

Perunga Grasshopper <i>Perunga ochracea</i>	-	En	7	Yes*	Yes*	-
Pink-tailed Worm-lizard <i>Aprasia parapulchella</i>	Vu	Vu	6	Yes*	Yes*	No
Striped Legless Lizard <i>Delma impar</i>	Vu	Vu	8	Yes	Yes*	Yes - examine feasibility
Flora						
Austral Toadflax <i>Thesium australe</i>	Vu	Vu	2	-	No	Yes
Button Wrinklewort <i>Rutidosis leptorhynchoides</i>	En	En	5	Yes	Yes	-
Canberra spider orchid <i>Caladenia actensis</i>	CR	CR	3	Yes	Yes	-
Ginnenderra Peppercress <i>Lepidium ginninderrense</i>	Vu	En	3	Yes	-	Yes
Hoary Sunray <i>Leucochrysum albicans</i> var. <i>tricolor</i>	En	-	25	-	-	Yes
Pale Pomaderris <i>Pomaderris pallida</i>	Vu	Vu	5	-	No	Yes
Small Purple Pea <i>Swainsona recta</i>	En	En	7	Yes	Yes	Yes
Small snake-orchid* <i>Diuris subalpina</i>	-	Rare	1	-	-	-
Tarengo leek orchid <i>Prasophyllum petilum</i>	En	En	0	Yes	Yes	Yes
Tuggeranong Lignum <i>Muehlenbeckia tuggeranong</i>	En	En	0	Yes	Yes	Yes

*Recommended taxonomic revision to *D. subalpina* yet to be recognised by the Council of Heads of Australasian Herbaria; still referred to sometimes as *D. pendunculata* from which it has been split.

Recommendation

- 3.12 Carry out an analysis to identify which grazing sensitive species, including threatened species and species of cultural significance to the Ngunnawal Traditional Custodians and other Indigenous families, could be included in a translocation program to restore grazing sensitive species to nature reserves with appropriate habitat, and where threats (including excessive or insufficient kangaroo grazing) are adequately managed. Develop a strategic multi-species and multi-site translocation plan, ideally considering non-reserved as well as reserved land. To the extent possible, use plants and animals that are being moved out of the footprint of the urban expansion; implement the program to gain knowledge about species ecology and limits to recovery; to involve community environment groups in the program; and to administer it efficiently.

4. ECONOMIC IMPACTS

Summary assessment

It is challenging to assess whether kangaroo culling on rural lands is achieving the objective of maintaining the economic viability of properties. There are no data available on spatial and temporal changes in kangaroo density on rural land. The Review was not provided with any data on changes in livestock density, or pasture condition (if these data exist). However, records are kept of the numbers of kangaroos licenced to be shot per property, and the numbers that are reported as shot, and these numbers roughly track weather conditions (e.g., increasing after wet years shift to dry years). This suggests the rural cull is realistically responding to changes in kangaroo grazing pressure. Property-level decisions about how many kangaroos are reasonable to cull are based on the Rural Cull Calculator, which is logical, and designed to cover the needs of most properties.

The regulation and management of rural culls requires landholders to conduct operations to a standard that exceeds the national Code for non-commercial shooting of kangaroos.

Main recommendations

Kangaroo density on rural lands is highly variable, with some properties having no kangaroos, and others, especially some that border reserved areas, with very high densities. An ACT-wide spatial assessment could identify variation in kangaroo density across rural lands, and focal areas for collaborative kangaroo management. Focal areas would include 1) locations with grazing sensitive threatened species. In such cases, the ACT Government could ensure landholders are technically supported so that total grazing pressure, including kangaroo grazing, is managed appropriately at these locations. 2) Rural leases next to reserved land that routinely have very high kangaroo densities; this is likely to degrade the ecological health of the reserved land and the economic yields and sustainability of the rural lease. The Land Management Agreements are one possible mechanism for formalising the collaboration over kangaroo management at focal areas, but there may be more suitable alternatives. Management could involve culling, strategic fencing, guardian dogs, etc, and there are likely to be opportunities for landholders to seek funding through grant systems (e.g., Regional Landcare Partnerships Program), or stewardship payments (e.g. Nature Repair Market). These suggestions are consistent with multiple actions in the 'Rural Landscapes' chapter of the ACT's Natural Resource Plan (ACT Government 2022).

The results of the spatial assessment could also be used to design and implement a monitoring program for changes in kangaroo density across rural lands in the ACT, ensuring that locations with grazing sensitive threatened species, and interfaces of rural and reserved land, are both included. The monitoring could be carried out periodically, for example every 4-5 years, possibly varying the frequency to coincide with major weather changes from wet to dry conditions and vice versa. The purpose of the program would be to generate information on kangaroo densities that can be used to inform livestock and kangaroo grazing management by rural landholders, and inform more specific objectives in the collaborative landholder-government planning. Ideally monitoring on rural lands would be embedded in an ACT-wide program (see cross-plan recommendations).

4.1 Plan

Kangaroos are a drawback for nature-based tourism. The main negative economic impact of high densities of kangaroos is on rural land, because kangaroos compete for grazing with stock (including horses), and damage fences. Collisions with kangaroos on roads also result in economic costs through vehicle damage and injury to people, but this issue is reviewed in the Social Impacts section.

In relation to land managed for agricultural outcomes, the objectives in the 2017 Plan are:

- *Rural land:*
 - *Objective - Free-ranging kangaroo populations on rural lands are managed so that their densities do not seriously impact on the economic viability of rural properties.*
- *Government horse paddocks:*
 - *Objective - Free-ranging kangaroo populations on government horse paddocks are managed so that their densities do not seriously impact on the viability of the paddock complexes.*

There are no specific performance criteria or outcomes articulated for these objectives, to allow landholders some flexibility in deciding the acceptable level of kangaroo grazing for their situation. In addition, the Land Management Agreements, required for every rural lease, could provide for more specific objectives to be set. In any case, in the absence of quantitative or qualitative data for total grazing pressure, kangaroo densities and pasture condition (see Sections 4.3 and 4.4), performance against the objective cannot be assessed.

The 2010 and 2017 Plans note that kangaroos bring positive economic benefits via nature-based tourism. However, on rural land, increasing densities of kangaroos negatively affect the viability of farming businesses by damaging fences, and grazing grass that could otherwise be eaten by livestock. Overgrazing by the combination of livestock, kangaroos and rabbits can lead to erosion, affecting longer-term economic viability. Kangaroo grazing has also affected the operation of government horse paddocks, leading to substantially fewer horses being maintained at paddocks where there are high numbers of kangaroos. During the consultation carried out during this review, farmers also mentioned that kangaroos contributed to the spread of weeds, including from roadsides to farms and then out to protected areas, with environmental and economic consequences.

There are economic costs from kangaroo-vehicle collisions, from damage to vehicles and medical costs to vehicle occupants (Cope and Herbert 2023; Dunne and Doran 2021), but the 2017 Plan states that reducing these impacts is not an objective of kangaroo management. Nevertheless, there is an objective relating to vehicle collisions, in section 6.4 of the 2017 Plan:

- The incidence of vehicle-kangaroo collisions in the ACT is reduced.

but the Plan states that actions to achieve this objective are the responsibility of road management. This Review considers the issue of road collision further in [Section 5.2 Road collisions](#).

Recommendation

[See recommendation 2.2 about setting SMART objectives; See recommendation 4.4 for survey and monitoring to inform those objectives]

4.1 The revised Plan could identify where any relevant lease-level objectives in relation to kangaroo management should be identified. See recommendation 4.2.

4.1.1 Does the Plan make an evidence-based case for kangaroo management on rural lands?

The 2010 and 2017 Plans review the evidence for grazing competition between stock and kangaroos, and for kangaroo grazing in paddocks that are being spelled, or that have been sown with forage. There is no contention over the general effects of overgrazing, and that farmers must manage grazing from kangaroos, livestock, and introduced herbivores to match pasture productivity. Therefore, if kangaroo numbers increase (for a given amount of forage), livestock numbers need to be reduced.

