Australian Capital Territory

Nature Conservation (Canberra Grassland Earless Dragon) Action Plan 2025

Disallowable instrument DI2025–57

made under the

Nature Conservation Act 2014, s 105 (Draft action plan—final version and notification)

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1 Name of instrument

This instrument is the *Nature Conservation (Canberra Grassland Earless Dragon) Action Plan 2025*.

2 Commencement

This instrument commences on the day after its notification day.

3 Action plan

Schedule 1 to this instrument sets out the final version of the action plan for the Canberra Grassland Earless Dragon.

4 Revocation

This instrument revokes the Grassland Earless Dragon (*Tympanocryptis pinguicolla)* Action Plan as contained in the *Nature Conservation (Native Grassland) Action Plans 2017* (DI2017-288) (pp 208-227).

Bren Burkevics
Conservator of Flora and Fauna

13 May 2025

Schedule 1 Action Plan—Canberra Grassland Earless Dragon

(See s 3)

ACT Government

Action Plan for the Canberra Grassland Earless Dragon

2025-2035

Tympanocryptis lineata

Authorised by the ACT Parliamentary Counsel—also accessible at www.legislation.act.gov.au

Acknowledgement of Country

We acknowledge the Ngunnawal people as traditional custodians of the land and recognise any other people or families with connection to the lands of the ACT and region. We wish to acknowledge and respect their continuing culture and the contribution they make to the life of this city and this region.

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Table of Contents

Acknowledgement of Country ii

Table of Contents i

List of Tables ii

List of Figures ii

List of Acronym iii

Acknowledgements iv

Introduction 1

Conservation status 1

1.1. National 1

1.2. Australian Capital Territory 1

1.3. New South Wales 2

Policy and Plan context 2

Vision and Priority Outcomes 4

Strategy Overview 5

OUTCOME 1: Extant populations restored and expanded 8

OUTCOME 2: Quality habitat secured, restored and connected 16

OUTCOME 3: Viable captive metapopulations are maintained 25

OUTCOME 4: Community and policy support for CGED conservation 32

Monitoring, analysis, evaluation, and research 37

Research plan 39

Conclusion 42

References 42

Appendix A: Current knowledge for the Canberra Grassland Earless Dragon 43

Appendix B: Workshop participants 62

List of Tables

Table 1. The activities required to deliver against the Extant Populations Restored and Protected (Outcome 1) 10

Table 2. The activities required to deliver against the quality habitat secured, restored and connected (Outcome 2) 18

Table 3. The activities required to deliver against the viable captive metapopulations are maintained (Outcome 3). 27

Table 4. The activities required to deliver against community and policy support for CGED conservation (Outcome 4)..... 34

Table 5. Research projects to improve Canberra Grassland Earless Dragon outcomes 40

List of Figures

Figure 1. Total Theory of Change for the Action Plan for the Canberra Grassland Earless Dragon 2025 - 2035 7

Figure 2. Theory of Change for extant populations restored and protected (Outcome 1) 9

Figure 3. Responsible agency, timing and resourcing for extant populations restored and protected (Outcome 1) 15

Figure 4. Theory of Change for the quality habitat secured, restored and connected (Outcome 2)..... 17

Figure 5. Responsible agency, timing and funding resourcing for the quality habitat secured, restored and connected (Outcome 2). 24

Figure 6. Theory of Change for viable captive metapopulations are maintained (Outcome 3) 26

Figure 7. Responsible agency, timing and funding resourcing for viable captive metapopulations are maintained (Outcome 3) 31

Figure 8. Theory of Change for community and policy support for CGED conservation (Outcome 4)..... 33

Figure 9. Responsible agency, timing and funding resourcing for community and policy support for CGED conservation (Outcome 4) 36

Figure 10. The monitoring, analysis and evaluation framework for Canberra Grassland Earless Dragon conservation 38

Figure 11. Management plans and adaptive feedback paths for site management..... 39

List of Acronyms

ACT	Australian Capital Territory
CGED	Canberra Grassland Earless Dragon
IUCN	International Union for Conservation of Nature
MZ	Melbourne Zoo
NTG	Natural Temperate Grassland
PVA	Population Viability Analysis
TNR	Tidbinbilla Nature Reserve
ToC	Theory of Change
UC	University of Canberra

Acknowledgements

This Action Plan for the Canberra Grassland Earless Dragon was developed from the outcomes of a stakeholder workshop, which was facilitated using the IUCN One Plan planning framework (IUCN Conservation Planning Specialist Group). The workshop was held on 31st August 2023 in Canberra, ACT, and was hosted by the Office of Nature Conservation, EPSDD, ACT Government. We thank the workshop participants for sharing their expertise and providing their valuable contributions to this process. A full list of workshop participants is provided in Appendix B.

Introduction

This document presents a comprehensive plan to ensure the long-term survival of wild Canberra Grassland Earless Dragons, *Tympanocryptis lineata* (CGED) in the ACT and nearby NSW. It brings together the knowledge and expertise of highly qualified researchers, ecologists and practitioners involved in the conservation and management of Canberra Grassland Earless Dragon and the critically endangered Natural Temperate Grasslands (NTG) ecological community upon which this species relies.

The current distribution of the Canberra Grassland Earless Dragon is restricted to NTG within the Majura and Jerrabomberra valleys of the ACT and bordering regions of NSW. Wild populations have been monitored intensively since 2006, with rapid declines recorded in all ACT populations from 2017. Captive ex-situ populations exist in the ACT and Victoria (DCCEEW 2023). Background information on CGED ecology, research and monitoring to date is captured in appendix A.

The restricted range and recent declines highlight the challenges this plan faces. Threats come from both environmental and human pressures. A collaborative approach across land tenures that is endorsed by all stakeholders is essential to deliver effective conservation action for the species. The purpose of this plan is to provide a path forward for undertaking prioritised and coordinated conservation actions critical for the survival of the species in the wild. This plan will guide activities of government bodies, universities, community-based organisations, and all other stakeholders actively engaged in Canberra Grassland Earless Dragon conservation.

Conservation status

1.1. National

The Canberra Grassland Earless Dragon is listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999.* In July 2000, a listing assessment for the species was conducted concurrently with three other grassland earless dragon species; the Victorian Grassland Earless Dragon *T.pinguicolla*, Bathurst Grassland Earless Dragon, *T.mccartneyi* and the Monaro Grassland Earless Dragon, *T.osbornei*. The overarching goal of the National Recovery Plan for the four grassland earless dragon species is to stop decline and support the recovery (DCCEEW 2023).

1.2.Australian Capital Territory

The Canberra Grassland Earless Dragon is listed as critically endangered under the *ACT Nature Conservation Act 2014*.

1.3. New South Wales

The Canberra Grassland Earless Dragon is listed as critically endangered under the *NSW Biodiversity Conservation Act 2016*.

Policy and Plan context

The Action Plan for the Canberra Grassland Earless Dragon acts as a complementary document to support delivery of the National Recovery Plan for the four identified grassland earless dragons. This plan will work in concert with several other National, ACT and NSW management plans and strategies, including, but not limited to:

- The ACT Nature Conservation Strategy, 2013-2023
- National Recovery Plan for Four Grassland Earless Dragons (*Tympanocryptis* spp.) of Southeast Australia (DCCEEW 2023)
- NSW Canberra Grassland Earless Dragon (*Tympanocryptis lineata*) Saving Our Species Strategy (NSW DPE 2023)
- ACT Native Grassland Strategy and Action Plans (ACT Government 2017), including the ACT Action Plan for the Grassland Earless Dragon contained therein.
- Herbage Mass Management Plan for Lowland Grassy Ecosystems of the ACT (ACT EPSDD 2019)

50 YEAR VISION

Viable populations of Canberra Grassland Earless Dragons are established across multiple climatically suitable and protected sites, which could include where the species occurs now (2023), where it has formerly occurred, and at novel sites.

Vision and Priority Outcomes

The long-term vision of this Action Plan is that in 2075, viable populations of the Canberra Grassland Earless Dragons are established across multiple climatically suitable and protected sites.

This plan has a delivery timeframe of ten years (2025-2035). Four time-appropriate, priority outcomes for achievement in this ten-year period to contribute towards the realisation of this fifty-year vision are as follow:

1. **Extant populations are restored and expanded.**

   Wild populations of Canberra Grassland Earless Dragons are enhanced over the next ten years, delivering positive population growth for the species through the establishment and maintenance of seven viable populations. This includes the establishment of at least three new populations (including one assisted migration) and see the species is downlisted to endangered.

2. **Quality habitat is secured, restored, and connected.**

   Canberra Grassland Earless Dragons have adequate, secure, climate ready, high quality, connected habitat, which may be on a range of tenures. Actions for delivery against this priority outcome will strongly support the enhancement and establishment of wild populations.

3. **Viable captive metapopulations are maintained.**

   Viable captive metapopulations of Canberra Grassland Earless Dragons are established and maintained. Actions for delivery against this priority outcome will strongly support the enhancement and establishment of wild metapopulations.

4. **Community and policy support for Canberra Grassland Earless Dragon conservation.**

   Supporting structures (such as policy frameworks and community education) developed to support delivery of the other three thematic priorities within the plan.

Strategy Overview

This plan was developed using the IUCN One Plan Framework. A full day stakeholder workshop, attended by 33 participants and facilitators, was used to develop pathways to achieve ten-year priority outcomes. Stakeholders included people and organisations that have expertise in the ecology of Canberra Grassland Earless Dragons or their Natural Temperate Grassland habitat, or who are land managers of tenures upon which the species persists or who represent organisations with an active working interest in CGED conservation. A full list of workshop attendees is provided in Appendix B.

Prior to the workshop, a small group of Canberra Grassland Earless Dragon experts summarised current knowledge, identified threats and proposed drivers of decline (Sarre *et al.* 2023) . This information was distributed to participants prior to the workshop and provided the basis for discussions. A summary of this current knowledge is included in Appendix A.

The workshop adopted the Theory of Change (ToC) approach to explore pathways to create change. ToC is a framework that requires participants to clearly articulate their desired outcome(s) and then to deconstruct the pathways for achieving these outcomes as clear, logically linked causal chains. This is done by working backwards from the outcomes to set out the interim outcomes, then the outputs of the project, all the way back to activities. ToCs enable identification of underlying assumptions embedded within casual links between these steps. For more details on the ToC tool, its use and process, see Theory of Change Primer STAP.

This plan presents an overall Theory of Change (ToC) (Figure 1), which combines four, more detailed thematic ToCs centred around the priority outcomes for extant populations, habitat, captive metapopulations and community and policy support. Within each thematic ToC, pathways to achieving the four priority outcomes are deconstructed into activities, outputs and interim outcomes. Additional information about assumptions is presented in each themed Priority Outcomes Table, with a unique code for each activity within the table.

Each themed ToC is supported by a table that identifies parties responsible for the delivery of activities and outputs, and the corresponding indicators. A timeline for activities, including identifying activities that are required to be undertaken in sequential order, assumptions, and potential barriers is also included. Activities that are considered key linkage activities are highlighted. In addition to the tables, Gannt charts are used to provide the timeline and funding

security for each activity, and to identify “critical links and activities” – where the progress towards an outcome cannot progress unless an action is undertaken, and an assumption is true.

Thirty-seven outcomes and interim outcomes were identified across all four thematic ToCs. Several outcomes were consistent across ToCs, with secure resources and funding, data sharing mechanisms and knowledgeable people considered essential for all outcomes.

A cross-jurisdictional Canberra Grassland Earless Dragon Recovery team and expert working group will be established as part of this plan to assist with communication and driving implementation.

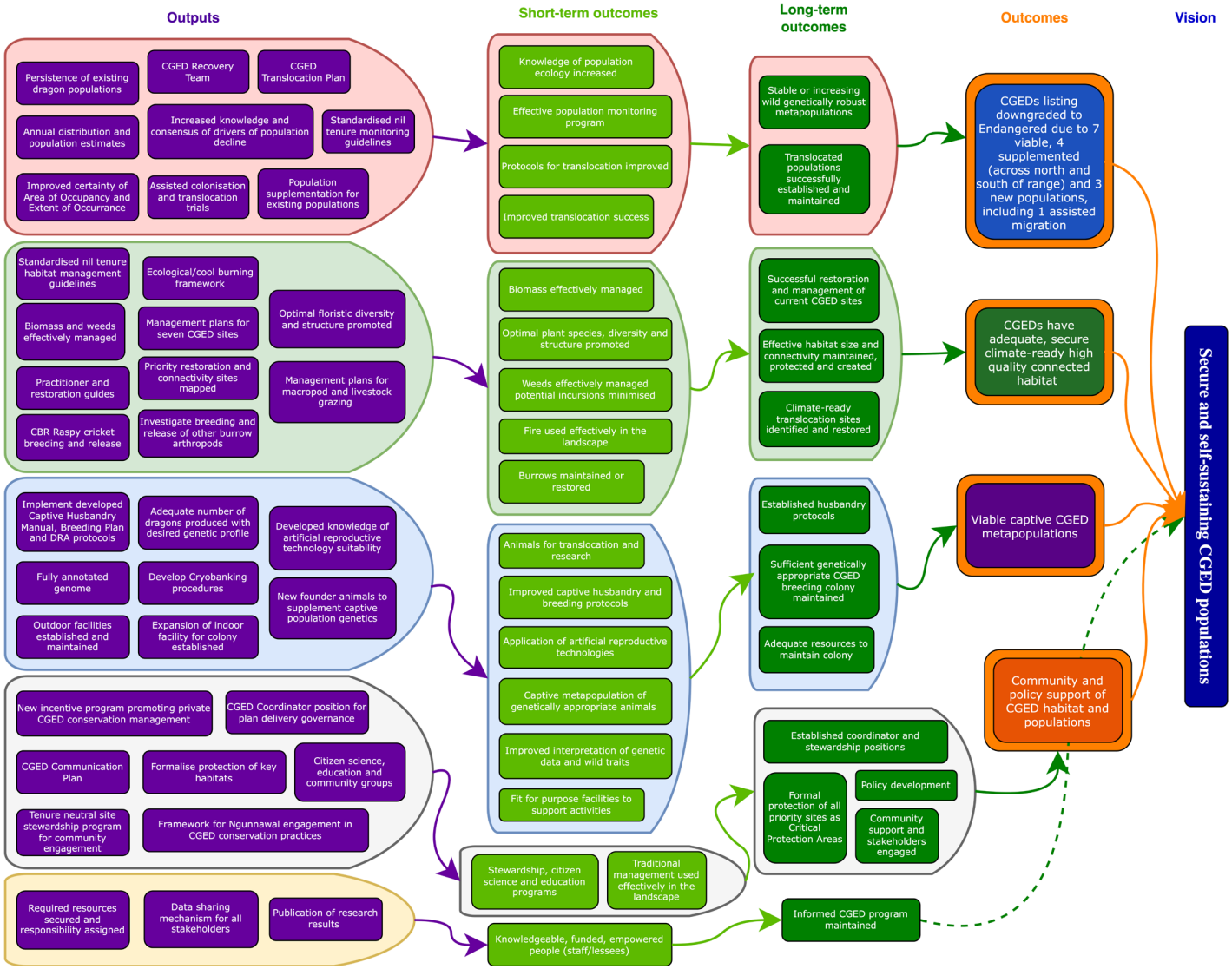


Figure 1. Total Theory of Change for the Action Plan for the Canberra Grassland Earless Dragon 2025 - 2035

