	50-75%	5-25%
Total vegetation cover (median)	50-75%	25-50%	5-25%
Inter-tussock space (median)	75-100%	25-50%	5-25%
Dominant tussock grass genus (mode)	Nassella	Austrostipa	Absent



Plate 3 Sparse tussock grass (invasive Serrated Tussock *Nassella trichotoma*) with grazed other grass species, little



Plate 4 Serrated Tussock tufts and grazed with low biomass (golf ball method)

embedded/surface rock and <1% native species cover



Plate 5 Serrated tussock dominates the Study Area



Plate 6 Low native species cover, no tussocks or tussocks heavily grazed with a *Chloris* spp. being the dominant grass species



Plate 7 Large cracks were present across the site, although not frequent, could form large openings suitable for burrows



Plate 8 Sporadic small shrubs (Sifton Bush) in an open, grazed grassland within the Study Area



Plate 9 Serrated Tussock density was high and formed much of the biomass in a few patches



Plate 10 Well maintained burrow



Plate 11 Well maintained burrow, with soil spoil evidence of arthropod burrow maintenance



Plate 12 Wolf spider emerging from a burrow, likely a Garden Wolf Spider (*Tasmanicosa godeffroyi*)



Plate 13 Black crickets were commonly observed in burrows and across the Study Area, most likely Black Field Crickets (*Teleogryllus commodus*)



Plate 14 Tussock Skink (*Pseudemoia pagenstecheri*) emerging from a large crack/burrow



Figure 10 Location of the 92 quadrats across the Study Area



Figure 11 Path of the 17 transects that were walked across the Study Area

4.5 Existing Threats

Introduced predators occur in the area. Scats of Red Fox *Vulpes vulpes* and/or Cats *Felis catus* were observed. Weed cover is high and prevalence of invasive Serrated Tussock, African Box-thorn, Artichoke Thistle and Sifton Bush. For example, Sifton Bush has clearly expanded its range within the Study Area from 2012 to 2024 and is easily observed in satellite imagery (Figure 12, Figure 13).

High intensity grazing was present in patches, likely caused by a large mob of Eastern Grey Kangaroos *Macropus giganteus* and small herd of cattle. Few European Rabbit *Oryctolagus cuniculus* scats and burrows were observed, which is surprising given the widespread distribution of the invasive species in the broader landscape. The cattle have been placed on site to manage weed growth, but it is possible that the cattle combined with a large mob of kangaroos has caused intense grazing across a proportion of the site. Current soil disturbance is moderate, where a few vehicle tracks and hooved cattle have caused considerable soil disturbance in localised areas.



Figure 12 Study Area in 2012, Sifton Bush (darker green patches) extent restricted (Source: NearMap)

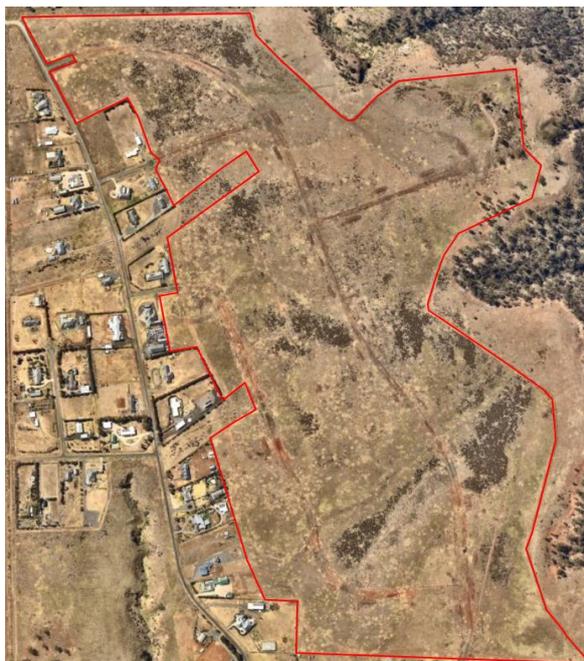


Figure 13 Study Area in 2024, extensive patches of Sifton Bush clear (Source: NearMap)