There is some debate in the scientific literature about the extent and nature of dietary overlap between livestock and kangaroos, the relative amount of forage they consume and their contributions to overall grazing pressure, and the conditions under which competition is most pronounced (for example, see, Pahl 2020). However, there is no contention over the general effects of overgrazing, and that farmers must manage that grazing to match pasture productivity. If kangaroos (or rabbits or deer) are present, farmers must estimate how much of their forage budget will be consumed by these animals, and adjust livestock numbers accordingly. By culling kangaroos, farmers can make more of their forage budget available to livestock. There has been some interesting work to estimate the equivalence of grazing by a kangaroo to one sheep, with earlier work suggesting a standard kangaroo was equivalent to 0.4 or 0.7 of a standard sheep, but later work revising that number closer to 1 (reviewed in, Pahl 2020).

The 2017 Plan states that there are 150 rural leases in the ACT, covering 39,500 hectares or 17% of the Territory. Rural leases are required to develop Land Management Agreements, which set out the cooperative management of the lease for sustainable management that maintains the ecological and cultural values of the land. The Agreements are approved by the Conservator. A recent audit of the operation of Land Management Agreements for rural leases noted that as of March 2020 there were 180 Land Management Agreements for 27,000 ha of rural

land, with leases varying in size from 2 to 500 hectares (ACT Auditor-General 2021). The government response to this audit states that there are 183 rural leases (held by 159 families), across 40,000 ha, of which 25,000 ha is considered arable. The gross value of agricultural production in the ACT in 2019 was \$34 million, mostly from livestock grazing (ACT Government 2021b).

4.1.1.1 Kangaroo density on rural lands in the ACT

There are very few data available on the density of kangaroos on ACT rural land (unless they are part of a KMU), and most estimates come from over 20 years ago. The average kangaroo density suggested by the estimates is 0.76 kangaroos/ha, but with low confidence.

There are very few data available on the density of kangaroos on ACT rural land (unless they are part of a KMU), and the estimates come from over 20 years ago (Table 2). Current data on kangaroo density from the commercial NSW commercial harvest zone that surrounds the ACT is also shown in Table 2. It seems likely that kangaroo densities in rural areas are highly variable, depending on the location of the farm. For example, during the consultation carried out during this Review, some farmers said they had very few kangaroos on their grazing lease, while others stated that very large numbers of kangaroos were a serious problem. The latter situation occurred for farms adjacent to bushland without active kangaroo management, presumably because this interface offers the ideal combination of cover and pasture (see also, Viggers and Hearn 2005). For rural lands that are part of KMUs, then the average kangaroo density estimated by monitoring across the KMUs between 2018-23 is the best estimate for those rural lands, but they cover a small area.

The 2010 Plan notes the lack of recent data on kangaroo density on rural lands, and states gaining density data is important. The situation has not changed since then, and the value of getting density information has only increased.

Table 2. Densities of kangaroos on rural land in the ACT, and from the NSW Southeast Tableland kangaroo harvest zone, which surrounds the ACT.

Year	Density (per ha)	Source
1986	1.67	Farm (Perry and Braysher 1986)
1995	0.50	Appendix 5; 2010 Plan
1996	0.59	Appendix 5; 2010 Plan
1996	0.48	Appendix 5; 2010 Plan
1997	0.39	Appendix 5; 2010 Plan
2015-23	0.37	Average density of kangaroos SE Tableland harvest zone NSW (NSW DPE 2023).
2018-23	1.35	Average density of kangaroos across all KMUs (some of which include small areas of rural lands) (value calculated during this Review). Note the area of rural land in the KMUs is small relative to the overall area of rural land, and it may not be representative.,
average	0.76	

Recommendation

[Consider an ACT-wide spatial assessment to identify variation in kangaroo density across rural lands, and focal areas for kangaroo management outside of the reserved areas. See recommendation 4.3.]

4.1.2 Does the plan have a conceptual model and evidence-based thresholds on rural lands?

Kangaroo grazing impacts and management are considered within the conceptual framework of Total Grazing Pressure from livestock, introduced species (rabbits, deer), as well as kangaroos. However, there is no guidance in the 2017 Plan on what that means in practice, perhaps because that is better handled in other planning

instruments such as the Land Management Agreements. There are two scenarios where enhanced collaboration between rural landholders and the Government over grazing management is important, and more specific kangaroo grazing impact thresholds may need consideration: one is at locations on rural lands with grazing sensitive native species, and the second is at the interface of reserved land and rural land. Where these interfaces are within a KMU, the conservation cull process triggers collaboration with the landholder, but there is no such trigger when the reserved land is not within a KMU.

The 2017 Plan notes that “the concept of total grazing pressure” has been used as the conceptual framework for determining suitable kangaroo densities on ACT rural lands.” However, there is no information on what that means in practice. The Rural Cull Calculator sets an upper limit on the number of kangaroos that can be killed, and then relies on the judgement of the lessees to manage kangaroos within that bound, and in accordance with the regulations set to protect kangaroo welfare (i.e., competency test, culling season). The Calculator encourages lessees who need to manage kangaroos to do so annually with modest culls, rather than intermittently with larger culls. Presumably most lessees will take a pragmatic cost-benefit approach toward the kangaroo density they aim to achieve, by stopping culling when the grazing benefits for livestock are less than the rising costs of continuing to kill kangaroos as their density declines.

On rural leases, kangaroo (and livestock) management may be especially important at sites with grazing sensitive species (including threatened species), or on farmland/bushland interfaces with very high kangaroo densities, where high total grazing pressure could damage pasture and soil. There is no information in either the 2017 Plan or the Rural Cull Calculator on how to identify such priority areas and then plan grazing management to protect farming viability and conservation values. The [Land Management Agreements](#) are one potential prism for identifying such priority areas and the relevant kangaroo management targets. For example, the Land Management Agreement for a rural lease that has a grazing-sensitive threatened species could identify the spatial location for the threatened species, and the specific grazing management (covering livestock, rabbits, and kangaroos) that will be used to maintain the grass layer appropriately at this location. This Review cannot assess whether this level of planning is occurring. However, a recent audit of Land Management Agreements found them lacking in the detail required to articulate such outcomes, and to monitor progress towards achieving outcomes (ACT Auditor-General 2021). The ACT Government has committed to improving the level of management detail in plans, and improving monitoring and compliance (ACT Government 2021b).

In another example, some rural leases are adjacent to reserves with high kangaroo densities. Where the rural land is part of a KMU, there are operational and monitoring mechanisms (kangaroo counts, grass layer monitoring, regular communication between government staff and landholders) in place to support a collaborative approach to kangaroo management across the KMU. In contrast, the consultation for the Review revealed that some rural leases are adjacent to reserves, and this interface has high kangaroo densities, with no kangaroo management taking place in the reserve portions; in these situations there are fewer mechanisms to support collaboration over kangaroo management, except for when the authorisation to cull is being sought. At that point, there can be discussion between government staff and the landholder about the numbers to be culled. In the 2017 Plan, this specific scenario is addressed in *section 6.1.1 ‘Kangaroo movement between government managed land and rural leases’*, and it opens the door for collaborative action between the landholder and the ACT Government. More involved collaboration between the lessee and the ACT Government could be articulated via the Land Management Agreement process, but the Review does not know whether this occurs or not. Extending the very detailed planning and monitoring approach used in conservation culls in Canberra Nature Park to other reserved lands in the ACT is unrealistic, but planning support for rural landholders to ensure that management is as targeted and effective as possible, and maintains the values of the reserved land, is achievable.

Recommendation

- 4.2 Consider the options for enhancing government-landholder collaboration over kangaroo management planning on rural leases where kangaroo grazing, as a component of total grazing pressure, is a problem for threatened species; or where high kangaroo densities are occurring on the interface between rural lands and reserves without regular kangaroo management, leading to high grazing pressure on rural land that damages short- and longer-term economic viability, and high grazing pressure on conservation land that damages ecological health. Options may include ensuring that the specific issue, the management response, the

required monitoring, and roles and responsibilities are detailed in revised Land Management Agreements, or some other mechanism.

4.2 Implement

Kangaroos on rural lands may be culled by landowners with authorisation from the Conservator. Authorisations are applied for, and granted, annually.

4.2.1 Rural Culling Calculator

The Rural culling Calculator sets a maximum number of kangaroos to be culled based on the area and shape of a property. Given the average densities on rural lands (see 4.1.1.1), the allowable cull appears generous, but kangaroo density is likely to vary substantially around this average.