OUTCOME 1: Extant populations restored and expanded

The current state of wild populations of Canberra Grassland Earless Dragons in the wild is precarious and management intervention is essential for recovery. There are 14 sites across ACT and nearby NSW where Canberra Grassland Earless Dragons have been detected since their rediscovery in 1991 (Osborne *et al.* 1993). Dragons persist in at least seven of these sites, however substantial population declines have been detected in recent years at all sites, with no detections at some sites in recent years. Increasing wild populations is a primary objective of this plan and relies on effective management action (Figure 2 and Table 1). Current knowledge provides guidance on ideal habitat parameters and likely drivers of decline, while research strives to provide additional support to management actions and improve conservation success (Appendix A).

It is accepted that translocation of captive bred dragons is a necessary action to supplement existing populations and establish new ones. A genetic understanding of current metapopulation dynamics and desired genetic diversity will guide translocation activities of captive and wild individuals. The development of a translocation population viability analysis (PVA) will also provide details on the minimum population size and metapopulation parameters required for long-term persistence, and preferred translocation sites. Research and modelling will determine sites for new population translocations and predict long-term suitability with climate change predictions. Outcomes from the PVA will be used to develop a 10-year tenure-blind translocation plan for the species. Continued program support is essential for management to meet the target goals.

Downgrading Canberra Grassland Earless Dragons listing to endangered is to be achieved through addressing the threats outlined in this plan, leading to the increase and expansion of self-sustaining Canberra Grassland Earless Dragons populations.

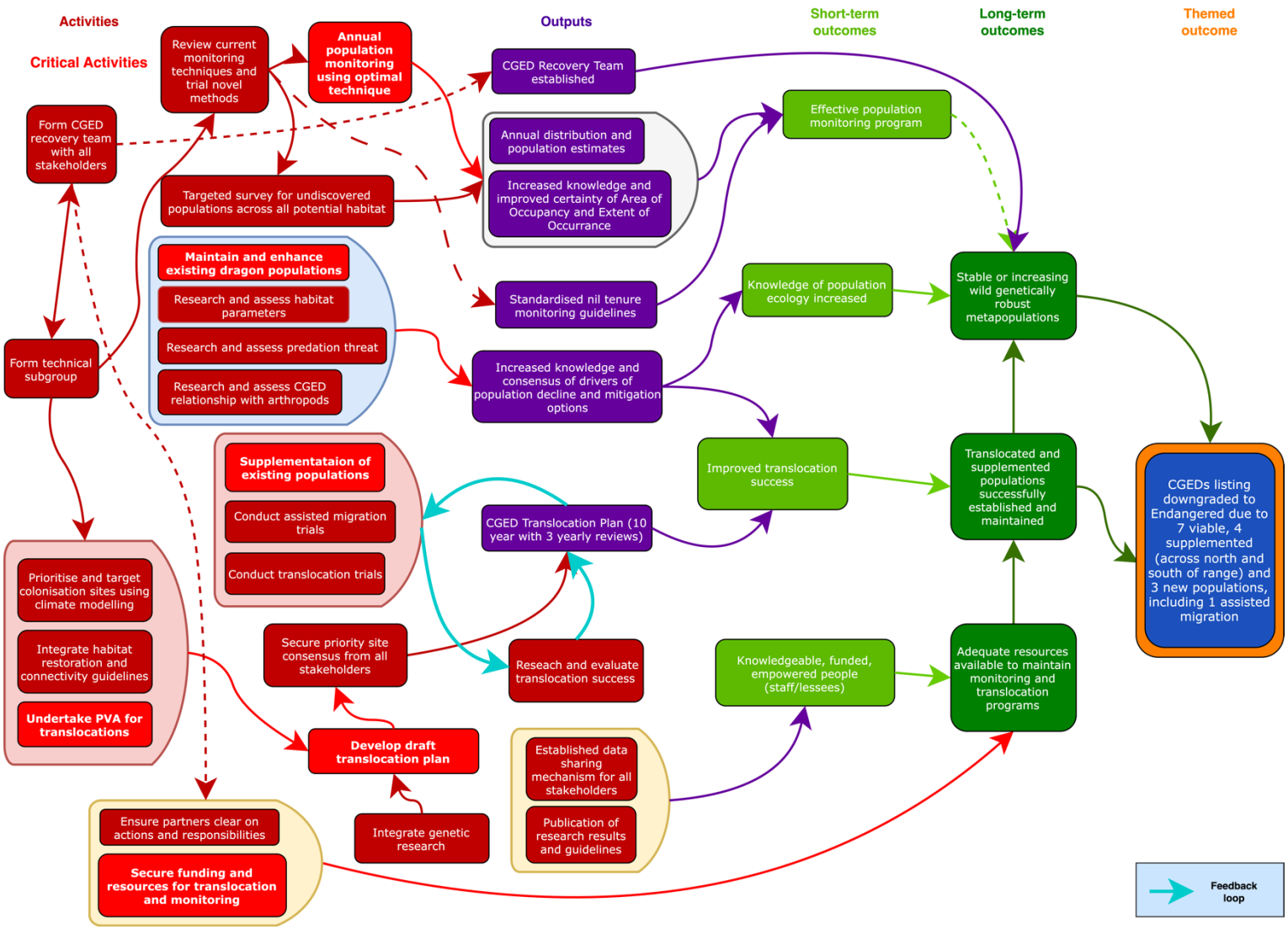


Figure 2. Theory of Change for extant populations restored and protected (Outcome 1)

*Table 1. The activities required to deliver against the Extant Populations Restored and Protected (Outcome 1) and associated responsible agency, timeline, assumptions and barriers and activity indicators. Activities considered to be key linkage activities are highlighted in **red**. Where commencement dates predate plan, work has already commenced.*

Outcome 1.1 Stable or increasing wild genetically robust metapopulations							
Outputs / Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
CGED recovery team established	A.1	All relevant stakeholders represented on recovery team	ACT Government	2025/26	CGED conservation requires management intervention (**R1**). Personnel expertise and capacity available.	Loss of institutional knowledge with staff turnover	CGED recovery team
	A.2	Technical working group formed	CGED recovery team	2025/26	Personnel expertise and capacity available	Loss of institutional knowledge with staff turnover	Technical sub-group
Effective long-term population monitoring program implemented	B.1	Review and test current monitoring techniques to ensure accuracy and trial novel methods	All land managers	Ongoing	Personnel expertise and capacity available	Ongoing funding	Monitoring is effective at detecting change in populations
	B.2	Develop standardised nil tenure CGED monitoring guidelines	CGED recovery team	2026/28, reviewed biennially	Monitoring techniques adequately tested	Detection sensitivity of available survey methods inadequate	CGED monitoring guidelines based on results of Action B.1.
	B.3	**Undertake annual dragon distribution and population monitoring using optimal technique across potential habitat range**	All land managers	Ongoing	Monitoring techniques adequately sensitive to detect low populations and small population changes and monitoring does not have a negative impact on populations	Coordination across all land tenures	Annual updated distribution map and population indices for at least 7 subpopulations
	B.4	Targeted survey for undiscovered populations across all potential habitat	All land managers	Ongoing	Understanding of potential habitat to direct surveys	Insufficient funding and access to all potential habitat	All potential habitat surveyed

Outcome 1.1 Stable or increasing wild genetically robust metapopulations							
Outputs / Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Knowledge of population ecology increased	C.1	**Maintenance and enhancement of existing dragon subpopulations**	All land managers	Ongoing	Understanding of and capacity to mitigate drivers of decline and no new threats emerge	Management capacity to address threats	Number of current populations that remain viable
	C.2	Research and assessment of dragon habitat parameters	UC	2025/29	Personnel expertise and capacity available	Ongoing staff and funding capacity	Increased knowledge and improved certainty of Area of Occupancy and Extent of Occurrence
	C.3	Research and assessment of the ecological relationship between CGED and burrow-constructing arthropods	ACT Government/UC	2026/28	A relationship between CGED and arthropods exists	Ongoing staff and funding capacity	Number of field-based trials completed
	C.4	Research and assessment of threats to dragons from predation	ACT Government/ UC	2027/29	Personnel expertise and capacity available	Ongoing staff and funding capacity	Increased knowledge and predation mitigation options

Outcome 1.2 Translocations successfully supplement and establish dragon populations							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Protocols for translocation improved	D.1	**Develop Translocation plan (10 year plan)**	ACT Government/ UC	2025/27, reviewed every 3 years	Translocation necessary to supplement existing population (**R2**). Personnel expertise and capacity available	Metapopulation and climatic modelling data available	Translocation plan
	D.2	Prioritise and target colonisation sites using climate modelling	UC	2025/26	Climate modelling and habitat parameters are accurate	Climate modelling accurate	Number of colonisation sites
	D.3	Research and evaluate translocation success	ACT Government/ UC	2024/26	Personnel expertise and capacity available	Ongoing staff and funding capacity	Increased knowledge of translocation requirements
	D.4	**PVA developed to guide minimum population size and metapopulation parameters for translocations, and preferred sites**	UC	2025/26	Sufficient dragons bred in captivity to meet PVA recommendations	Ongoing staff and funding capacity	PVA completed; CGED breeding meets PVA recommendations
	D.5	Integrate genetic research to achieve metapopulation outcomes	UC	2024/29	Personnel expertise and capacity available	Sufficient genetic understanding available	Annotated genome
	D.6	Integrate habitat restoration and connectivity guidelines	UC	2025/29	Personnel expertise and capacity available	Habitat restoration adequate for connectivity sites	Suitable connectivity sites
	D.7	Secure priority site consensus from all stakeholders	CGED recovery team / All stakeholders	2025/29	Personnel expertise and capacity available	Opposing ideas	Priority sites listed and ranked

Outcome 1.2 Translocations successfully supplement and establish dragon populations							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Improved translocation success	E.1	Population supplementation for existing populations	ACT Government/ UC	2025 – ongoing	Sufficient, genetically diverse dragons bred in captivity to meet PVA recommendations	Suitable sites for supplementation and available dragons	Number of established populations to receive captive bred dragons as directed by PVA
	E.2	Conduct assisted migration trials	ACT Government/ UC	2027 – ongoing	Genetic knowledge capable of providing advice on metapopulation requirements	Metapopulation data available	Number of established populations to receive dragons as directed by metapopulation analysis
	E.3	Conduct translocation trials to establish new dragon populations	ACT Government/ UC	Ongoing	Prioritisation of colonisation sites, PVA and captive breeding sufficiently completed.	Suitable habitat available for new populations	Number of new dragon populations established

Outcome 1.3 Adequate resources available to maintain monitoring and translocation programs							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Knowledgeable and empowered people (staff/lessees)	F.1	Develop a data sharing mechanism for all stakeholders	CGED recovery team	Develop by 2027 – ongoing	Personnel expertise and capacity available	Ongoing funding	Platform for data sharing accessible for all stakeholders
	F.2	Publication of research results and guidelines on population monitoring, translocation and threat mitigation	All agencies	Plans/guidelines 2026/29, research ongoing	Resource availability supports research and management plan activities	Ongoing staff and funding capacity	Three plans for captive colony management and publications on dragon genetics, captive breeding and translocation
	F.3	Partners clear on actions and responsibilities	CGED recovery team	Ongoing	Coordination and transparency between partners	Partner capacity to meet responsibilities	All relevant agencies represented in CGED recovery team
	F.4	**Funding and resources secured for staff, training and associated activities**	All agencies	Ongoing	Continued program support essential to meet target goals (**R3**)	Ongoing staff and funding capacity	All staff appropriately trained and monitoring and translocation programs continually funded