5.0 Likelihood of Occurrence

The Study Area is in a highly modified landscape dominated by exotic vegetation. The Long Forest NCR is adjacent to the Study Area and Lerderderg State Park is to the north. It is unknown if VGEDs could use the woodlands and grassy woodlands of these areas to disperse, but the freeway to the south would certainly be a barrier to movement. There are other isolated patches of grasslands across the landscape, but the long history of agriculture and infrastructure has possibly disturbed the soil and degraded the grasslands to such an extent that VGED presence may be unlikely. The Study Area's habitat was significantly different to a theoretical reference site and does not contain all the habitat parameters assumed to be necessary for VGED, suggesting it is unsuitable for VGED given the suite of habitat parameters.

The dominance of *Nassella* and other invasive species likely decreases the suitability of the Study Area for VGED. However, native grasses (*Austrostipa*, *Rytidosperma*) were also common, and it is possible that unidentifiable native tussocks had been grazed low by the large mob of kangaroos. The surveys were conducted outside of the optimal season for grassland detection, thus some grasses could have been missed. AECOM (2023) vegetation assessments identified approximately 15 ha EVC 132_63 *Low-rainfall* Plains Grassland patches within the Study Area, including one patch that met the threshold criteria for the EPBC Act threatened ecological community NTGVVP. If VGED once occurred throughout areas of NTGVVP and NTGVVP was widespread across the landscape, it is possible that VGED historically occurred across the Study Area. There is insufficient published information to determine whether VGED can inhabit patches of invasive grasslands, even if alongside isolated patches or intermittent tussocks of native grass. There is some evidence that other dragon species can inhabit degraded grasslands (Stevens et al. 2010).

Tussock height was low, and it is assumed that VGED require moderate to high tussock height. Monaro Grassland Earless Dragon prefer native tussock cover of 20-30 cm height, which was reflected in the theoretical "reference" median (Table 3), but few areas had moderate to high tussock height in the Study Area. Grazing was possibly too extensive and inter-tussock space too high to satisfy requirements for VGED suitable habitat. For preferred VGED habitat, low intensity grazing and/or fires are necessary to ensure the right balance of tussock to bare soil, similar to other species of the Victorian Volcanic Plains (Howland et al., 2016; Morgan & Lunt, 1999; Schultz et al., 2017). Overall, rock cover was lower than what is believed to be preferred by VGED. McGrath (2015) recommends grazing that maintains a native tussock cover of 20-30 cm average height and land management that

maintains structural diversity of rock outcrops and existing exposed rocky areas is necessary for the persistence of MGED. These habitat parameters are largely absent from the Study Area and thus potentially make it unsuitable for VGED.

Arthropod activity was good, with many crickets calling and moving about the site. Wolf spiders were common, as were moths, millipedes, centipedes, slaters/wood lice and other insects. The specific diet of VGED is unknown, but other grassland dragons feed on invertebrates, including beetles, moths, crickets and grasshoppers (Diamond 2010). Therefore, there is possibly sufficient prey diversity for VGED. A Tussock Skink was observed during burrow density transects, but no other reptiles were observed. Tussock Skink or other reptile presence is not necessarily an indicator of potential suitability for VGED, but it does demonstrate that the Study Area is suitable for at least one reptile species. It would be expected that other lizards and snakes are present.

Cryptogam cover was typically low to moderate, but in places it was moderate to high (>50%). This suggests that the soil has not been recently disturbed in those places. Cryptogam crusts that occur in inter-tussock spaces can perform vital functions to aid in seed germination, protect the soil from erosion, assist in water infiltration and increase nutrient cycling (Klopatek, 1992). Cryptogams have been shown to increase soil stability in loamy and sandy soils in south-east Australia (Eldridge & Leys, 2003). Cryptogams require undisturbed soil and space to populate. Soil disturbance was highest nearest to vehicle and cattle tracks and recent infrastructure (e.g. water troughs). It appeared that the cattle herd, or evidence of hoof damage, was localised. Similarly, the density and structure of arthropod burrows suggest the soil is undisturbed in places. Little soil disturbance is a key requirement for VGED presence, since well-formed tussocks and burrows cannot exist where there is disturbed soil. Therefore, low to moderate cryptogam cover suggests that soil disturbance may be sufficiently low in areas for VGED suitable habitat.