The cull on rural lands seeks to reduce the economic costs of kangaroo grazing to farmers, and the managers of the government horse paddocks. Rather than setting a target density, the calculator sets a maximum that can be culled in a calendar year as:

$$2 \text{ per ha} \times \text{immigration factor.}$$

The immigration factor = $1 + (PA/5)$ where PA is the perimeter (km) to area (km²) ratio. The immigration factor compensates for difficulties applying the calculator to small properties and long narrow properties. What this means in practice is that small properties may apply to cull a higher number of kangaroos, and properties that have a longer perimeter for the same area can apply to cull more kangaroos (Fig. 5).

Mixed sex culls on rural land are conducted between 1st March to 31st July. The rural cull calculator also allows for no more than 30% of the total cull for the calendar year to be a male-only cull, occurring from 1st August to 31st October.

The Rural Culling Calculator Determination states that the calculator aims to support the needs of property owners while preventing excessive culling; and that the formula is based on the experience of government ecologists over many years, and replaces earlier, more complex formulas that considered variation among properties in carrying capacity, the nature of neighbouring land, and the extent of previous culls.

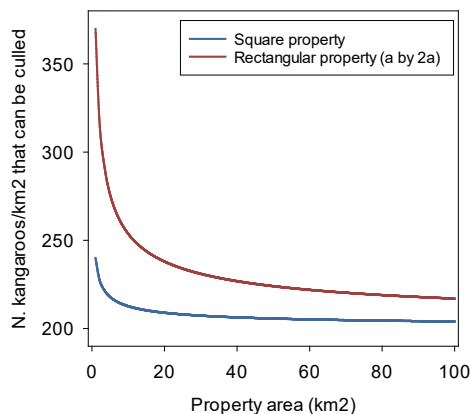


Fig. 5. The culling limit for hypothetical properties of increasing area, when they are shaped as a square, or a rectangle where the longer boundary is twice the length of the shorter boundary. Properties with more perimeter for the same area will always be able to request a higher cull, and small properties can request a higher cull.

4.2.2 Culling operation

Landholders must pass the Territory competency test every two years (including shooting accuracy and species identification components), and mixed-sex culling must only occur within the March-July culling season, with a male-only cull allowed between August to October. Random audits occur to check compliance with the Code, and conditions of the authorisation.

Shooters must pass a competency test every two years, with tests shooting accuracy, knowledge of the National Code for non-commercial macropod shooting (NRMMC 2008), and macropod identification skills. If a shooter fails the test, they must wait two years before they can re-sit the test. Based on the consultation carried out for this Review, this long wait to re-sit the test can pose serious difficulties for farmers and professional shooters, if they need to defer culling on their lease, or defer their business activities, for two years. It would be better to allow shooters to re-sit the test more quickly, after one year. In addition, the tests could include tests of shooting using night-vision equipment, because most shooters are operating at night.

Rural landholders must apply annually to cull kangaroos on their lease(s). The application is reviewed by the ACT Government, following an internal process. Compliance of landholders and shooters with the licence conditions, and the non-commercial Code, are checked in random audits (more detail in section 6.1.1 [Kangaroo welfare during culling](#)).

Rural landholders consulted as part of the Review were positive about the processes of obtaining authorisation to cull kangaroos, the use of the Rural Cull Calculator, and their interactions with ACT Government staff. Some suggested reducing the competency tests to once every five years, but others felt that every two years was appropriate. There was also commentary about the off-target licence conditions being too punitive, because misidentification could happen from time to time despite people's best efforts. Similarly, the male-only cull was challenging to undertake because the penalties for mistakenly shooting a female were severe. Landholders suggested that the tags applied to culled kangaroos should be biodegradable.

Recommendations:

[Suggested modifications to shooting/licencing protocols, are captured in recommendation 6.1]

4.3 Monitor

The ACT Government keeps records of the number of kangaroos that are authorised to be shot, and then the numbers that are reported as shot, on each property. The number of properties and kangaroos authorised/shot rose between 1997 and 2018-19, but have fallen since then. There are no current data on the density of kangaroos on rural land, and no data on pasture condition for most rural land (that this Review is aware of).

For rural leases within KMUs, there are data on kangaroo population density over time, and grassy layer structure from the reserve portions of these KMUs. This monitoring is carried out by the ACT Government and is reviewed in the section on [Environmental Impacts](#).

For rural leases outside the KMUs, there are no data on kangaroo density, or grass condition, over time.

Across all rural leases, records are kept of the number of kangaroos authorised to be shot on each property, and the number that are reported as shot by the landholders. The number of properties applying for authorisations, and the total number of kangaroos authorised to be culled, increased from 1997 to 2017, but has declined since 2019, perhaps because the break of the drought (2017-19) lessened the need to kill kangaroos to preserve feed for livestock, and because the wet conditions made for poor shooting conditions (Fig. 6a). The number of

kangaroos reported as shot shows a similar increase to 2018-19, then decrease. The number killed is always less than the number authorised, with the discrepancy more marked in the last seven or so years when authorisations are higher (Fig. 6b).

The increase in the number of authorised properties (and thus the number of kangaroo kills authorised) from 1997 to 2019 may be due to:

- Enhanced compliance with regulations over time, due to positive engagement by ACT Government staff with rural landholders.
- Increasing kangaroo populations after the end of the Millennial Drought from 2010 to 2016, followed by high kangaroo numbers relative to food availability in the 2017-19 drought. Non-commercial licences and culling figures also increased in NSW and Qld over the period 2013-17 (Wilson and Edwards 2019).

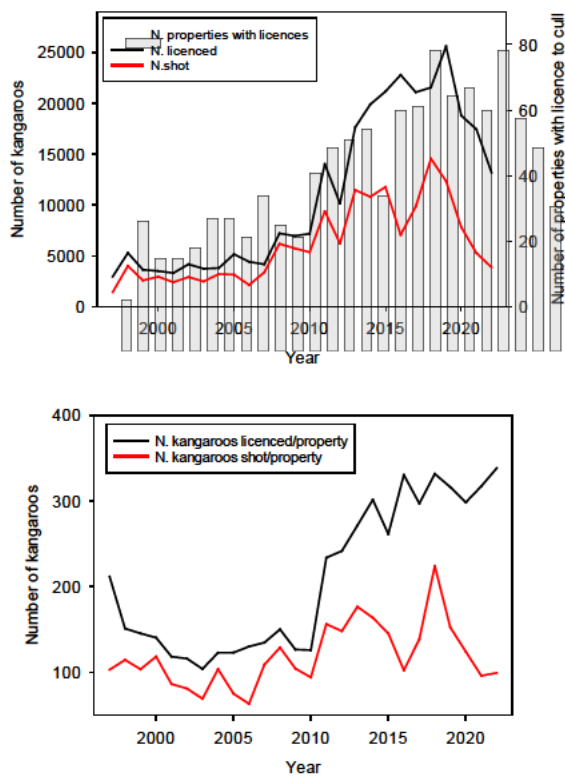


Fig. 6. (a) shows the number of properties authorised to cull kangaroos (bars and right-hand axis) over time, the total number of kangaroos authorised to be culled (black line), and the total number reported as shot (red line). The lower panel (b) shows the number of kangaroos authorised (black line) and reported as shot (red line), per property. Data for these graphs were supplied by the ACT Government.

Recommendation

[Design and implement a monitoring program to describe spatial and temporal variation in kangaroo density and pasture condition across rural lands in the ACT. See recommendation 4.3.]

4.4 Evaluate and Adapt

Given the paucity of data on kangaroo densities on rural land, it is difficult to evaluate the impacts of the rural cull on kangaroo populations, and the Review is not aware of any data on pasture condition from the rural leases (although it may exist).

The Review is not aware of data on total grazing pressure or pasture condition on rural lands, although it may exist.

If we take the average density for kangaroos on rural land shown in Table 2 (0.76/ha) and apply it to the total area of rural lands in the ACT (39,500 ha), this suggests a total population of 30,000 kangaroos. The average number reported as killed each year between 2017 to 2022 was 9100, or about 30% of the total population. For a back-of-the-envelope alternative approach to estimating the total kangaroo population on ACT rural lands, this Review uses the work of Hone (2007), who suggests that if we assume a high population growth rate of 40%, then about 30% of the kangaroos would need to be culled each year to maintain a stable population size. If we assume the kangaroo population on rural lands is stable and has a growth rate of 40%, and the annual cull (of 9100) is 30% of the total population, then the total population is 30,300, which is very similar to the population size based on using the density estimates. However, if the population growth rate of kangaroos is lower, then the kangaroo density on rural lands must be higher than 0.76/ha, to sustain the reported levels of culling.