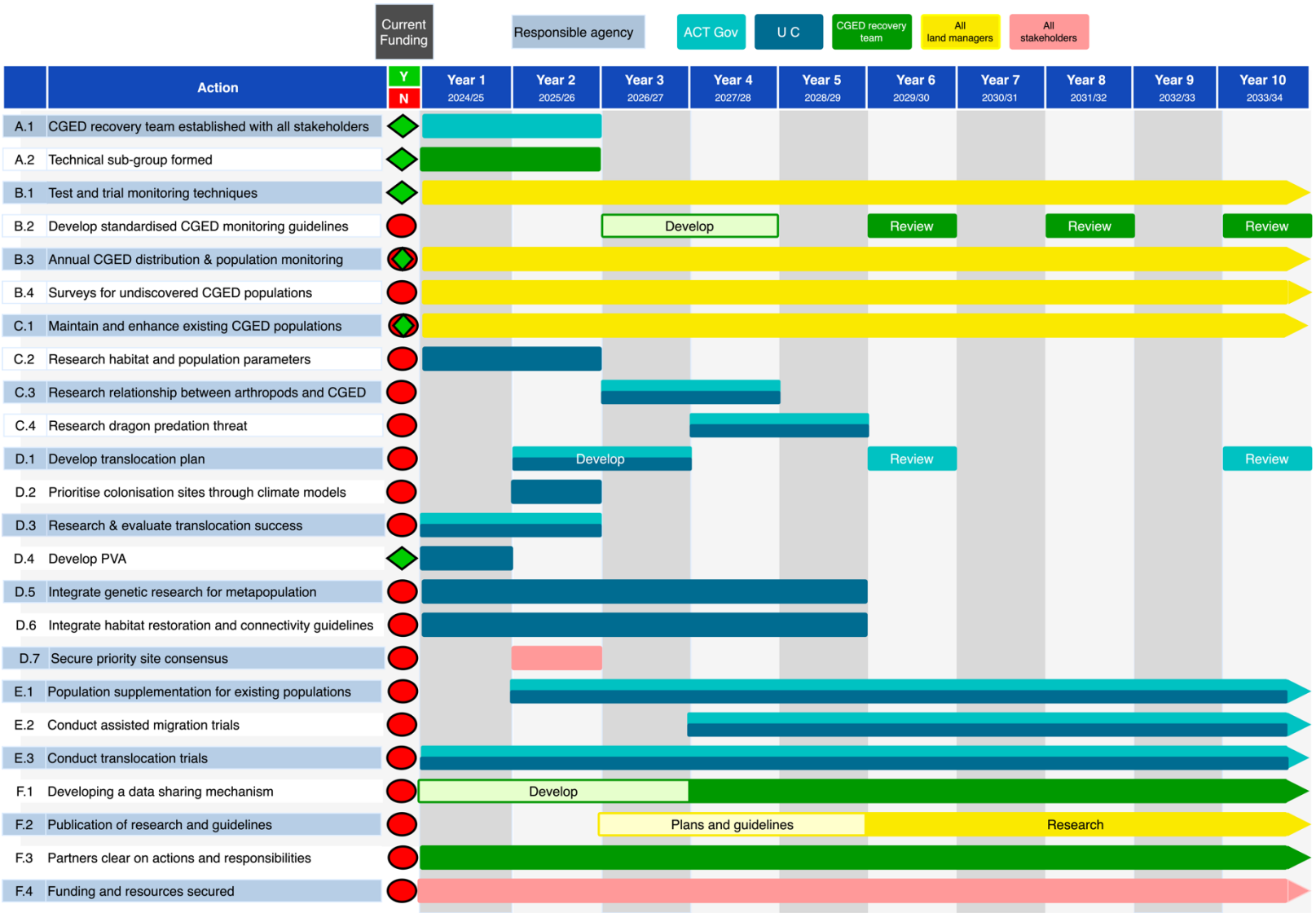
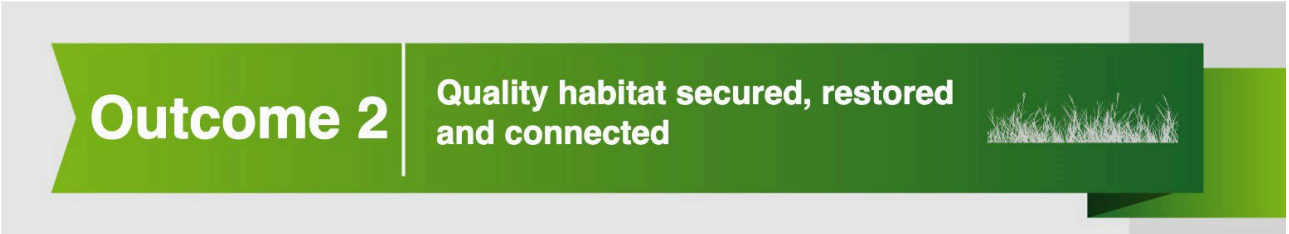


Figure 3. Responsible agency, timing and resourcing for extant populations restored and protected (Outcome 1)
Note: Timeline commences prior to plan release to capture existing work underway. Plan review will take place in final year of 2035.



OUTCOME 2: Quality habitat secured, restored and connected

Canberra Grassland Earless Dragons are dependent on quality habitat to survive. Loss in the area and quality of native grasslands is considered the major driver of decline. Habitat quality is linked to plant species, community composition, grassland structure and biomass and invertebrate burrow availability. Research has quantified ideal Canberra Grassland Earless Dragon habitat, but achieving and maintaining habitat has proved challenging. Management options for restoration are grazing, slashing, burning, weed control and native seed reintroduction. Improved understanding on the effectiveness of these methods in achieving desired outcomes, and further knowledge on optimal timing, frequency and area of management needed, is required (Figure 4 and Table 2).

Canberra Grassland Earless Dragons use invertebrate burrows for egg deposition and shelter. Declines in burrow-producing grassland invertebrates, such as the Canberra Raspy Cricket, may mean that burrow availability is a limiting resource. Artificial burrows may be used to provide shelter. Alternatively, if the threatening processes are addressed, reintroduction of invertebrates to encourage increased production of natural burrows may be a more effective solution.

Current Canberra Grassland Earless Dragon populations are fragmented, and this negatively impacts metapopulation dynamics. To prioritise sites for restoring habitat connectivity, an understanding of metapopulation genetics, effective techniques for rehabilitation of connecting habitat, and future climatic suitability of sites is required.

Figure 4. Theory of Change for the quality habitat secured, restored and connected (Outcome 2).

*Table 2. The activities required to deliver against the quality habitat secured, restored and connected (Outcome 2) and associated responsible agency, timeline, assumptions and barriers and activity indicators. Activities considered to be key linkage activities are highlighted in **red**. Where commencement dates predate plan, work has already commenced.*

Outcome 2.1 Successful management and restoration of current CGED habitat							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Optimal grassland habitat promoted	G.1	Identify optimal tools and timing for management	CGED recovery team	2025/26, reviewed annually	Personnel expertise and capacity available	Ongoing staff and funding capacity	Documented information for management tools
	G.2	Consensus of best practice management techniques	CGED recovery team	2025/26, reviewed annually	G.1 identification achieved	Ongoing staff and funding capacity	Habitat management guidelines
	G.3	Develop standardised nil tenure habitat management guidelines	CGED recovery team	2026/28, reviewed annually	G.2 consensus achieved	Ongoing staff and funding capacity	Habitat management guidelines
	G.4	Manage for optimal floristic diversity and structure	All land managers	Ongoing	Loss of quality habitat is major driver of decline (**R1**). Knowledge of optimal conditions and management actions known	Knowledge and capacity to implement management	Number of dragon sites with ideal floristic diversity and structure
	G.5	**Effectively manage biomass**	All land managers	Ongoing	Effective biomass management actions and timing known	Knowledge and capacity to implement management	Number of dragon sites with target biomass
	G.6	**Effectively manage weeds**	All land managers	Ongoing	Effective weed management actions and timing known	Knowledge and capacity to implement management	Number of dragon sites with reduced weed loads

Outcome 2.1 Successful management and restoration of current CGED habitat							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Fire used effectively in the landscape	H.1	Develop ecological/cool burning framework	All land managers	Ongoing	Knowledge of optimal fire regime known	Knowledge and capacity to implement management	Ecological/cool burning framework
	H.2	Enabling framework for Ngunnawal engagement and cool burning practices	ACT Government/ Ngunnawal	2025/28 Ongoing implementation	Mechanism for cultural burning into operations developed	Establishing a system through FMU operations	Cultural burning undertaken at CGED sites
Burrows maintained or restored	I.1	**Research and assess the relationship between burrow-constructing arthropods and burrow abundance**	ACT Government/ UC	2025/29	Abundance of burrow-constructing arthropods relates to abundance of burrows	Ongoing funding	Research projects on topics such as aggressive behaviour, predation, burrow possession & defence
	I.2	Establish Canberra Raspy Cricket breeding colony and other species if applicable	ACT Government	2027/29 Ongoing as required	Crickets can be bred in captivity	Ongoing staff and funding capacity	Number of successfully bred crickets
	I.3	Release and monitor Canberra Raspy Crickets	ACT Government	2029 – ongoing as required	Reintroduction of invertebrates will increase burrow availability (**R2**). High survivorship of captive crickets and an increase in crickets translates to an increase in burrows	Ongoing funding	Number of surviving crickets and number of burrows at release site
	I.4	Research and assess in situ recovery of burrow-constructing arthropods	ACT Government/ UC	2026/28	Threats to burrow-constructing arthropods can be addressed	Ongoing staff and funding capacity	Number of field trials testing management prescriptions on arthropod & burrow abundance

Outcome 2.1 Successful management and restoration of current CGED habitat							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Development of flexible rapidly adaptive, evidence-based spatial planning tool	J.1	Develop and spatially embed macropod grazing plan	CGED recovery team	2025/27, reviewed annually	Personnel expertise and capacity available	Knowledge on optimal management techniques available	Macropod grazing plan for managing grasslands for CGED.
	J.2	Develop and spatially embed livestock management plan	CGED recovery team	2027/29, reviewed annually	Personnel expertise and capacity available	Knowledge on optimal management techniques available	Livestock grazing plan for managing grasslands for CGED.
	J.3	Develop and spatially embed habitat restoration guide	CGED recovery team	2025/26, reviewed annually	Personnel expertise and capacity available	Knowledge on optimal management techniques available	Grassland restoration guide
	J.4	Develop and spatially embed practitioner CGED habitat management guide	CGED recovery team	2027/29, reviewed annually	Personnel expertise and capacity available	Knowledge on optimal management techniques available	CGED habitat best practice management practitioners guide

Outcome 2.1 Successful management and restoration of current CGED habitat							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Knowledge of habitat requirements and management increased	K.1	Ongoing research & assessment of habitat requirements	ACT Government/ UC	Ongoing	Personnel expertise and capacity available	Ongoing funding	Increased knowledge and improved certainty in habitat parameters
	K.2	Research role of secondary grasslands in habitat	ACT Government/ UC	2027/29	Personnel expertise and capacity available	Ongoing funding	Increased knowledge and improved certainty on the habitat value of secondary grasslands
	K.3	Research and assess influence of mammalian herbivores and fire regime on habitat quality	ACT Government/ UC	2027/30	Personnel expertise and capacity available	Ongoing funding	Increased knowledge on the impact of grazing and fire on habitat quality
	K.4	Research historic sheep grazing regimes	ACT & NSW Governments/ UC	2027/29	Personnel expertise and capacity available	Access to historical data	Increased knowledge and improved certainty of the impact sheep grazing has in grassland maintenance
	K.5	Research & assess drivers of decline	ACT Government/ UC	2027/28	Personnel expertise and capacity available	Ongoing funding	Increased knowledge and improved certainty on relative impact of CGED threats

Outcome 2.2 Effective habitat size and connectivity maintained, protected and created at climate ready sites							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Knowledge of habitat requirements and management increased	L.1	Prioritise and target connectivity and translocation sites using metapopulation analysis	UC	2025/29	Metapopulation understanding required to prioritise connectivity sites (**R3**). Genetic knowledge capable of providing advice on metapopulation dynamics	Fully annotated genome developed	Number of connectivity sites
	L.2	Prioritise and target connectivity and translocation sites using climate modelling	UC	2025/29	Future climate understanding required to prioritise connectivity sites (**R3**). Climate modelling and habitat parameters are accurate	Climate modelling accurate	Number of connectivity sites
	L.3	Select showcase restoration supersite	ACT Government	2027 – ongoing	Suitable site available		
	L.4	Undertake restoration activities at priority sites	All Land Managers	2025 – ongoing	Rehabilitation required to establish habitat at connectivity sites (**R3**). Personnel expertise and capacity available		
	L.5	Monitor and evaluate effectiveness of management actions	All Land Managers	2025 – ongoing	Personnel expertise and capacity available		
	L.6	Document site histories to highlight successful land management strategies	ACT Government	2026/29	Personnel expertise and capacity available	Access to historical data	Number of sites with management history documented

Outcome 2.2 Effective habitat size and connectivity maintained, protected and created at climate ready sites							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Buffer recommendations effectively incorporated into planning	M. 1	Establish development buffer guidelines	ACT Government	2027/29	Personnel expertise and capacity available	Land tenure adoption of guidelines	CGED habitat development buffer guidelines
Outcome 2.3 Adequate resources available to maintain habitat management activities							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Data sharing mechanism for all stakeholders	N.1	Technical group to share current habitat management information and learnings through a portal that can be accessed by all stakeholders	CGED recovery team	Develop by 2027 – ongoing	Personnel expertise and capacity available	Ongoing staff and funding capacity	Platform for data sharing accessible for all stakeholders
	N.2	Publication of research results and management plans	All agencies	2028 – ongoing	Resource availability supports research and management plan activities	Ongoing staff and funding capacity	Ten site management plans and 3 guideline documents
Knowledgeable and empowered people (staff/lessees)	O.1	Partners clear on actions and responsibilities	CGED recovery team	2025 – ongoing	Coordination and transparency between partners	Partner capacity to meet responsibilities	All relevant agencies represented in CGED recovery team
	O.2	**Funding and resources secured for staff, training and associated activities**	All stakeholders	Ongoing	Sustainable financing secured	Ongoing staff and funding capacity	All staff appropriately trained and monitoring and translocation programs continually funded