The Study Area's burrows ranged from 10 to 70 mm in width and 0.5 to 250 mm in depth and many burrows were well-maintained by wolf spiders (preferred by other dragon species). Canberra Grassland Earless Dragon used burrows with entrance widths of 15–130 mm (Stevens et al. 2010) and MGED used burrows with 20-35 mm and 6-29 mm depth (McGrath 2015). McGrath (2015) found that MGED prefer burrows where there are no additional burrows within a 4 m² quadrat (or 0.25 burrows/m²). This is more than double than calculated for the Study Area (0.11 burrows/m²). We included all well-maintained burrows greater than 10 mm, thus if we were to use the preferred diameter of MGED/CGED of 16-35 mm this would have reduced the number and density of burrows even further. However, a high density of burrows may not be necessary since CGED have large home ranges for a lizard of their size (0.09 to 0.48 ha), centred on one or two burrows (Stevens et al. 2010). Canberra Grassland Earless Dragon exhibits site fidelity to one or two burrows and will usually remain within 1 m of this burrow (Stevens et al. 2010). Similarly, adults rarely move more than 40 m over days or weeks. Consequently, burrow size and density may be sufficient for VGED.

Arthropod burrows are one of the most influential features for habitat use by CGED and CGED have been found in landscape features previously thought unsuitable (e.g. degraded, low-lying grassland with moderate disturbance/weeds, Stevens et al. 2010). Therefore, it is possible there is adequate burrow type, density and soil cracks across a few areas within the Study Area for VGED suitable habitat, despite the widespread cover of invasive tussock grass. However, the increase in woody weeds, such as Sifton Bush, may have reduced and isolated grassland (native or invasive) patches to such an extent to decrease the likelihood of VGED presence. It is also unknown if VGED can exist in degraded native/invasive grasslands. Consequently, the Study Area has a few isolated patches of native grass with good burrows and more widespread invasive grass tussocks that could be used by VGED, however, the long history of landscape disturbance and little connectivity would decrease the likelihood that VGED could have persisted at the site.

6.0 Potential Impact

It appears that the Study Area may have isolated patches that could be used by VGED, but the level of landscape disturbance probably limits the connectivity to a broader population. Any areas that have high density of Sifton Bush and Artichoke Thistle are unlikely to be suitable for VGED and therefore there would be no impact on VGED if this vegetation was removed. Similarly, if vegetation in highly soil disturbed areas were to be removed, it would be anticipated there would be no impact on VGED as it is unlikely to occur in these areas.

It is unknown if VGED can occur in degraded native/invasive grassland areas. Conservation Advice (DCCEEW 2023a) outline native tussock grasslands as a requirement of VGED habitat. However,

related species are known to use degraded grasslands and therefore it is possible VGED could use this habitat. The landscape context of the site decreases this likelihood of VGED suitable habitat within the degraded native/invasive grasslands and therefore there is a low likelihood of VGED suitable habitat presence. If more information becomes available, this assessment may change. Currently, there is insufficient information to determine if there would be an impact, since it is unclear if VGED can occur in degraded grasslands. If VGED cannot occur in degraded grasslands, it is highly unlikely there would be an impact on VGED as no suitable habitat exists. If VGED can occur in degraded grasslands, there is a low likelihood of VGED presence and thus impacts would be possible.

7.0 Conclusion

Habitat patches within the Study Area has well-maintained burrows, soil cracking and patches of native/invasive tussock grassland. These habitat parameters, particularly within any remnant patches of NTGVVP or Plains Grassland, are potentially suitable for VGED. However, the long history of agriculture across the landscape has reduced and isolated native grasslands that may have once been inhabited by VGED. Additionally, the spread of woody weeds has reduced the extent of grasslands, potentially isolating and degrading grassland patches that may no longer be suitable for VGED. Consequently, there is a low likelihood that the habitat in the Study Area is suitable for VGED, but the presence of VGED cannot be discounted due to its cryptic nature and low detectability and little information about its tolerance to degraded grasslands.

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