Obtaining current density estimates, and understanding how this density varies spatially across the rural lands, would help strategic management. For example, this information could help prioritise locations for collaborative management between the government and landholders, including:

- Locations with grazing sensitive threatened species. In such cases, landholders could be supported with information on how best to monitor and manage total grazing pressure, including kangaroos, at these sites.
- Rural leases next to reserved land that routinely have very high kangaroo densities; this is likely to degrade the ecological health of the reserved land and the economic yields and sustainability of the rural lease.

The Land Management Agreement may be an appropriate mechanism for cooperating over kangaroo management at these locations. Management could involve culling, strategic fencing, guardian dogs, etc, and there are likely to be opportunities for landholders to seek funding through grant systems (e.g., Regional Landcare Partnerships Program). Such stewardship work may also be supported in the near future through the Commonwealth's [Nature Repair Market](#), and similar initiatives.

The results of the spatial assessment could also be used to design and implement a monitoring program for changes in kangaroo density across rural lands in the ACT, ensuring that locations with grazing sensitive threatened species, and interfaces of rural and reserved land, are both included. The monitoring could be carried out periodically, for example every 4-5 years, possibly varying the frequency to coincide with major weather changes from wet to dry conditions and vice versa. The purpose of the program would be to generate current information on kangaroo densities that can be used to inform livestock and kangaroo grazing management by rural landholders, and inform more specific objectives in the collaborative landholder-government planning.

These suggestions are consistent with multiple actions in the 'Rural Landscapes' chapter of the ACT's Natural Resource Plan (ACT Government 2022), especially in the themes of Native vegetation and biodiversity; Soil and groundcover management; Agricultural policy and practice; Land management and tenure policy; for example:

- Review LMA to ensure they are fit for purpose to conserve key ecological values and align with initiatives for farm diversification and sustainable land use.
- Implement effective monitoring and enforcement of LMA to ensure the sustainable management of rural lands.
- Investigate opportunities for supporting the protection of important environmental assets on rural lands through land stewardship programs.
- Develop integrated rural lands and agricultural policy that ties together all aspects of sustainable land management—natural, cultural and social values.

Recommendation

4.3 Consider an ACT-wide spatial assessment to identify variation in kangaroo density across rural lands, and identify focal areas for collaborative kangaroo management on rural lands; including:

- Locations with grazing sensitive threatened species.
- Rural leases next to reserved land that routinely have very high kangaroo densities.

The assessment could also be used to design an ongoing monitoring program for changes in kangaroo density on rural lands, that would inform kangaroo management broadly, but including in the focal areas noted above.

4.5 Communicate

The ACT Government interacts with landholders directly and does not share specific details of the rural culling program with the broader public, for privacy reasons.

The ACT Government interact with landholders via the management of competency tests, and the issuance of authorisations to cull kangaroos. For rural lands within KMUs, there is also case-by-case communication to support the kangaroo management outcomes sought across the KMU. From the consultation carried out as part of this Review, this communication seems to operate well (albeit the consultation was based on a small sample of landholders). For rural lands outside the KMUs, there is a level of frustration for some landholders that neighbour reserved land with unmanaged kangaroos, and deal with very high kangaroo densities.

5 SOCIAL IMPACTS

Summary assessment

The 2017 Plan focuses on kangaroo-vehicle collisions as the main social impact of high density kangaroo populations living in the urban and peri-urban bushland fragments. The Plan has an objective to reduce the incidence of such collisions. This objective does not appear to be met: the absolute number, and the per capita rate of collisions, may be increasing. The urban expansion may be causing more people to use roads that intersect areas where kangaroos are living, and mitigation measures are not keeping pace. Collision rates increase during dry conditions, when kangaroos range more widely in search of food.

Main recommendations

The available data show where the collision hotspots are. The ACT Government could consider mitigation strategies that could be put in place immediately (e.g., reducing speed limits in hotspots, especially when kangaroos are most likely to be active on the road verge), whilst trialling longer-term solutions to reduce collision risk whilst enhancing habitat connectivity with vegetated overpasses and underpasses. Research to improve data collection on collisions, and to evaluate the most cost-effective options in an adaptive management framework, would be useful.

5.1 Plan

The 2010 and 2017 Plans describe the diversity of social impacts of kangaroos, but objectives, outcomes and actions related to these impacts are more loosely organised than those relating to environmental and economic impacts.

The values associated with kangaroos are diverse. Kangaroos are an iconic Australian marsupial, and many Canberra residents and visitors experience pleasure and joy from having these native animals in urban bushland. Farmers may regard them as a pest, and car drivers may view them as a hazard. People (drivers, passengers and other witnesses, wildlife rangers, wildlife carers) involved in vehicle collisions with kangaroos can experience emotional trauma from these events. Watching kangaroos starve during drought is traumatic, and the issue of kangaroo population management itself is traumatic for some people (Robinson and Grace 2022; Seymour 2023). When kangaroo densities increase, the more negative social effects (car collisions, conflict with farming objectives, mass starvation) intensify.

The 2010 and 2017 Plans describe the diversity of social impacts of kangaroos, but objectives or outcomes related to these impacts are not clearly organised. There is an objective relating to vehicle collisions (section 6.4 of the 2017 Plan), but the Plan states that culling is not carried out to reduce road collisions and the actions to achieve this objective are the responsibility of road management:

- Vehicle-kangaroo collision objective: The incidence of vehicle-kangaroo collisions in the ACT is reduced.

The section of the 2017 Plan that describes the four key policy areas contains another relevant objective under the Human Welfare policy:

- Human Welfare Objective - Kangaroo management and community education minimise negative encounters between people and kangaroos in the ACT.

And another objective nested in the Kangaroo Welfare Policy:

- Kangaroo Welfare Objective - Kangaroo management in the ACT is undertaken in a way that accords with ACT legislation, codes of practice and current Australian standards for animal welfare.

Thus, the 2017 Plan lacks some clarity over which social impacts from high density kangaroos are in scope in the implementation of the 2017 Plan, how these impacts will be reduced (and who is responsible for the actions), and how the outcomes will be measured.

In this section on Social Impacts, the Review considers some key impact pathways (Road collisions; Kangaroo attacks on people; Carcass utilisation; Trauma to people caused by kangaroo management). For Road collisions,

which is the pathway with the most fully developed adaptive management approach in the 2017 Plan, the Review summarises the Planning, Implementation, Monitoring, Evaluation, Adaptation and Communication activities. For the other pathways, the Review assesses relevant material presented in the 2017 Plan and any other documents produced since then, and discusses some additional issues.

The final section proposes that considering social impacts through a lens of One Welfare could bring these disparate pathways, along with some other components of the 2017 Plan, together into a single coherent framework.

5.1 There is potential in a revised Plan to develop more clarity over the 'social impacts' relevant to the implementation of the kangaroo management Plan; how these impacts will be reduced, or balanced; who is responsible for the actions; and how the outcomes will be measured. Social impacts could be better viewed through a 'One Welfare lens', applied equally for impacts to people, as well as to kangaroos and other animals.

5.2 Road collisions

5.2.1 Plan and Implement

The main social impacts from high kangaroo densities noted in the 2017 Plan stems from the consequences of collisions between vehicles and kangaroos. These collisions can injure or kill the kangaroo, damage the vehicle, and traumatise, injure (or kill) people in the car. Rangers, ~~wildlife carers, and vets~~ are called out to euthanase injured animals, and to move carcasses, which can be unpleasant or traumatic experiences. The 2017 Plan has an objective relating to vehicle-kangaroo collisions:

- The incidence of vehicle-kangaroo collisions in the ACT is reduced.