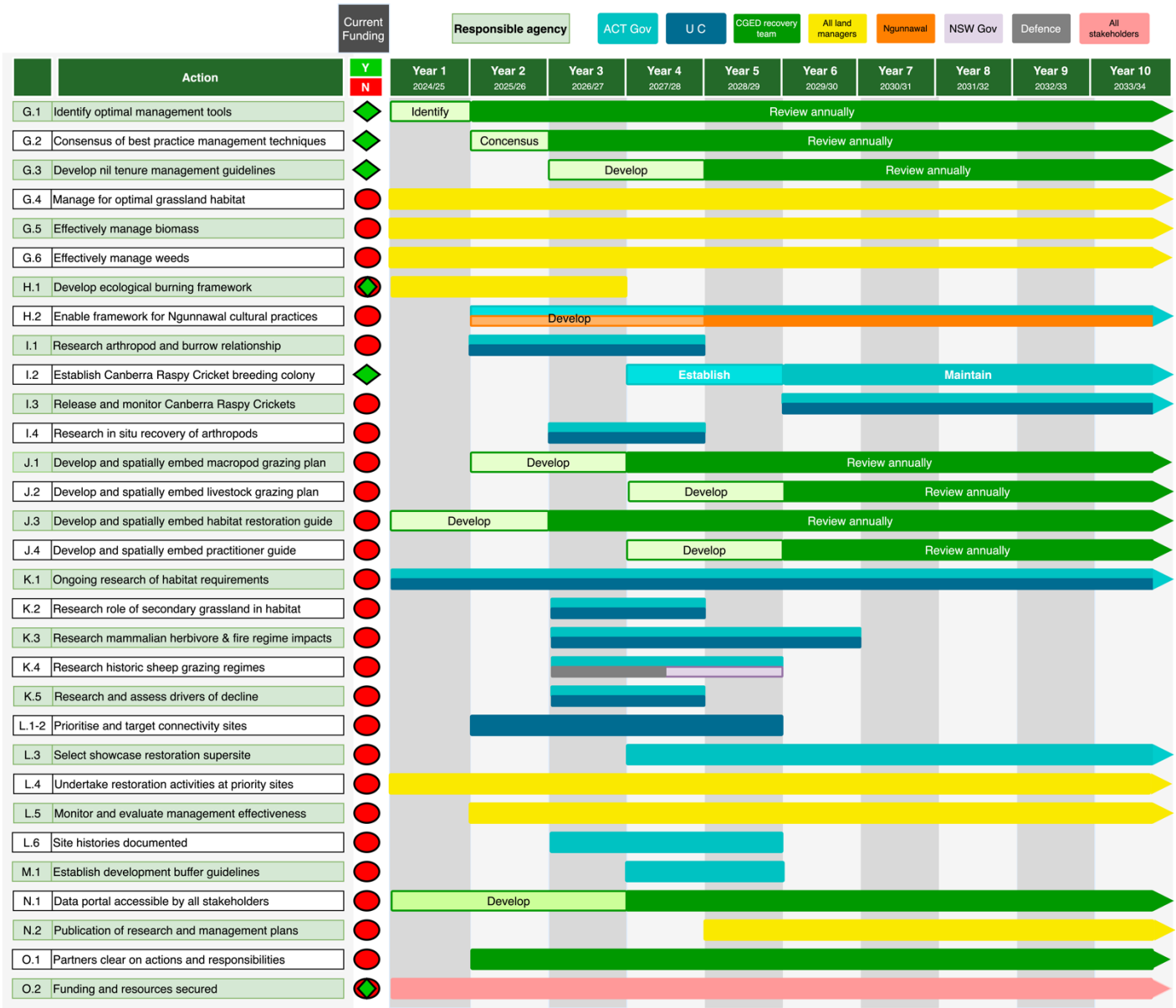


Figure 5. Responsible agency, timing and funding resourcing for the quality habitat secured, restored and connected (Outcome 2). Note: Timeline commences prior to plan release to capture existing work underway. Plan review will take place in final year of 2035.

OUTCOME 3: Viable captive metapopulations are maintained

Captive breeding populations are essential for maintaining long-term wild Canberra Grassland Earless Dragon populations (Figure 6 and Table 3). Captive bred animals are required to supplement existing populations, and to establish new ones. Captive colonies are also critical for increasing and maintaining genetic diversity of wild metapopulations and securing the persistence of desired genes. Captive colonies may also produce individuals that can be used for research. Captive colonies are currently found at Tidbinbilla Nature Reserve (TNR), Melbourne Zoo (MZ) and University of Canberra (UC) and require specialised facilities. Colonies are held in indoor and outdoor facilities. Captive husbandry guidelines for CGED that are used by all captive breeding facilities, that evolve with increased knowledge, will ensure husbandry is standardised, colony animals remain healthy, and breeding outputs are sustained.

An increased understanding of the genetic profile of dragons is considered critical for future breeding to ensure that genetic diversity is maximised, novel genes are preserved, and favourable wild traits are promoted. The development of the fully annotated genome would provide the information necessary to meet these captive breeding objectives. Captive breeding includes options of artificial breeding technologies and genetic storage using cryopreservation tools. These tools are not currently used for dragons but offer several advantages, such as reducing the reliance on natural breeding and provide long-term storage of genetic material that may otherwise be lost. It is recommended that the potential benefits of these technologies be researched.

As part of the emergency response to the rediscovery of the Victorian Grassland Earless Dragon, a Population Viability Analysis (PVA) was undertaken. In the absence of data from the Victorian Grassland Earless Dragon, Canberra Grassland Earless Dragon data was used as a surrogate to produce the PVA. The results indicate that a colony 500 breeding individuals are required to maintain evolutionary potential and to produce 100 individuals annually for translocations.

Figure 6. Theory of Change for viable captive metapopulations are maintained (Outcome 3)

*Table 3. The activities required to deliver against the viable captive metapopulations are maintained (Outcome 3) and associated responsible agency, timeline, assumptions and barriers and activity indicators. Activities considered to be key linkage activities are highlighted in **red**. Where commencement dates predate plan, work has already commenced.*

Outcome 3.1 Established best practice husbandry protocols for captive colonies							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Captive husbandry manual, breeding plan and disease risk analysis improved and developed	P.1	Develop breeding plan (5-10 year goals with yearly detailed plans) based on genetic information	UC	2025/26, reviewed annually	Personnel expertise and capacity available	Agency capacity	CGED breeding plan
	P.2	Develop best practice guidelines for captive husbandry (indoor/outdoor)	TNR/MZ/UC	2024/26	Personnel expertise and capacity available	Agency capacity	Captive husbandry guidelines
	P.3	Develop Disease Risk Analysis (DRA)	ACT Government	2024/26	Personnel expertise and capacity available	Agency capacity	Disease risk analysis assessment
	P.4	**PVA developed to guide breeding requirements for captive population size and desired genetics**	UC	2025/26	Dragons successfully breed in captivity at a level capable of meeting PVA recommendations and suitable facilities are available to house the captive population	Agency capacity	PVA completed; CGED breeding meets PVA recommendations
Developed knowledge and application of artificial reproductive and cryopreservation technologies	Q.1	Research artificial reproductive technologies	UC	2025/28 Feasibility study, ongoing implementation if feasible	Personnel expertise and capacity available	Ongoing funding	Recommendations into the viability of technique and accepted methods if suitable
	Q.2	Research artificial means such as cryobanking of retaining genetic diversity through gamete storage	UC	2025/28 Feasibility study, ongoing implementation if feasible	Personnel expertise and capacity available	Ongoing funding	Recommendations into the viability of technique and accepted methods if suitable
	Q.3	Funding and resources secured for research and development	UC	2026/27 - Ongoing	Sustainable financing secured	Ongoing funding	Actions B.1 & B.2 were completed

Outcome 3.2 Sufficient genetically appropriate CGED breeding colony maintained							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Production of CGED for insurance populations, translocation and research	R.1	**Produce the required number and genetically appropriate captive CGED for translocation and research as informed by the captive PVA**	TNR/MZ/UC	2026/28 – current breeding program Review annually	Dragons can be bred in captivity and there is an understanding of the appropriate genetics. Breeding facilities have the capacity to hold adequate numbers of CGED.	Breeding rate insufficient, breeding facilities too small to house numbers needed	Adequate number of dragons with desired genetics. Numbers to be advised by PVA.
	R.2	Maintenance of genetically diverse captive colonies as insurance populations	TNR/MZ/UC	2024 – ongoing	Breeding facilities have the capacity to hold adequate numbers of CGED.	Breeding facilities too small to house numbers needed	A minimum of 3 captive populations of adequate size and genetic diversity
Improved interpretation of genetic data and wild traits	S.1	Develop fully annotated genome	UC	2027/29	Personnel expertise and capacity available.	Ongoing funding.	Annotated genome.
	S.2	Identify and breed for desirable wild traits	UC	2028/33	Research can identify, understand and link genes to desired traits to guide selective breeding.	Genome not annotated and/or desirable traits not understood or linked.	Demonstrated understanding of traits that promote persistence of wild CGED.

Outcome 3.2 Sufficient genetically appropriate CGED breeding colony maintained							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Captive metapopulation of genetically appropriate animals	T.1	Use genetic metapopulation data to guide annual breeding plans to maximise genetic diversity	UC	Ongoing	Yearly breeding plan is produced before each breeding season is adaptive to adjust and incorporate new information and technologies.	Ongoing funding	Genetic diversity and any identified desirable trait is maintained or improved in each generation.
	T.2	Undertake targeted surveys to discover and capture individuals with novel genetic material suitable for inclusion into the captive colonies	All land managers and all captive breeding group	2024/27 surveys 2027 – ongoing as required for captive metapopulation genetic diversity	Animals remain available in the wild to supplement breeding genetics	Unable to find new founder animals or novel genetics. Unable to obtain approvals and licences to take animals from wild populations (Commonwealth, ACT and NSW).	New animals with desired genetics successfully breed.

Outcome 3.3 Adequate resources available to maintain colony							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Knowledgeable and skilled people (staff/lessees)	U.1	Publish research results and guidelines on captive breeding and genetic research.	All stakeholders	2026 – ongoing	Resource availability supports research and management plan activities	Agency capacity and ongoing funding	Three plan/guidelines for captive colony management and publications on dragon genetics, captive breeding and translocation
	U.2	Ensure partners clear on actions and responsibilities	CGED recovery team	2025 – ongoing	Coordination and transparency between partners	Agency capacity	All relevant agencies represented in CGED recovery team
	U.3	**Secure funding and resources for staff, training and associated activities**	All agencies	Ongoing	Sustainable financing secured	Ongoing funding	All staff appropriately trained
Fit for purpose facilities to support activities	V.1	Establish and maintain ring tanks and other suitable outdoor holding facilities suitable for holding/breeding CGED	TNR	2024/28 established 2028 – ongoing maintained	CGED can be held and can breed in sufficient numbers in outdoor enclosures and operational funds are secured	Ongoing funding and resourcing	Adequate number of ring tanks and/or other outdoor enclosures established at TNR
	V.2	Establish specialised indoor captive breeding facilities for CGED	TNR	2026/31	Captive colonies require specialised facilities over the long term and operational funds secured	Ongoing funding and resourcing	Specialised CGED breeding facility developed

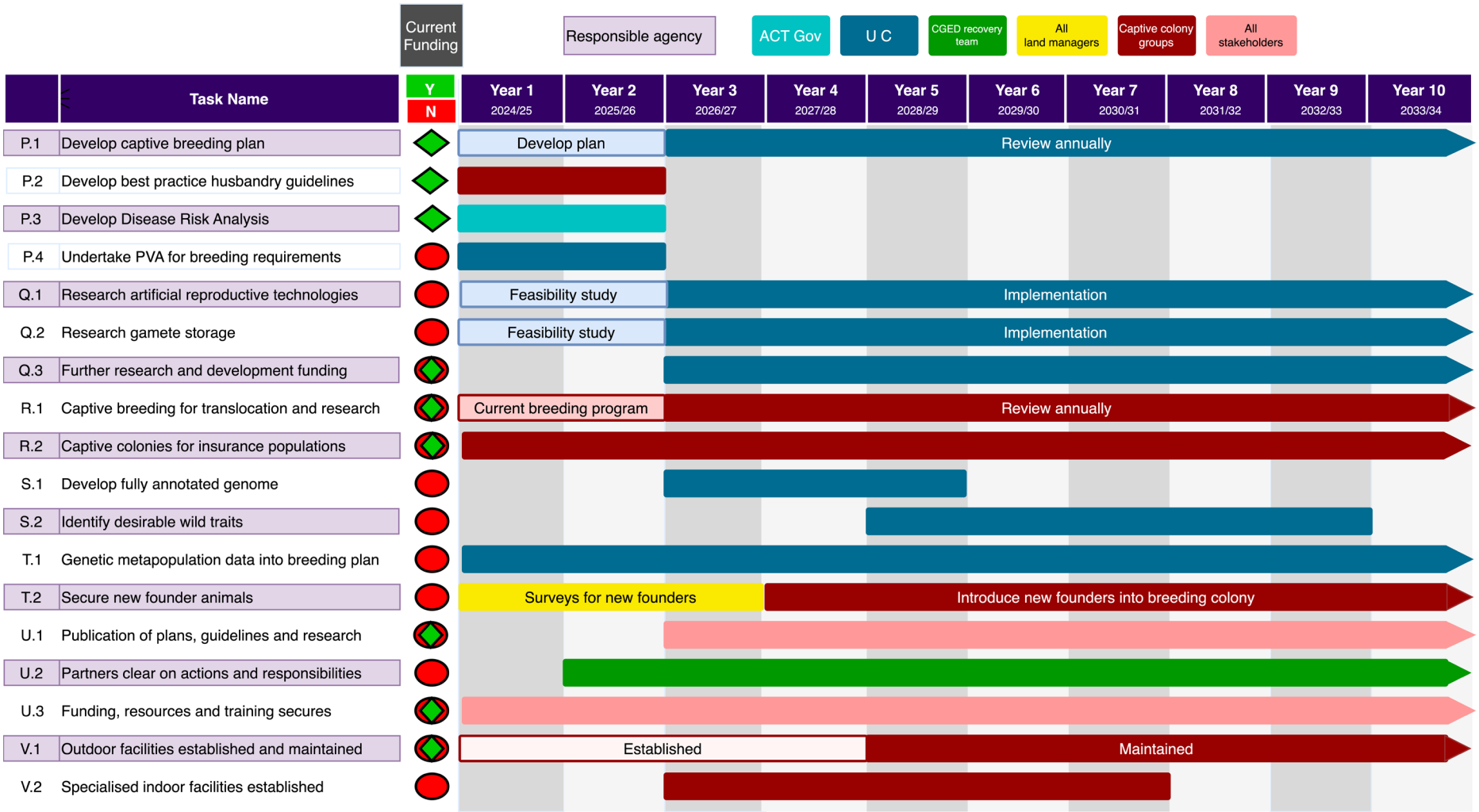


Figure 7. Responsible agency, timing and funding resourcing for viable captive metapopulations are maintained (Outcome 3).
Note: Timeline commences prior to plan release to capture existing work underway. Plan review will take place in final year of 2035.

OUTCOME 4: Community and policy support for CGED conservation

Canberra Grassland Earless Dragons are found in natural temperate grasslands across different land tenures. Long-term dragon conservation therefore relies on all land managers and stakeholders working together. This includes linking researchers, managers and policy makers with non-government groups and the general community. There are several community groups already actively restoring and monitoring grassland habitats, and these groups could be engaged to play an active role in restoration of habitat and to promote conservation. The provision of financial support for private land conservation may be another option (Figure 8 Table 4).

Local community support will be encouraged to complement conservation measures undertaken by research and land managers. Public awareness and education, reserve guardians and engaging of local conservation groups are supported by the plan through a Stakeholder Engagement Coordinator.

Urban development is a significant threat to Canberra Grassland Earless Dragon habitat and connectivity. Current policies are inadequate, and changes are required immediately to define and protect critical grassland habitat. There is opportunity to link these changes to legislative reforms at the Commonwealth level, including a review of offsets, regional planning, and the Nature Repair Market.

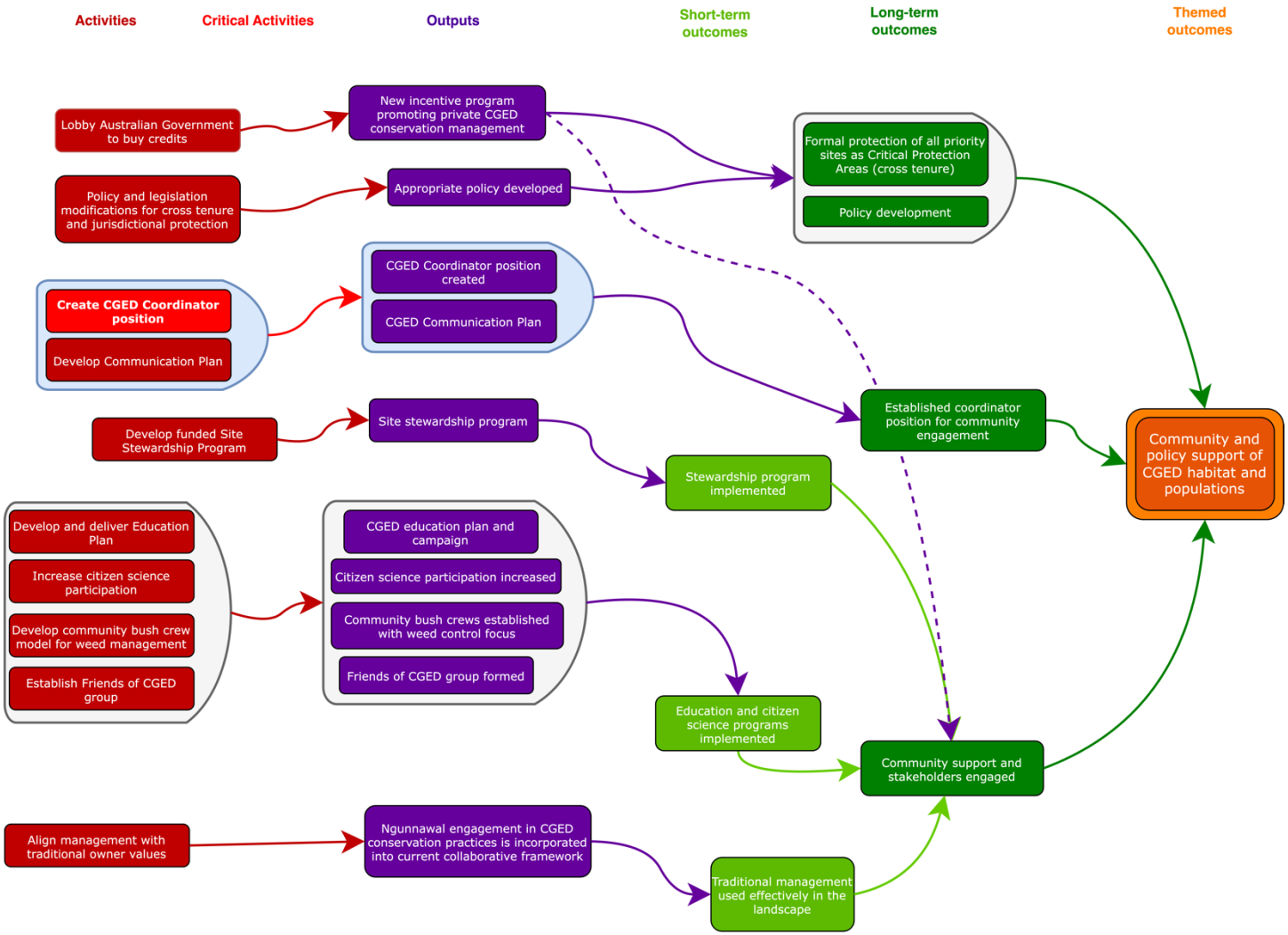


Figure 8. Theory of Change for community and policy support for CGED conservation (Outcome 4)

*Table 4. The activities required to deliver against community and policy support for CGED conservation (Outcome 4) and associated responsible agency, timeline, assumptions and barriers and activity indicators. Activities considered to be key linkage activities are highlighted in **red**. Where commencement dates predate plan, work has already commenced.*

Outcome 4.1 Strengthen community support and education							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Establish a CGED coordinator position for community engagement	W.1	**Create CGED Coordinator position**	CGED recovery team	2024 employ - ongoing	Personnel expertise and capacity available	Qualified person available	Coordinator employed/effective
	W.2	Develop CGED Communication Plan	CGED recovery team	2025/26 develop, reviewed annually	Personnel expertise and capacity available	Ongoing funding	Communication Plan developed
	W.3	Develop funded site stewardship program	ACT Government	2025/27 develop, reviewed annually	Personnel expertise, capacity, and funding available	Ongoing funding	Stewardship Program implemented
Encourage community support for CGED habitat	X.1	Develop and deliver CGED Education Plan	CGED recovery team	2025/26 develop, reviewed annually	Personnel expertise and capacity available	Ongoing funding	Education Plan developed
	X.2	Increase citizen science participation	ACT Government	2025/26, ongoing	Community is interested in citizen science program	Level of community engagement	Number of citizen science projects
	X.3	Develop community bush crew model for weed management	ACT Government	2025/26, ongoing	Community is interested in participating in a bush crew group	Level of community engagement	Number of active bush crews
	X.4	Establish Friends of CGED group	ACT Government	2025/26, ongoing	Community is interested in participating in a Friends of CGED group	Level of community engagement	Friends of CGED established
	X.5	Align management with traditional owner values	ACT Government/Ngunnawal	Ongoing	Stakeholder and Ngunnawal traditional values will align	Opposing management values	Number of cultural management activities

Outcome 4.2 Policy development leading to greater CGED protection							
Outputs/Interim outcomes	Activities		Lead agencies	Timeline	Assumptions	Barriers	Indicator
Formal protection of all priority sites as Critical Protection Areas	Y.1	Develop new incentive program promoting private CGED conservation management	ACT Government	2026 – ongoing	There will be landholder interest in private CGED conservation	Level of community engagement and funding	Number of landholder agreements
	Y.2	Policy & legislation modifications for cross tenure and jurisdiction protection	ACT Government	Ongoing	Personnel expertise and capacity available	Political resistance	Increase in area of protected habitat
	Y.3	Lobby Australian Government to buy credits	ACT Government	Ongoing	Personnel expertise and capacity available	Political resistance	Number of credits

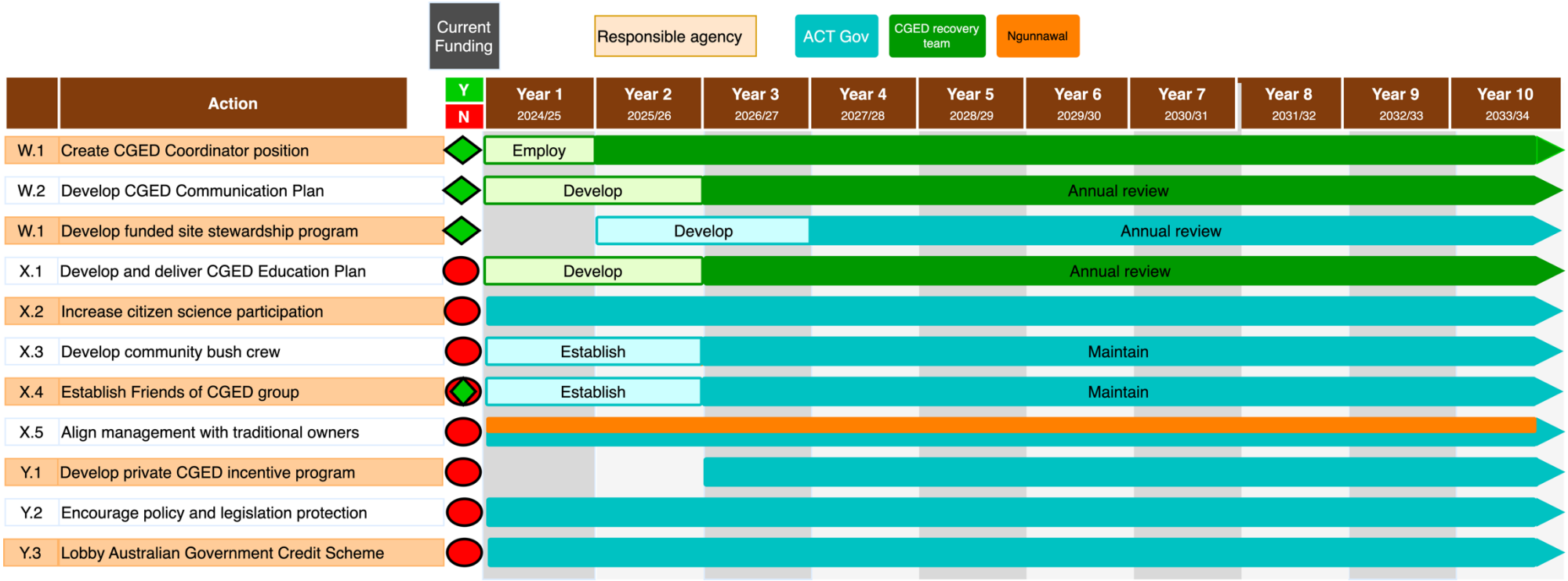


Figure 9. Responsible agency, timing and funding resourcing for community and policy support for CGED conservation (Outcome 4).
Note: Timeline commences prior to plan release to capture existing work underway. Plan review will take place in final year of 2035.

Monitoring, analysis, evaluation, and research

Monitoring and management approaches will continue to follow best current knowledge and will be reviewed and adapted regularly. To enable this adaptive process, a framework of monitoring, evaluation of data and review has been incorporated into this plan (**Figure 10).** This process also identifies governance around this shared issue, enabling joint decision making by land management stakeholders.

Monitoring of Canberra Grassland Earless Dragon populations and grassland condition currently occurs on an annual basis at long term sites. It is the intent for this to continue, with targeted and/or broader searches for new populations, to bring animals into captivity (e.g. **Table 4** Action B.4: survey for new populations). The development of a data sharing mechanism is to be completed by year 3, after which monitoring results can be reported and shared annually for analysis and evaluation (**Table 2** Action N.1).

Initial management actions abide by the precautionary principle, maintaining current livestock grazing regimes in sites where Canberra Grassland Earless Dragon persist in reasonable numbers (e.g. part of Cookanalla) or maintaining kangaroo grazing (Mikes Hill area.). Review and evaluation of research findings and management action effectiveness are scheduled in **Figure 10**, including the reporting and feedback pathways to enable an adaptive approach.