The 2017 Plan states clearly that kangaroos are not culled to reduce the frequency of road collisions; and that achieving the objective of reduced collisions is the responsibility of the Transport Canberra and City Services Directorate. However, the Environment, Planning and Sustainable Development Directorate and the Transport Canberra and City Services Directorate (via the ACT Road Safety Fund) has supported some research, ~~funded by the ACT Road Safety Fund~~, to identify the spatial location of collision hotspots, and the landscape and other factors that tend to be associated with hotspots.

Mitigation options for reducing the collision rates are reviewed in the 2010 and 2017 Plans, and a more recent report (Cope and Herbert 2023). The Plan outlines policies designed to reduce collision frequency, including:

- Modifying attributes of the road (e.g., fencing, underpasses).
- Studies to improve understanding of the factors contributing to collision risk, and the effectiveness of alternative mitigation measures.
- Modifying driver behaviour with awareness programs.

Staff in the Transport Canberra and City Services Directorate noted that the risk of collision varies over time, with far higher collision rates, and therefore more community concern, during dry years. Staff noted that the justification for collision-mitigating interventions from their part of the public service centre on issues of road safety, rather than kangaroo welfare. The Directorate uses police records of car accidents to inform its collision mitigation actions, as well as the ranger callout data (see 5.2.2.1 below).

Fencing, underpasses, and some signage options have been trialled. However, funding for these initiatives is limited and intermittent. For example, funding was available via the "Black Spot Program" to build fencing along the Tuggeranong Parkway and monitor its effectiveness. The project ended in 2016 and the final report, which includes an assessment of the efficacy of the fencing, is due very soon. In contrast to this example funded by the Black Spot Program, most vehicle-kangaroo collision mitigation measures are not implemented in an adaptive management approach, or evaluated. Anecdotally, underpasses have limited value, partly because they attract predators such as feral cats, and native species then tend to avoid using them. Research suggests that permanent signage has very little effect, and so it is not usually used; temporary signs are put in place along some road

Commented [SL44]: I've changed this section following our meeting with Pawel

Commented [WC45]: Officially, only wildlife rangers do this in the ACT

Commented [WC46R45]: Ah, but you note below that wildlife groups have data, so they are unofficially attending kangaroos, so fine to leave in here

sections that attract kangaroos when heavy vehicle traffic is expected. Staff felt that reducing speed limits on the main arterial high-speed roads would not be supported by the public. Resourcing for trialling new options, such as virtual fencing (e.g., <https://www.shoalhaven.nsw.gov.au/Council/News/Council-trials-virtual-fence-to-save-wildlife>), is not usually available.

When new roads are planned, the consultants carrying out the Environmental Impact Study would usually look at data on kangaroo collisions (from the ranger callout data, or from police reports), when making suggestions about road design, and whether fencing, underpasses or other wildlife collision measures, are required. Similarly, there may be suggestions about the planting design for the median strip, to discourage grazing kangaroos. Although the Transport and Environment Directorates are somewhat also involved in this process providing recommendations about including such features in the road corridor. However, these recommendations are not always included, in some cases because it is not possible to incorporate them within the required road design specifications, that involvement seems perfunctory. There may be opportunities for to design roads with more input from ecologists and road safety staff to provide more input into the design of features in the road corridor, with the aim of reducing collision rates.

5.2.2 Monitor

Data on the frequency of kangaroo-vehicle collisions from public survey and ranger callouts indicate that both the absolute number of collisions, and the frequency per capita, may be increasing. A collation of two different datasets suggests that between 2600 (based on ranger callouts to collisions) and 5800 (based on public survey results) kangaroos have been killed annually on Canberra roads since 2015. A similar number of kangaroos are injured during collisions, with their fate unknown. An analysis of the spatio-temporal patterns of collisions shows that they increase during dry years, and during the winter months. Collisions are more likely on roads with higher speed limits, and on roads next to KMUs with high kangaroo densities and short grass (a situation that encourages kangaroos to come to road verges to feed or cross roads to find food elsewhere). Road intersections, and the ends of roadside barrier fences, can also be collision hotspots.

Based on public survey results, about a third of Canberran residents have been in a vehicle (as a driver or passenger) that has struck a kangaroo, at some point in the past. Collisions result in injury to the vehicle occupants about 5% of the time (~740 collisions in 2022), and an insurance claim about 60% of the time. Estimates of the annual cost of kangaroo-vehicle collisions range from \$2.5 to 8 million.

5.2.2.1 Kangaroos affected

The ACT Government contracted Micromex Research to conduct surveys to understand how Canberra residents felt about kangaroos and their management five times between 2008 and 2023. Some of the survey questions relate to kangaroo-vehicle collisions, and provide a data source on the frequency and outcomes of such collisions ACT-wide (i.e., covering a larger road network than those surrounding the Canberra Nature Park reserves). The reports are available on the [ACT Government website](#). Key statistics across the reports are:

- Kangaroo-vehicle collisions are common: in the most recent survey (2022) 36% of Canberran residents stated that they have been in a vehicle (as a driver or a passenger) that has hit a kangaroo in the ACT, at some point in the past.
- Collision resulted in the death or serious injury to the kangaroo about half of the time.
- Of the 50% of collisions where the kangaroo moves away from the road, the proportion that slowly die from injuries is unknown.
- The per capita rate of collisions may be increasing, from 6% of respondents (who have driven a car that hit a kangaroo in the previous three years) in 2011 to 14% in 2022 (Table 3). Presumably this is because of the increasing human population and Canberra's urban expansion, which increases the area of overlap between people and kangaroos.
- An 'authority' is notified about the collision about a third of the time.

The survey data can be used to estimate the approximate number of kangaroo-vehicle collisions each year. Accounting for the growing population size of Canberra, the collision rates translate to an increasing number of collisions over time, to 12,300 and 14,800 per year between 2019 and 2022 (Table 3). Given about half the

Commented [WC47]: I had a go at editing this paragraph based on a chat with Greg Baines from the Conservators team. He suggested removing reference to ecologists/consultants having input to 'road design' because there are very specific guidelines for how the actual road must be constructed, so instead input is/would be for recommendations for features in the road corridor and managing the road corridor to reduce kangaroo collisions. He said road developers are usually happy and open to receiving recommendations about wildlife collision mitigation measures, but these don't always make it into the final plans. The new Biodiversity Sensitive Urban Design Guide https://www.planning.act.gov.au/data/assets/pdf_file/0011/2324675/ACT-Biodiversity-Sensitive-Urban-Design-Guide.pdf provide the uptake of such recommendations?

collisions result in the death or serious injury of the kangaroo, the data suggest that since 2015, an average of 5805 kangaroos were killed or seriously injured on the roads each year (Table 3). This number may be an underestimate, because a) some respondents were involved in more than one collision, and b) the figures do not account for kangaroos that hop away from the collision site and die later from their injuries. The number may be an overestimate if some seriously injured kangaroos survive, or if survey respondents recall collisions that occurred outside the three-year period, or outside the ACT.

In some collisions, ACT Government rangers are called to euthanase the injured animal or remove the carcass. Information on these callouts is available in an ACT government database (ACT Government 2023b). From December 2015, a smartphone application using Collector for ESRI ArcGIS has helped to improve the accuracy and timeliness of data collected (Dunne and Doran 2021). The database was downloaded, and the figures for collisions with eastern grey kangaroos are shown in Table 3. The average number of collisions that kill a kangaroo are 2589 per year, or 7 kangaroos per day. These figures include some low annual figures during the COVID lockdown period. They also likely underestimate kangaroo mortality from vehicle collisions because not all collisions are reported, and because some kangaroos move off the road after the collision and later die.

The kangaroo collision estimates based on the Micromex survey data are about twice those from the ranger call outs (Table 3). This difference is expected because respondents also reported that they notified an authority about the collision only around one third of the time. In addition, as noted above, if respondents are being asked to recall incidents over a three year period, it is possible the date and location of collisions that they have experienced are incorrectly recalled, and the collision figures are inflated.

Table 3. Estimates of the number of kangaroos killed in the ACT, based on public surveys carried out [by Micromex for the ACT Government](#) (blue columns) and on [ACT Government ranger call out data](#) (green columns).

Micromex: The % drivers involved in a collision with a kangaroo at least once in the past 3 years are taken from the survey reports. These values are used to calculate the number of collisions per year, adjusting for the increase [in Canberra population size](#) over time; the % of adults that have drivers licence (93%; from the 2022 Micromex report); and the population that are under 18 (~20%). The number of kangaroos killed or seriously injured is approximately 50% of the collisions, according to survey respondents across all the reports. For every kangaroo killed or seriously injured in a collision, there is another kangaroo that is struck but hops away, injured, with its fate unknown.