As part of this plan, habitat management guidelines and decision-making frameworks will be developed where not already available and incorporated into the overall management spatial portal. Using these tools, site management plans can be made for habitat of both existing populations, as well as for preparation for reintroductions/assisted migrations. A visual representation of the relationships between plans, on-ground action, governance arrangements and adaptive feedback loops is presented in **Figure 11.**

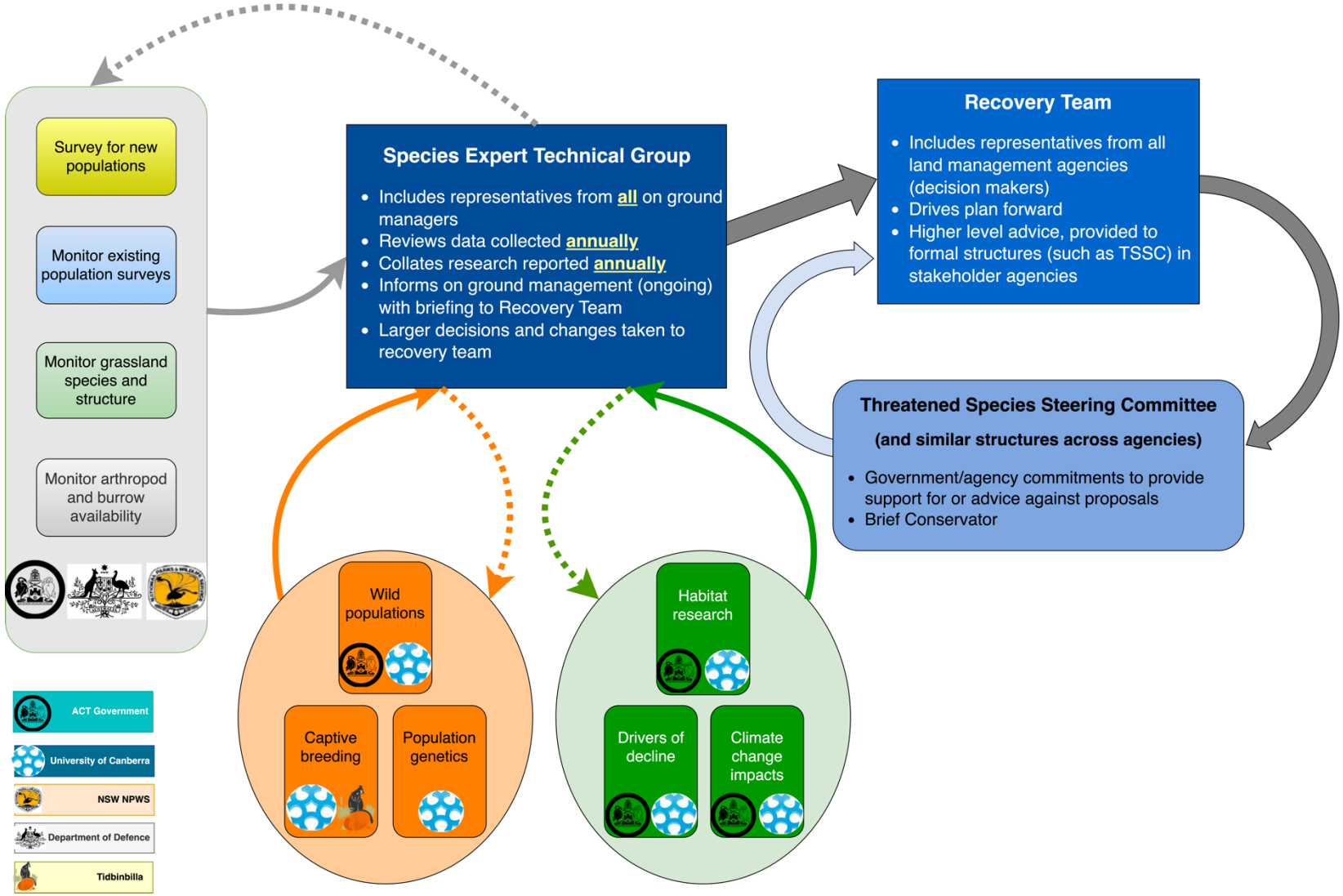


Figure 10. The monitoring, analysis and evaluation framework for Canberra Grassland Earless Dragon conservation

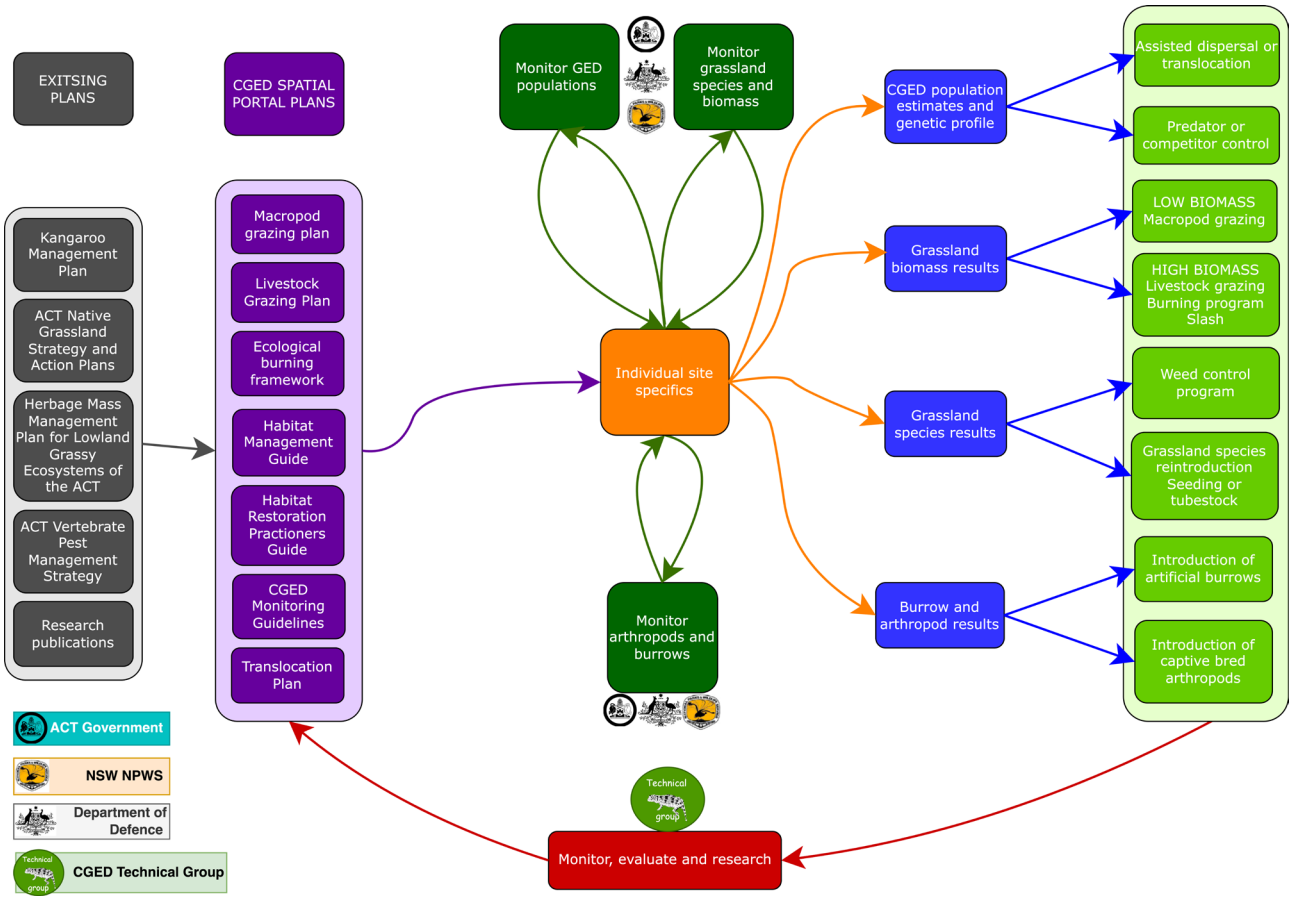


Figure 11. Management plans and adaptive feedback paths for site management

Research plan

Ongoing research programs are critical for the recovery and conservation of Canberra Grassland Earless Dragons. The proposed research programs focus on topics that increase knowledge to inform direct management actions to achieve outcomes identified in this plan (**Table 5**). Research findings will be incorporated into management as outcomes are available, and consequential actions reviewed. This may give rise to further questions to improve conservation action, therefore it is expected that research questions and priority focus will evolve over this plan. Research listed in **Table 5** represents current priorities and knowledge gaps.

Table 5. Research projects to improve Canberra Grassland Earless Dragon outcomes. Where commencement dates predate plan, work has already commenced.

Activity no.	Research description	Lead agencies	Time frame	Cost estimates & funding source	Desired outcome/indicators
B.1	Trial new and novel survey techniques to improve detectability (detection dogs, camera surveillance, eDNA)	ANU, Zoos Vic and NSW Government	1-3 years	$70K detection dogs, research grants	Significantly increase survey accuracy and efficiency
D.4 N.4	Develop PVA to guide captive breeding and translocation activities	UC	1-3 years	Internal	Provide critical information on minimum viable population size.
K.3	Continue to trial grassland management regimes that achieve ideal grassland species and structure in all climatic conditions	ACT Government & UC	1-10 years	$30K	Provide critical information on effectiveness of management & inform adaptive management
K.2	Investigate the role of secondary grasslands as habitat	ACT and NSW Government UC	2-6 years	$100K	Increased capacity to identify potential habitat & management actions
J.4	Continue to trial methods for grassland restoration	ACT Government & UC	1-10 years	Varied cost	Provide critical methods for increasing habitat
L.1 L.3	Identify habitat connectivity opportunities	UC	2-5 years	Research grants	Provide information on potential connectivity between GED populations
K.5	Continue to investigate drivers of decline	ACT Government & UC	1-10 years	Varied cost	Increased capacity to identify and mitigate potential threats
C.3 I.1 I.5	Investigate the drivers of arthropod and burrow decline and ecological relationship with CGEDs	UC	1-10 years	Varied cost	Increased capacity to identify potential threats to arthropods and resulting impact on GEDs
D.5	Continue to investigate metapopulation dynamics and wild traits of wild and captive populations	Tidbinbilla & UC	1-5 years	Research grants	Preserve genetic diversity and reduce the risk of inbreeding

Activity no.	Research description	Lead agencies	Time frame	Cost estimates & funding source	Desired outcome/indicators
C.4	Investigate the impact of predation at different CGED life stages from different predator species, density and conditions and research mitigation options	UC	1-10 years	Research grants	Knowledge of predation pressure and increased capacity to control predation
D.3	Continue to trial methods for successful translocation programs	ACT Government & UC	1-10 years	Research grants	Implement best practice procedures to promote maximum survival after translocation
N.5	Investigate the relationship between CGED offspring fitness and captive breeding facility conditions	Tidbinbilla & UC	1-5 years	Internal	Provide desired numbers of resilient CGED offspring
I.4	Continue to trial methods for captive breeding of burrow- constructing arthropods for translocation	Tidbinbilla & UC	1-5 years	Research grants	Provide desired numbers of burrow-constructing arthropods for reintroduction
O.1 O.2	Investigate the feasibility of cryopreservation and artificial reproductive technologies	UC	2-4 years	Unknown costs	Preserve genetic diversity & reduce risk of inbreeding
L.3	Investigate the optimal habitat buffer to mitigate impacts of urban development	UC	2-4 years	Research grants	Provide guidelines to protect habitat from development impact
D.2	Identify potential climate change impacts on CGED and refugia	ACT Government & UC	1-10 years	Research grants	Increase population resilience and identify translocation sites

Conclusion

This Action Plan for the Canberra Grassland Earless Dragon was developed from the outputs of a stakeholder workshop using the IUCN One Plan planning framework, and captures current knowledge and expertise, and priority activities and outputs required to achieve desired conservation outcomes for the species over the next decade. Through the development of a recovery team and technical group, coordination of project actions will occur across stakeholders.

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Appendix A: Current knowledge for the Canberra Grassland Earless Dragon

1. Current knowledge

The Canberra Grassland Earless Dragon is one of four grassland earless dragon species. All are endemic to natural temperate grasslands of southeast Australia, and all are considered endangered (DCCEEW, 2023). The Canberra Grassland Earless Dragon is the only one of the four species found in the Australian Capital Territory.

Taxonomy, distribution & conservation status

Prior to 2019 only a single grassland earless dragon species was described, *Tympanocryptis pinguicolla*. A genetic and morphometric revision by Melville et al (2019) identified four different species and defined the Canberra Grassland Earless Dragon, *Tympanocryptis lineata* as a separate species. Despite being redescribed as 4 separate species, all species remain listed under state and federal legislation, with the Canberra Grassland Earless Dragon listed as Critically Endangered (DCCEEW, 2023).

The Canberra Grassland Earless Dragon is geographically isolated and restricted to Natural Temperate Grasslands (NTG) in and around the eastern Canberra region. There are 14 distinct sites where Canberra Grassland Earless Dragons have been found since their rediscovery in 1991 (Figure 1).

Ecology & habitat

Canberra Grassland Earless Dragons are small (less than 150mm head to tail), cryptic lizards with stout bodies and short legs. Canberra Grassland Earless Dragons typically live less than two years in the wild but have exceeded five years in captivity (Doucette and Sarre, 2018). Young hatch mainly in January to March (Dimond, 2010; Langston, 1996; Doucette unpublished data) and grow rapidly, reaching sexual maturity at approximately 6 months in males and 8 months in females (Langston, 1996). Females lay clutches of three to seven (typically five) eggs at around 10 months of age in an arthropod burrow 10–13 cm deep (Doucette and Sarre, 2018). Incubation period ranges between 9-12 weeks (Langston, 1996) and females have been observed to visit nest sites daily during incubation (Doucette unpublished data). Hatching coincides with a peak in invertebrate abundance (Benson, 1999; Nelson, 2004). Invertebrates are the main prey item of Canberra Grassland Earless Dragons, which they capture through sit and wait hunting strategies. Favoured food items include ants, beetles, spiders and moths (including larvae) (Benson, 1999; Dimond, 2010; Howe, 1995). Prey selection trials also indicate that selectivity may be based on prey caloric value, with captive Canberra Grassland Earless Dragons selecting crickets over ants (Taylor 2014).

Areas of Natural Temperate Grassland and native pastures with low levels of exotics are favoured Canberra Grassland Earless Dragon habitat (Smith 1994). The grasslands are typically on well drained soils dominated by

tall speargrass (*Austrostipa bigeniculata*) and shorter wallaby grasses (*Rytidosperma* spp.) with open inter-tussock spaces (Figure 3) (Osborne et al., 1993; Robertson and Evans, 2009). A habitat configuration that includes vegetation structure with a grass height of 5-15 cm, some large grass tussocks and 6-30% bare ground is considered ideal for the Canberra Grassland Earless Dragons. Such optimal habitat provides thermal refuge and ideal hunting opportunities for Canberra Grassland Earless Dragons (Smith 1994; Stringer 2018). The presence of arthropod burrows is also critical for Canberra Grassland Earless Dragons, providing shelter and nest sites. Burrows created by the Common Wolf Spider (*Lycosa godeffroyi*) and the Canberra Raspy Cricket (*Cooraboorama canberrae*) create ideal habitat for Canberra Grassland Earless Dragons (Benson, 1999; Osborne et al., 1993). Research into the dimension and position of burrows has led to the development of artificial burrows (Figure 2).

Canberra Grassland Earless Dragon home ranges of 925–4768 m^2 include one to two natural burrows, with some overlap in home ranges (Stevens et al., 2010). Movement by adults between burrows of 40 to 110m has been recorded (Benson, 1999; Langston, 1996; Nelson, 2004; Stevens et al., 2010). Information on the dispersal pattern and movement of juveniles is limited (DCCEEW, 2023).

Figure 1. The 14 distinct sites Canberra Grassland Earless Dragons are known to have inhabited in recent history. Shaded boundaries are indicative of general area of the site only.

Figure 2. An example of optimal grassland diversity and structure (Photos by L. Padgham and W. Dimond)

Population structure and trends

Canberra Grassland Earless Dragons are divided into three genetic units or subpopulations that appear geographically isolated, with no evidence of gene flow between populations in the last 15 years (Carlson et al., 2016; Colley, 2021; Hoehn et al., 2013). Subpopulations are found in Jerrabomberra West, south Canberra (both in Jerrabomberra Valley), and north Canberra (Majura Valley; Colley, 2021). It is unknown whether these populations were historically isolated or if current changes in land use and habitat quality now pose a barrier. Data suggests that even 100m of sub-optimal grassland pose a dispersal barrier (Colley, 2021) and rivers, roads, rail lines and industrial development create a significant dispersal impediment (Carlson et al., 2016; Colley, 2021; Hoehn et al., 2013).

The initial monitoring program was undertaken in the 1990s and at that time, Canberra Grassland Earless Dragons were detected at 14 sites. Subsequent monitoring however has measured a decline across all sites. Decline events occurred between 1997 and 1999 at six sites (Airport, AMTECH, Callum Brae, Campbell Park, Malcolm Vale, and Jerrabomberra East sites; Dimond et al., 2012), at Jerrabomberra West between 2006 and 2008 and across Jerrabomberra East between 2016 and 2023. Population increases have been recorded on occasion, with several populations increasing during 2016 and in 2006 at Queanbeyan NR and Jerrabomberra West. The highest density ever recorded for Canberra Grassland Earless Dragons was at Jerrabomberra West in 2006 where dragons were 19.8 individuals per hectare (Dimond et al., 2012). Canberra Grassland Earless Dragons are now below detection levels across 36% of their former range (AMTECH, Callum Brae, Campbell Park, Malcolm Vale, Jerrabomberra West NR) despite repeated surveys (Dimond et al., 2012; B. Howland pers. comm., W. Osborne pers. comm.).

The persistence of Canberra Grassland Earless Dragons is of concern, with maximum measures of 32 breeding individuals (Colley 2021) far below the minimum number of 100 required to avoid inbreeding (Frankham et al., 2014). Population modelling has also indicated that Canberra Grassland Earless Dragons are in peril. A population viability analysis of the Jerrabomberra West population predicted a high probability of extinction at that site by 2020 (Dimond, 2010). Surveys since that time have failed to detect any Canberra Grassland Earless Dragons.

2. Conservation threats and drivers of decline

Several threats and possible drivers of decline have been identified as impacting the conservation of Canberra Grassland Earless Dragons (Table 1). Decline in habitat area and quality and the impact of fragmentation on population genetics are considered the major threat for Canberra Grassland Earless Dragon populations. Additional threats from climate change impacts, predation pressure, potential disease and the interactions between are also of concern (Figure 4).

Decline in habitat and quality

Declines in Natural Temperate Grasslands across the ACT region have declined by over 95% since European occupation (ACT Government 2017; Langston 1996) and the subsequent impact to populations was equally severe (Dimond et al., 2012). Within the remaining grasslands, there are two fine scale habitat characteristics are considered the most influential drivers of decline. These drivers are incompatible grass structure and lack of arthropod burrows. Canberra Grassland Earless Dragons have very specific requirements for vegetation structural requirements and their distribution within sites is limited by the quality of vegetation and numbers of burrows (Sarre et al., 2020; Stringer 2018; Osborne unpublished data from 1994; Benson 1999). Such specialised requirements mean that all sites known to contain populations of Canberra Grassland Earless Dragons have areas of potential habitat that is suboptimal or unusable (ACT Government 2017). Such a reduction in suitable habitat is likely to compound dispersal barriers and reducing the carrying capacity of individual sites (ACT Government 2017).

Grazing is an important activity that shapes the diversity and structure of grasslands. Changed grazing regimes from sheep, rabbits and macropods to macropods and rabbits alone has required additional management activities be introduced, such as burning, slashing and reintroduction of livestock grazing. Understanding the required timing and intensity of these activities to achieve the optimal grassland diversity and structure is still under investigation. Expansion of weeds into grasslands have also impacted habitat quality. Some species are predicted to be more of a threat to Canberra Grassland Earless Dragon persistence and listed as very high or high risks - African Lovegrass, Chilean Needle Grass, Cape weed, Patterson's Curse and St John's Wort (Walker and Osborne 2010). A significant consequence of suboptimal grass structure is the impact on burrow-constructing arthropod fauna and in turn, a reduction in burrows.

Other agricultural practices such as ploughing, cropping, sowing of exotic pastures, fertilisation, de-rocking & pesticide use all contribute to a decline in CGED habitat quality. Such activities disturb the soil, encourage weed invasion and reduce invertebrate populations (DCCEEW, 2023). The majority of Canberra Grassland Earless Dragon populations are currently found on public land with low risk of intensive agricultural practices.

Habitat fragmentation

The remaining Canberra Grassland Earless Dragon sub-populations are highly fragmented (Carlson et al., 2016; Colley, 2021; Hoehn et al., 2013), small (Colley, 2021), and in some cases highly related (Carlson et al., 2016). It is unclear if fragmentation is a driving process or emerging, but it does severely limit the opportunity for recovery through metapopulation growth and connectedness. The small effective population sizes observed (Colley, 2021) suggest that without intervention, inbreeding is likely to be a limiting factor in the future. Assisted dispersal and supplementary individuals from captive breeding provide an opportunity to address population genetic concerns.

Climate change

The changing climate poses challenges for Canberra Grassland Earless Dragons through a combination of factors in a yet uncertain relationship. Investigation into rainfall and dragon abundance found no clear relationship (Sarre et al., 2020). However, a link between changes in mean daily maximum temperatures and activity levels in that Canberra Grassland Earless Dragons has been demonstrated (Doucette et al., 2023). The amount of time required by Canberra Grassland Earless Dragons to be active has increased by around 40% since 2000 because of increases in temperature alone (Doucette et al., 2023), however activity decreases with increasing ambient temperature. The fitness consequences of this are yet unmeasured.

Predation

Canberra Grassland Earless Dragons are susceptible at all life stages, but direct predation has only been observed for adults. Predation of adult Canberra Grassland Earless Dragons has occurred from snakes and birds, with up to 14% of radio-tracked Canberra Grassland Earless Dragons predated (MacDonald et al., 2016). Other radiotelemetry research of wild living animals has revealed negligible predation upon adults (Lisa Doucette unpublished data). The predation of Canberra Grassland Earless Dragons by mammalian and invertebrate remains unmeasured. Opportunistic observations have documented two instances of a praying mantis predating upon naive released Canberra Grassland Earless Dragons (B. Croak pers comm 2023). Encroaching urbanisation is also likely to increase Canberra Grassland Earless Dragon exposure to feral cats and foxes (DCCEEW, 2023).

Disease

Disease has not been detected in wild Canberra Grassland Earless Dragons populations, but ha been detected in captive colonies. Monitoring of captive and in situ populations is important to rapidly detect and address any new and emerging diseases.

No one threat operates in isolation and the level of impact will be site and situation specific. Table 1 lists the different attributes considered important for Canberra Grassland Earless Dragon persistence and the role these attributes play as drivers of decline. Figure 3 provides a schematic representation of the complex interactions of factors influencing Canberra Grassland Earless Dragon populations.

3. Current monitoring programs

Grassland earless dragon populations

Regular abundance monitoring of the larger ACT Canberra Grassland Earless Dragon populations has been undertaken since 2002 using fixed grids of artificial burrows (Osborne, 2018: Dimond, 2010; Dimond et al., 2012; Fletcher et al., 2009). The number of grids surveyed (2-10 per site) and the number of days of survey (11-23) has varied over the years. Key sites for population monitoring are those with an established long-term monitoring program (Majura Training Area, Jerrabomberra West Grassland Reserve, Jerrabomberra East Grasslands) which are monitored to determine long-term population trends and to evaluate the effects of management actions. Monitoring has begun more recently at Cookanalla in the Jerrabomberra Valley. Monitoring at the NSW sites have been maintained in transects rather than the grid-based approach used by the ACT monitoring team and therefore the two are not directly comparable.

The probability of detecting a Canberra Grassland Earless Dragon on grids using the current monitoring is approximately 0.01 averaged across all years and sites (Sarre et al., 2020), meaning that there is only a 1% chance of detecting an individual that is present at a grid during one survey visit. Such low detection probabilities limit confidence in abundance estimates and makes any population trends difficult to detect (Sarre et al., 2020).

Monitoring the genetic structure of existing Canberra Grassland Earless Dragon populations has identified three genetic subpopulations (Carlson et al., 2016; Colley, 2021; Hoehn et al., 2013) and found that no gene flow between them has occurred in recent years (Colley, 2021). Investigations into dispersal barriers, such as roads and rail lines, is ongoing.

Grassland diversity and structure

ACT Grassland Conservation Strategy and Action Plans (ACT Government 2017) and Herbage Mass Monitoring Protocol (ACT Government 2019) outline the grassy layer monitoring protocol for assessment of grassland condition. Surveys assess the dominant plant species, grass height and cover and the amount of rock, thatch and litter present. In addition, the Lowland Native Grassland Ecosystem Condition Monitoring Plan outlines the condition of all grasslands assessed against a series of metrics that include grassland communities and weed incursions (Brawata et al 2017). Ongoing annual surveys contribute to the understanding of grassland response to different climatic conditions and management interventions.

Table 1. Potential drivers of decline in Canberra GED (modified from Sarre et al 2023)

Attribute	Issue	Importance and impact	Reasons for change
Burrows	1. Lack of burrows	1. Thermal protection 2. Increase predation risk 3. Egg protection and incubation	1. Lack of invertebrates 2. Soil compaction from livestock 3. Biomass volume reduce suitability for invertebrates 4. Climate change/extreme weather impact on soil moisture 5. Herbicide and/or pesticide impact
Vegetation structure	1. Vegetation too short or too long reducing quality 2. Loss of heterogeneity 3. Lack of intermediate habitat	1. Impact foraging opportunities 2. Impact thermoregulation 3. Protection from predators 4. Inhibit movement 5. Food availability 6. Display and mating behaviour	1. Changes in fire 2. Type of grazing (selective or non-selective) 3. Inappropriate grazing pressure (overgrazed or absent) 4. Climate influenced (e.g. drought) 5. Weed incursions (e.g. love grass)
Vegetation composition	1. Reduction or loss of C4 grasses 2. Increased occurrence of weeds 3. Loss of native forbs 4. Change in niche with loss of forbs	1. Influence food for invertebrates 2. Impact resilience to weed invasion 3. greater enviro niche, 4. Changes vegetation structure 5. Change competition with grass	1. Historic agricultural practices (e.g. livestock grazing) 2. Changes in fire regime 2. Type of grazing (selective or non-selective) 3. Inappropriate grazing pressure (overgrazed or absent) 4. Climate influenced (e.g. drought) 5. Weed incursions (e.g. love grass). 6. Fertiliser or other nutrient addition, 7. Disturbance
Food availability	1. Loss of prey availability 2. Loss of prey diversity	1. Reduce survival 2. Reduce male growth and mate selection (e.g. males too small) 3. Inhibit egg laying capacity	1. Changes in fire regime 2. Type of grazing (selective or non-selective) 3. Inappropriate grazing pressure (overgrazed or absent) 4. Climate influenced (e.g. drought) 5. Weed incursions (e.g. love grass) 6. Fertiliser or other nutrient addition, 7. Disturbance

Attribute	Issue	Importance and impact	Reasons for change
		4. Increase foraging time, predation risk and thermoregulatory requirements	8. Historic agricultural practices (e.g. livestock grazing), 9. Herbicide and/or pesticide impact 10. Unfavourable climate fluctuations 11. Inappropriate vegetation structure and composition
Predators	1. High predation rates	1. Reduce survival 2. Inhibit population growth 3. Limit recruitment	1. Increase in brown snakes due to mice abundance and urban fragmentation 2. Increased mammalian predators (cats and foxes) due to supplementary food from urbanisation 3. Increase in urban birds (ravens, magpies) 5. Increase in invertebrate predators with favourable conditions 6. Land-use promotes predator increase
Increased overheating risk	Extremes in weather, leading to more droughts, more rain in shorter periods and hotter temperatures	1. Reduced protection with change habitat structure and composition 2. Extreme heat mortality 3. Reduce food availability and foraging times 4. Desiccation of eggs 5. Impact egg laying moisture conditions (e.g. too dry or wet) 6. Eggs develop mould 7. Timing of ideal thermal niche shifts or reduced 8. Increase predation risk	1. Climate change emission levels 2. Unfavourable climate fluctuations 3. Inappropriate vegetation structure and composition
Genetic loss and/or inbreeding	Small populations with lack of movement within metapopulations	1. Inability to recolonise 2. Loss of fitness 3. Lack of adaptability 4. Inbreeding depression	1. Habitat loss 2. Reduced habitat quality 3. Barriers to dispersal (eg. road, rail, drains, development) 4. Tree planting in grasslands
Small population sizes	Small population paradigm / vortex	1. Impact population dynamics 2. Increase vulnerable to single event	1. Habitat loss 2. Reduced habitat quality