Ranger callouts: downloaded (Jan 2024) from the [ACT Government ranger callout data](#). Rangers are called out to remove carcasses or euthanase an injured kangaroo.

Year	Drivers involved in a kangaroo collision in the previous 3 years	Number of collisions per year	Number of kangaroos killed or seriously injured (50% of collisions)	Number of ranger callouts to kangaroo collisions (ACT gov data)
2011	6%	5473	2736	
2015	8%	7751	3876	
2016				2775
2017				2522
2018				4044
2019	12%	12278	6139	3446
2020				1731
2021				1220
2022	14%	14800	7400	1679
2023				3297
			Av. Since 2015 = 5805	Av. since 2015 = 2589

Holly Cope and Catherine Herbert (University of Sydney) recently undertook an analysis of ranger callout data as well as other data sources, to identify the locations of wildlife collision hotspots, and examine what landscape

features and other factors led to hotspot occurrence. They focussed on 2016-19, to avoid COVID-related artefacts. They also assessed the merits of different data sources (e.g., insurance claims, crash statistics) for understanding wildlife collisions and for estimating the costs of these collisions, and they carried out a brief review of mitigation strategies to reduce collision rates. They kindly supplied their draft, unpublished report for this Review (Cope and Herbert 2023). Their report finds that:

- More collisions involve male kangaroos than females (about two-thirds are male).
- Collision frequency increases in the winter (because food is scarce so kangaroos are drawn to road verges, and because the peak traffic overlaps with kangaroo activity more).
- Collision frequency increases in drier weather. For example, collisions peaked in 2018 in the ACT, and also in the six NSW Local Government Areas surrounding the ACT (across multiple data sources). The year 2018 had a record number of warm days, was the warmest year on record (for mean maximum temperature), and with below average rainfall. Other studies have similarly found that kangaroo-vehicle collisions increase in dry conditions, including one in Victoria showing that road kills were higher during the 1981-83 drought than before or after (Coulson 1989); and another in NSW that showed kangaroo road kills during drought were substantially higher (Lee *et al.* 2004). Cope and Herbert (2023) suggest that kangaroos were coming to road verges because conditions were very dry during 2017-19.

The locations of these collision sites are spatially uneven (Fig. 7). When collisions exceeded 65 per km of road (during 2016-19), the authors called those sites 'hotspots'. Characteristics of hotspots included:

- Major roads with speed limits of ≥ 80 km/h.
- For all hotspots: adjacent to a KMU with high kangaroo densities (on average, over 200% larger than the target density for the KMU), low grass height (< 8 cm grass height). Kangaroos were likely coming to road verges for food.
- Road intersections; the worst location was the intersection of Sulwood Dr and Athllon Dr, bounded by Farrer Ridge and Mt Taylor reserves.
- The authors noted that the ends of kangaroo exclusion fencing along roads could also be problem areas.

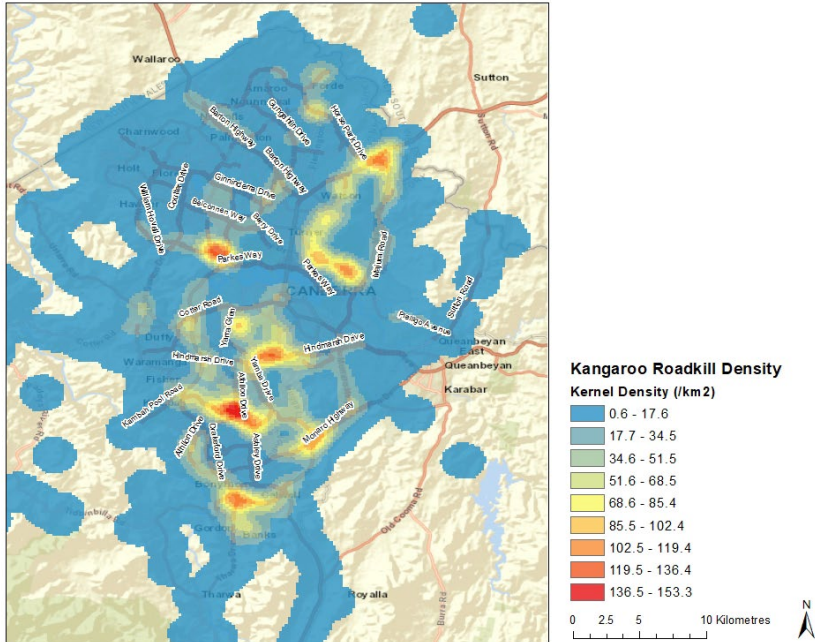


Fig. 7. Density of reports of kangaroo injuries or mortalities requiring attendance by the ACT Parks and Conservation Service rangers between 2016 and 2019. Figure courtesy of Holly Cope and Catherine Herbert.

The broad patterns of increasing collision frequency, and the locations of some spatial hotspots, were also identified in the 2010 Plan.

5.2.2.2 People affected

- Many Canberrans are experiencing the trauma of hitting a kangaroo with their car: about a third of Canberran residents stated in the Micromex surveys that they have been in a vehicle (as a driver or passenger) that has hit a kangaroo in the ACT at least once.
- The collisions caused injury to vehicle occupants about 5% of the time (varies between 2 and 11% across surveys) or ~740 collisions in 2022. Injuries may have affected one or more people. Note that other studies report higher injury rates, of around 30%; human fatalities from kangaroo collisions happen but are not common (reviewed in Herbert *et al.* 2021).
- The collisions result in an insurance claim ~60% of the time.
- Estimates for these annual costs of kangaroo collisions range from \$2.5 million (Cope and Herbert 2023) to \$8 million (Dunne 2017, cited in, Wilson and Edwards 2019).

5.2.3 Evaluate, Adapt, and Communicate

From the information summarised in the Planning and Monitoring sections just above, it seems that the objective of reducing the incidence of kangaroo-vehicle collisions in the ACT is not being met. Instead, the per capita frequency of collisions may be increasing. There may be scope to reduce collision frequency with strategic actions. There are precedents for integrating a range of mitigation measures from other urban and peri-urban environments (e.g., [Brisbane City Council](#)).

At this point, the success of long stretches of barrier fencing along roads at reducing collision rates is not clear, but should be available when the report from the Black Spots Program (mentioned above) is released.

As well as the data available in police records and ranger call-out data, ACT-based animal welfare groups also keep records about the locations of kangaroo-vehicle collisions, and have considered options for allowing kangaroos to cross busy roads to travel between reserves. These groups could provide community input to a strategic program that aims to reduce the collision rate.

Of relevance to this Review, is the finding that collision hotspots are all next to KMUs with high kangaroo densities and low grass biomass. Culling in reserves is not, and should not be, carried out to reduce collision risk. However, this information could inform the site selection for trials of mitigation options, such as virtual fencing.

Recommendations

5.2 Many people and kangaroos are adversely affected by collisions on Canberra roads, and the objective of reducing the incidence of vehicle-kangaroo collisions is apparently not being met.

Welfare outcomes for people and kangaroos would be enhanced if the frequency of kangaroo-vehicle collisions was reduced. Research to improve data collection on collisions, and to determine cost-effective mitigation options would be very helpful (e.g., strategic fencing, virtual fencing, vegetated overpasses, underpasses). Such options should allow kangaroos to move across habitat patches that are now fragmented by roads wherever possible, and be trialled and monitored in an adaptive management framework. In the meantime, the available data show where the hotspots for collisions are, and the EPSD Directorate could work with the Transport Canberra and City Services Directorate to consider the potential value of mitigation strategies that could be put in place immediately (e.g., reducing speed limits at collision hotspots with signs, speed bumps and speed cameras, especially at times when kangaroos are more active) whilst longer term solutions are developed. Community input to developing a short and long term strategic plan to enhance reserve connectivity whilst reducing collision risk for kangaroos, would help with its efficacy and socialisation.

5.3 Kangaroo attacks

Kangaroo attacks are rare, and the ACT Government includes advice to residents about how to avoid these events.

The 2017 Plan notes that there are no data on negative kangaroo-people interactions, but the events mostly occur when dogs harass kangaroos and the dog owner intervenes in the confrontation.

The management action is to inform the public about the risks of moving too close to large kangaroos, and to encourage dog owners to keep their dogs restrained. This information is visible on the ACT Government's eastern grey kangaroo website, including via a [downloadable factsheet](#).

This review is unable to assess whether this response has been effective at reducing the incidence of conflict between people and kangaroos. If the occurrence of such events is low, then discerning change is challenging.

5.4 Trauma to people concerned about kangaroo management

Most Canberrans support kangaroo management for welfare, environmental, and economic reasons. About 10% of Canberran residents do not and another 10% are unsure; a subset of these may experience trauma that kangaroo management occurs at all.

Most Canberrans support the current kangaroo management. The ACT government commissioned a [series of surveys](#) by Micromex Consulting to gauge community attitudes to kangaroo management and impacts in the ACT. These five surveys carried out between 2008 and 2023 have consistently shown:

- Over 75% of the public support culling kangaroos under certain circumstances whereas around 10% do not support culling under any circumstances (the balance of respondents, about 10%, are unsure).
- Most respondents (> 60%) consider that kangaroos are killed humanely.
- Respondents consider that justifications for culling are to prevent mass starvation of kangaroos during drought, to maintain the ecological health of reserves, to look after the economic viability of farms, to commercially harvest meat and skins (noting that this does not occur in the ACT), and to reduce collision rates with cars (in roughly that order). It is notable that kangaroo welfare is the most supported justification for culling.

The broad support for the governments kangaroo management program is likely influenced by the lived experience of Canberra residents, who have seen the effects of heavy grazing in the urban reserves, seen the large numbers of starving kangaroos during drought, and experienced the trauma of hitting kangaroos that are concentrating on road verges to seek food.

Nevertheless, the surveys equally show that around 10% of Canberrans do not support the kangaroo management, with another 10% unsure. For some people, the very issue of kangaroo management may be deeply traumatic (Robinson and Grace 2022; Seymour 2023).

The act of killing a native animal may be confronting to people for several reasons. For example, people may object to killing any sentient animal (an animal rights perspective); they may value charismatic species like kangaroos more highly than the smaller, more obscure plants and animals that live in the grass layer; they may object to killing a native animal as a means to fix a deeper human-caused problem (such as the loss, fragmentation and degradation of grassy ecosystems); they may worry about the pain or suffering experienced by culled kangaroos (a welfare perspective). These variations on animal rights-centric and welfare-centric views raise moral and ethical dilemmas that validly challenge a conservation-centric perspective (which is the prevailing compass of the 2017 Plan). Situations of conflict among conservation, welfare, and animal rights perspectives are increasing in frequency, as human alteration of natural systems increasingly results in situations, such as the ACT's kangaroo management, where managers face decisions about whether to kill native animals for conservation objectives. In addition, there is substantial discourse about how humans can integrate the interests of non-human animals into governance, including conservation governance (Schapper *et al.* 2022). Section 7 describes a framework for guiding decisions about animal control for conservation outcomes, although even this framework is conservation-centric, and assumes that the conservation of species is highly valued by all.

5.5 Carcass utilisation

Most carcasses from culls on conservation and rural land in the ACT are disposed of in burial pits or left in situ (for nutrients to recycle). A very small number of carcasses have been used in conservation programs (to feed native carnivores at wildlife holding facilities, or to make poison baits for foxes and dogs). Skins have also been given to local Indigenous people. Farmers can use culled kangaroos for their own domestic purposes, but the fraction so-used is very small. This 'wastage' is a concern to some, including Traditional Custodians, farmers, and some conservation groups, and inconsistent with ACT's Waste Management Strategy and Climate Change Strategy. A recent commissioned report considered the options for alternative uses of culled carcasses. The report suggests upscaling the current use of kangaroo meat in conservation programs, using commercial processing facilities in NSW to prepare meat and skins for consumption by people in the ACT Indigenous community, sending small carcasses to be used by certain wildlife facilities, and sending offcuts and offal to frass processors to produce fertiliser that could be used by community groups involved in ecological restoration activities. Carcasses from conservation culls would be gifted to these uses, but rural landholders may choose to recoup some costs from these pathways.

Carcass utilisation is discussed here, under social impacts, but noting there are economic implications: On rural lands landholders may recoup some money from selling carcasses that could help to offset the cost of culling. On conservation land, the costs of carcass disposal (over \$6 each not accounting for costs of collection and transport, AWS 2020) may be partly covered, or the costs of culling could increase if the processing of the carcasses exceeds those savings.

About 15,000 kangaroos are killed each year in the ACT by conservation culling (~2000), rural culling (~9100) and road kills (2600-5800) (see [Section 5.7](#) for details). The carcasses are either left in situ or buried in pits.

Carcasses left to rot in situ create micro-niches that favour some plants (including exotic species) and animals, and contribute to nutrient cycling and soil health (Barton *et al.* 2019; Barton *et al.* 2016). They may also attract scavengers. Large rotting carcasses may not have been a very common feature when people and dingoes were hunting them, and dingoes were also eating carrion. Regardless, leaving thousands of culled kangaroos, shot over the culling season, on the ground surface is not possible, especially on public land, which is why many carcasses are disposed of in pit burials.

A report prepared in late 2020 (AWS 2020) discussed the issues associated with pit burial, and alternative options for carcass utilisation. The report states that 'wasting culled animals does not meet community expectations when there are other methods available'. The objection to waste may be especially felt by Traditional Custodians. Pit burial takes up landfill space, causes higher methane emissions. The report states that reducing the organic material going to landfill, and instead finding other uses for this material, is aligned with the ACT's Waste Management Strategy and the ACT Climate Change Strategy.

Current carcass fate:

- On rural land, rural landholders can use carcasses of kangaroos they shoot, for example as meat (for human and animal consumption). Given the number shot, most carcasses are not used. Many are left in situ, but some landholders are concerned about attracting canids. Carcasses cannot be left where they are visible to the public. Some landholders bury their carcasses or pay their shooters to remove the carcasses from their land.
- On public land, most carcasses from culled kangaroos are buried. The skins from a small number have been given to Traditional Custodians; some have been provided to local wildlife facilities to feed native carnivores; a small number are processed into meat baits for ACT conservation programs for fox and dog control.
- Road-killed kangaroos are either left in situ, or moved (by rangers) to waste facilities for burial.

The AWS report agreed with the conclusion of an earlier study in 2011 that setting up a commercial kangaroo meat industry in the ACT was not economical, because the numbers culled were too low, and the culling was seasonal. (However, the report notes that ACT Traditional Custodians have expressed interest in a local processing facility). In contrast, the AWS report concludes that exporting kangaroo carcasses to existing NSW processing facilities is feasible. The AWS report also recommends expanding some existing carcass use options. The overall proposal is:

- Rural landholders could be given the option of selling carcasses to interstate processors (for human or pet food) under a Wildlife Trade Operation (approved under the Commonwealth EPBC Act). The payment for this meat could help offset the costs of culling, and might elevate the value of kangaroos to the farming sector, and enhance the management of total grazing pressure (see also, Wilson and Edwards 2019).
- Carcasses from the conservation cull could be collected for dressing (or dressed at the point of cull), then:
 - Offal and offcuts would be supplied to local frass producers, who use insects to produce high nutrient soil conditioner. [The product could be distributed to community groups for use in plant restoration programs].
 - Smaller carcasses would be given to local wildlife facilities for native carnivore food, and exported to NSW wildlife facilities for the same purpose.
 - Some smaller carcasses could be used locally to produce meat baits for conservation programs.
 - Larger carcasses would be exported to NSW facilities that process kangaroo meat for human consumption. Meat and skins would be delivered back to the ACT Indigenous community for food and traditional use (several pathways are described).

There would be no payment for carcasses from kangaroos killed in the conservation cull, to avoid any potential confusion about the objectives of that culling. The most recent public survey on attitudes and opinions about kangaroos in the ACT (Micromex 2023) suggests that although most (>55%) support kangaroo culling for commercial meat and skins, they do not support this purpose for culling in reserved lands (20%).