Attribute	Issue	Importance and impact	Reasons for change
		3. Inability to recolonize 4. Allee effect 5. Affect mate selection	3. Barriers to dispersal (eg. road, rail, drains, development) 3. Likelihood of single climate impact higher with climate change
Area of available habitat	Reduction in total grasslands	1. Limits population size 2. Larger populations have greater long-term viability 3. Reduced refugia from climate 4. Reduces niches 5. Restricting distribution and increasing risk from climate impacts	1. Agriculture use 2. Urban expansion 3. Suboptimal grassland diversity and structure
Quality of available habitat	Reduction and fragmentation of potential habitat	1. 1. Impact foraging opportunities 2. Impact thermoregulation 3. Protection from predators 4. Inhibit movement 5. Food availability 6. Display and mating behaviour	1. Changes in fire 2. Type of grazing (selective or non-selective) 3. Inappropriate grazing pressure (overgrazed or absent) 4. Climate influenced (e.g. drought) 5. Weed incursions (e.g. love grass) 2. Agriculture use
Pathogens	Animals get a fungus	1. Fungus can kill 2. Captive colony infection limits reintroduction potential	1. Climate change increase fungus risk 2. New emergent diseases

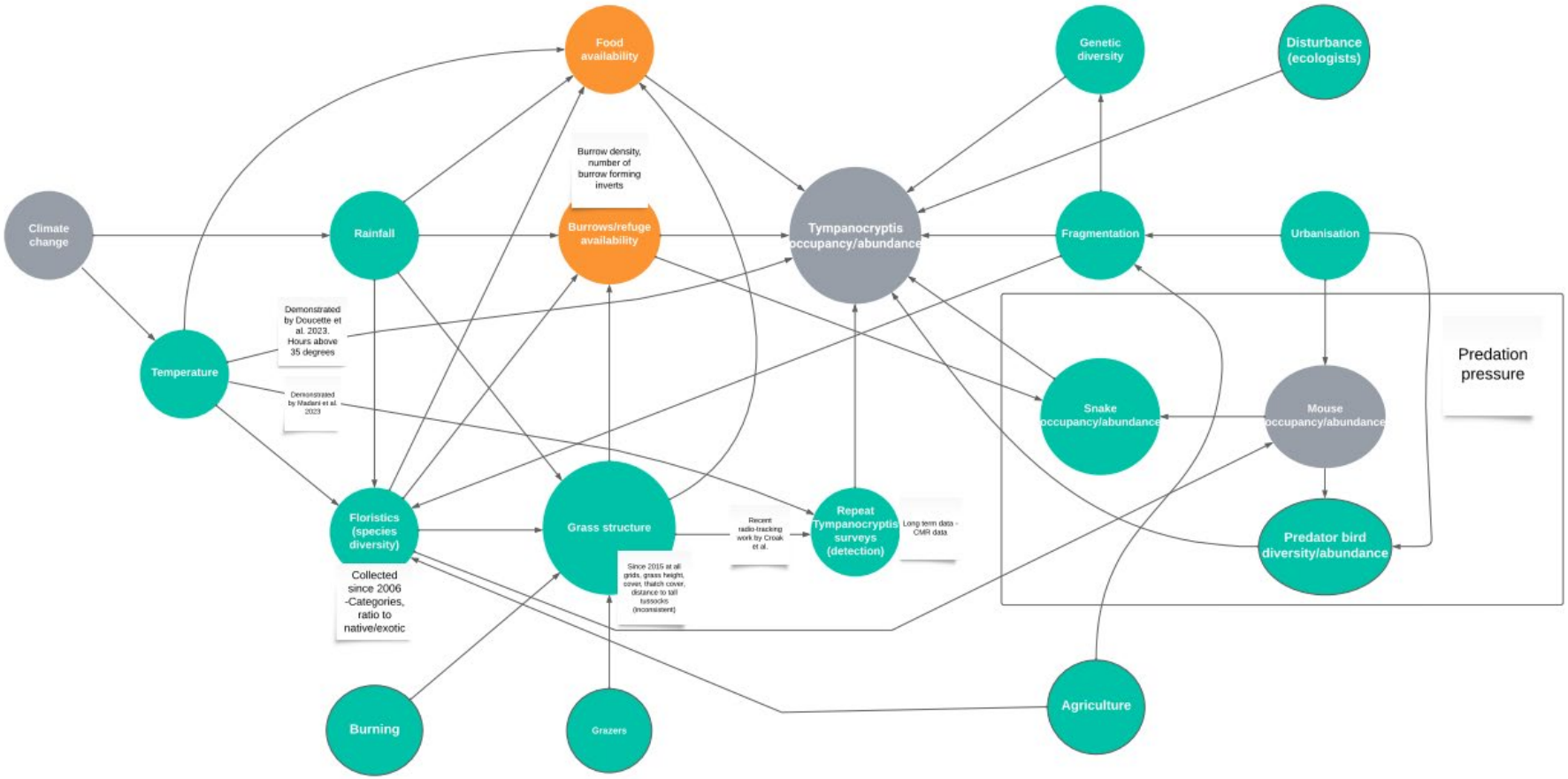

Figure 3. Interaction diagram produced with the expert working group. Diagram shows the potential drivers of decline and the interactions between the various contributing factors to the abundance of Tympanocryptis spp.

4. Current management

The focus of current management is to facilitate the persistence of existing Canberra Grassland Earless Dragon populations. To achieve this goal, the priority is to maintain a varied grassland structure and avoid herbage biomass extremes. Grass height of between 5 and 15cm with well-defined inter-tussock spaces composed of shorter grasses, forbs and bare ground (16-30%) is linked with Canberra Grassland Earless Dragon abundance (Howland et al., 2014) by maximising the range of shelter and thermal niches, and types of prey available for Canberra Grassland Earless Dragons (Stevens et al., 2010; Taylor, 2014).

Grassland management

Managing grassland condition for the target grass structure varies with site, grassland type and climate conditions. Several management options are currently used to maintain Canberra Grassland Earless Dragon habitat.

Grazing

Low to moderate level of sheep grazing that maintains grass coverage with low soil compaction is beneficial (Robertson and Evans 2012). Overgrazing creates excessive bare ground, increasing weed invasion, reducing invertebrates and increasing thermal and predation exposure. Insufficient grazing promotes high biomass, low inter-tussock spaces, inhibits basking and dispersal and increases fire risk. The timing, intensity and type of grazing regime capable of providing the desired grassland structure is a challenge. Sites where Canberra Grassland Earless Dragons persist have experienced different grazing regimes. For example, Cookanalla supports low sheep grazing, while the Mikes Hill area is grazed solely by kangaroos. The management for each site is outlined in Table 2 below.

Fire

The use of fire at sites follows a regime that creates a mosaic of burnt patches, while maintaining 30-50% unburnt areas (Figure 4). The timing of any burn considers the activity of the Canberra Grassland Earless Dragons and their capacity to avoid the fire, while also considering the dominant grass species response. The resulting guidelines are for afternoon burns between March and October for *Themeda* grasslands and either March to May or September to December for tussock grasslands. Previous ecological burns have been conducted in West Jerrabomberra, with spring burns in 2012-14 burning mosaic patches that ranged in size from 5-50m^2. Population monitoring suggest a positive response and no direct mortality (Gilbert 2018).

Figure 4. Patch burning in action and the mosaic burn pattern from the 2012 treatment (Photos by M. Gilbert).

Slashing

Slashing is considered a last resort management action as the residual thatch and soil compaction has a negative impact for Canberra Grassland Earless Dragons. If required, slashing is also undertaken during the afternoon when Canberra Grassland Earless Dragons are most active and should occur in the same months as listed for ecological burns. Slash height should not be below 10cm. The Majura West site at the Canberra Airport is managed through regular slashing at a height of 15cm.

Weed control

Weed control is site specific and dependant on the weed species of concern. Species that form dense swards such as Phalaris and African lovegrass are of particular concern. Management plans have been developed at some sites, such as the Jerrabomberra Valley African Lovegrass Management Plan (2019-2029).

Burrows

The observed decline in arthropod burrows has led to the introduction of artificial burrows. Artificial burrows are a small PVC pipe buried adjacent to a grass tussock. Artificial are used by Canberra Grassland Earless Dragons and have also proved useful for surveying (DCCEEW 2023).

Captive breeding and release of burrow-constructing arthropods, like the Canberra Raspy Cricket are also being investigated as a means of creating more natural burrows.

CGED captive breeding

There are currently three Canberra Grassland Earless Dragon captive breeding colonies that contain over 60 dragons between them. These are at Tidbinbilla Nature Reserve, University of Canberra and Melbourne Zoo. Dragons are housed in an internal animal house in all 3 facilities and external ring tanks at Tidbinbilla. Breeding is managed for genetic representation of Canberra Grassland Earless Dragons and maintaining a captive metapopulation across facilities is a priority.

5. Current Canberra grassland earless dragon sites

There are 14 distinct sites that Canberra Grassland Earless Dragons are known to have inhabited in recent history (Figure 1). Current knowledge on the dragon population and habitat quality is listed in Table 2. Information on land manager and potential threats and opportunities are also outlined.

Table 2. CGED site summary information. List of sites where Canberra Grassland Earless Dragon has been recorded since 1995. The Estimated area of habitat is provided and includes a mix of Grassland types. Natural Temperate Grassland = NTG, Manager refers to the current land manager and includes ACT Government, Federal Government, the Canberra Airport Group, ACT rural leases, NSW National Parks and Wildlife Service, and NSW private properties. GED population size is based on available monitoring data and expert opinion. Assumed extinct = not seen since 2010; undetected = not detected since 2021; small = likely less than 50 individuals; Moderate = likely between 50-100; High = more than 100 individuals; Translocated = a new population has been established from captive breed animals. Current Site management lists the primary management actions used to manage vegetation biomass.

	Estimated area of habitat	Grassland type	Manager	Estimated GED population size in 2024	Monitoring history	Current Site management
Canberra Airport	20-25	NTG, Native pasture	Canberra Airport Group	Undetected since 2017.	Periodically since 1992	Slashing, weed control.
Majura West	100-110	NTG, Native pasture, Exotic pasture	ACT Governm ent	Assumed extinct.	Monitored in 1997/98	Kangaroo grazing, weed control.
Campbell Park	35	NTG, Native pasture, Exotic pasture	Dept Defence	Assumed extinct.	Monitored in 1997/98	Kangaroo grazing, weed control, ecological burning.
Majura Training Area	140	NTG, Native pasture, Exotic pasture	Dept Defence	Small	Most years since 1997	Kangaroo grazing, weed control, ecological burning.

	Estimated area of habitat	Grassland type	Manager	Estimated GED population size in 2024	Monitoring history	Current Site management
Majura Training Area (Malcolm Vale)	90	Native pasture, Exotic pasture	Dept Defence	Assumed extinct.	Monitored in 1997/98	Kangaroo grazing, weed control.
Amtech	10-15	NTG, Native pasture, Exotic pasture	ACT Government	Translocated.	Monitored since reintroductions 2022	Kangaroo grazing, weed control.
Cookanalla	160-170	NTG, Native pasture, Exotic pasture	Rural broadacre	Small.	Periodically since 2013	Livestock, weed control.
Bonshaw North	60	NTG, Native pasture, Exotic pasture	ACT Government	Small.	2021 - present	Livestock, Kangaroo grazing, weed control, ecological burning.
Bonshaw South	90	NTG, Native pasture, Exotic pasture	ACT Government	Small.	2021 - present	Kangaroo grazing, weed control, ecological burning.
Queanbeyan Nature Reserve	66	NTG, Native pasture	NSW NPWS	Medium.	2006 - present	Kangaroo grazing, weed control, ecological burning.

	Estimated area of habitat	Grassland type	Manager	Estimated GED population size in 2024	Monitoring history	Current Site management
NSW Private land	40-60	NTG, Native pasture, Exotic pasture	Private landholder	Small.	2011 - present	Livestock, kangaroo grazing, weed control.
Jerrabomberra East	70	NTG, Native pasture, Exotic pasture	ACT Government	Medium.	1997- 2009 - present	Kangaroo grazing, weed control, ecological burning.
Jerrabomberra West	180	NTG, Native pasture, Exotic pasture	ACT Government Nature Reserve	Undetected since 2019.	2006 - present	Livestock, urban development.
Callum Brae	160	NTG, Native pasture, Exotic pasture	Rural broadacre	Assumed extinct.	2020/21	Kangaroo grazing, weed control, ecological burning.

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Appendix B: Workshop participants

Name	Organisation
Alex Mitchell	Melbourne Zoo
Alison Rowell	Private consultant
Arthur Georges	University of Canberra
Ben Croak	ACT Government
Berlinda Bowler	Department of Defence
Bernd Gruber	University of Canberra
Braithan BellGarner	ACT Government
Brett Howland	ACT Government
Brian Butler-Kemp	ACT Government
Carolyn Larcombe	Wandyali Restoration Trust
Chad Beranek	University of Newcastle
Chloe Sato	ACT Government
Clare Kerr	NSW Government
Clare McInnes	Umwelt
Deon Gilbert	Melbourne Zoo
Elizabeth Mitchell	Department of Defence
Emma Carlson	ACT Government
Frank Garofalow	ACT Government
Geoff Robertson	Friends of Grassland
George Madani	Dragon Allianz
Georgeanna Story	ScatsAbout Ecological
Grant Rootes	ACT Government
Jacqui Richardson	University of Canberra
Jess Thomson	University of Canberra
Ken Hodgkinson	CSIRO
Laura Rayner	ACT Government
Linden Chalmers	ACT Government
Maree Gilbert	ACT Government

Mary Mudford	ACT Government
Michael Thomson	Canberra Airport
Noel McCann	Canberra Airport
Peter Roberston	Wildlife Profiles
Phil Papas	Victorian Government
Renee Brawata	ACT Government
Richard Duncan	University of Canberra
Rob Armstrong	NSW Government
Rob Spiers	Capital Ecology
Rory Keenan	University of Canberra
Rosie Cooney	ACT Government
Ryan Colley	University of Canberra
Sarah May	Tidbinbilla Nature Reserve
Stephanie Pulsford	ACT Government
Stephen Sarre	University of Canberra
Steve Taylor	ACT Government
Sue McIntyre	Australian National University
Susan Mathams	Department of Defence
Sussanah Power	NSW Government
Thea O'Loughlin	ACT Government
Tim McGrath	Federal Government
Will Osbourne	University of Canberra
Zarko Danilov	Canberra Airport