Although the report did not discuss welfare, there would be one welfare benefits from adopting part or all of this proposal, because livestock would not be killed to feed animals kept in captivity, or to feed people, and so on. Kangaroos sent to a NSW processor would need to be shot according to the commercial Code rather than the non-commercial Code. The commercial Code has higher standards, but the ACT requirements for shooting already meet these standards.

The AWS report outlines ten further steps required to explore these options for carcass use. They include a deeper exploration of the regulatory steps involved. The proposal also needs to be costed fully (this is not in the ten next steps).

Recommendations

5.4 Continue exploring alternatives for carcass utilisation instead of the current practice of pit burial and leaving in situ, by undertaking the next steps outlined in the Australian Wildlife Services report, and fully costing their proposed model. A risk analysis should also be conducted. Involve the community in this discussion, by 1) including targeted questions about kangaroo carcass utilisation in the next public survey on kangaroo management; and 2) ensuring Traditional Custodians can participate fully in the discussion and decisions.

5.6 One Welfare as an 'impact area' in the kangaroo management planning framework

Attention to kangaroo welfare is prominent in the 2017 Plan, and references to welfare crops up frequently, in different contexts, throughout the document. Welfare outcomes for other animals, and for people, are raised (less often) in the context of specific issues, and sometimes labelled differently. For example, the impacts of kangaroo-vehicle collisions are nested under social and economic impacts. An alternative approach, that recognises recent amendments to the ACT Animal Welfare Act, the development of the ACT Wellbeing Framework, and the One Welfare concept, would be to replace 'Social Impacts in the Plan with 'One Welfare Impacts', providing a single coherent framework for considering all welfare outcomes from decisions to act (or not to act), to kangaroos, other animals, to people and to the environment.

Kangaroo welfare is referred to in the Purpose of the 2017 Plan *"The purpose of the controlled native species management plan is to set out the approach to be adopted in maintaining wild populations of Eastern Grey Kangaroos in the ACT while managing their environmental, economic and social impacts and ensuring their welfare".*

Welfare is also referenced in the Plan's Principles (section 4.2): *"Kangaroo welfare is a primary consideration in all kangaroo management and all kangaroos are to be treated humanely." And "Human welfare and the conservation of other grassy ecosystem species are key considerations in all kangaroo management."*

Policies regarding welfare then occur at different structural levels of the Plan. For example, Greenfield Development Sites and Other Land have area-specific policies that kangaroos are to be managed to achieve the best welfare outcomes. On Greenfield Development Sites, kangaroos may face unacceptable risks of vehicle collisions, dog attacks, and starvation because of the development (sections 5.4.3 and 5.4.4 in the 2017 Plan). But the 2017 Plan also makes animal welfare one of four key policy areas that cut across the entire Plan. This higher level kangaroo welfare policy has an explicit objective: that kangaroo management should adhere to legislation, codes of practice, and Australian standards (section 4.3.1 of the 2017 Plan).

In this review, detailed comments on the substance of the kangaroo welfare policy as expressed in the 2017 Plan are given at [6.1 Kangaroo Welfare](#). Here, the review makes the case for replacing **Social Impacts** in the 2017 Plan with **One Welfare Impacts** as an explicit impact area that guides kangaroo management with the aim of optimising net welfare outcomes across all sentient animals, including humans. By doing this the new Plan would:

- Signal clearly that One Welfare is a central issue in kangaroo management.

- Recognise feedback from some stakeholders during the consultation carried out as part of this Review, who wished to see welfare addressed more coherently.
- Provide a clearer framework for a raft of welfare-related issues that crop up in the 2017 Plan, but are currently dealt with in a piecemeal and sometimes incomplete fashion.
- Extend welfare considerations to encompass the welfare of all animals, people, and the environment, and allow contrasting perspectives about which welfare to prioritise to be considered within the same framework.
- Be more consistent with an Indigenous, holistic approach to Country.
- Respond to the intent of the 2019 updates to the ACT Animal Welfare Act 1992 (see below).
- Be aligned with the ACT Wellbeing Framework (see below).
- Be aligned with the international One Welfare movement (see below).

All the practices and adaptations to enhance welfare outcomes that have been incorporated into the existing kangaroo management program would be covered by this approach (e.g., a culling season to avoid shooting females with large pouch young or small young-at-foot; stringent requirements for licensed shooters; prioritising culling to occur only in reserves where this will have conservation benefit; small reductions in kangaroo population size each year, rather than less frequent but very large culls, resulting in fewer kangaroos being killed overall; etc. See [section 6.1 Kangaroo welfare](#) for more detail).

Additional issues that would be covered more coherently under this proposed approach include:

- Reducing the suffering of individuals from other species, when heavy kangaroo grazing in grassy ecosystems causes the loss of their resources and increases exposure to risk (e.g., from weather or from predators). Reducing kangaroo population sizes to avoid adverse welfare outcomes for other species may result in a net welfare gain (see [section 3.1.1.2](#)).
- Reducing the extent of suffering of individual kangaroos in high density populations that experience starvation and higher disease burdens when the food resources diminish from overgrazing or drought (see [section 6.1.3.3](#)).
- Reducing the adverse human and kangaroo welfare outcomes associated with kangaroo-vehicle collisions that are more frequent when kangaroo densities are high (see [section 6.1.3.4](#)).
- Fairly considering the negative welfare impacts to members of the public that are traumatised by kangaroo management (see [section 5.5](#)).

The [Animal Welfare Act 1992](#) was updated in 2019. This update included a “*new set of objects to ensure that animals are recognised as sentient beings (meaning they can subjectively feel and perceive the world around them), have intrinsic value and deserve to be shown compassion and have an acceptable quality of life, and to reflect the community’s expectations around animal welfare and the proper treatment of all animals*”¹.

The new Objects [4A(1)] are:

- a. animals are sentient beings that are able to subjectively feel and perceive the world around them; and
- b. animals have intrinsic value and deserve to be treated with compassion and have a quality of life that reflects their intrinsic value; and
- c. people have a duty to care for the physical and mental welfare of animals.

In amending the Act to recognise ‘sentience’ the [‘Explanatory Statement’](#) stated:

- *...animal welfare encompasses all aspects of animal health and wellbeing, and all people have a responsibility to take reasonable measures to protect the welfare of animals in all human-animal interactions.*
- *Animal welfare in a modern context describes how an animal is coping both mentally and physically and recognises that animals are sentient beings that have the capacity to feel and perceive things. Achieving good animal welfare relies on recognising the five freedoms of animals ... and encompass at a high level the freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury or disease,*

¹ [Explanatory Statement](#) for the Animal Welfare Legislation Amendment Bill 2019

freedom to express natural behaviour, and freedom from fear and distress. It also relies on recognising that animals deserve having a life worth living, in terms of both physical and mental wellbeing.

This update to the Welfare Act should be reflected in appropriate revisions to the Kangaroo Management Plan, and an effective way to achieve that would be to recognise welfare as a high-level impact area, on a par with environmental and economic impact areas.

The [ACT Wellbeing Framework](#) categorises areas (domains) that have been identified as consistently contributing to the overall quality of life for Canberrans (ACT Government 2020). ‘Wellbeing Impact Assessments’ are embedded into ACT Government Budget and Cabinet processes. The management Plan for the Canberra Nature Park states that the Park contributes to all 12 domains, or areas affecting our quality of life, as described in the ACT Wellbeing Framework. Kangaroo management in the ACT is integral to the management of Canberra Nature Park, and therefore all 12 domains are arguably relevant; the most pertinent domains for the three main impact areas relevant to kangaroo management are summarised in Table 4. Including One Welfare as an impact area in the revised kangaroo management plan would align with the ACT Wellbeing Framework.

Finally, thinking about optimising One Welfare would be consistent with the international ‘[One Welfare](#)’ movement: “*One Welfare projects are intended to address the interconnections between animal welfare, human wellbeing and the environment.*” One Welfare encourages a broad, multidisciplinary approach that can connect science, ethics, economics, conservation, and other values (Kennedy *et al.* 2022; Pinillos *et al.* 2016).

Table 4. The relationship between the most pertinent domains and indicators in the ACT Wellbeing Framework, and how they map onto the impact areas central to kangaroo management.

Domain in the Wellbeing Framework, and aspiration for the domain (in italics, paraphrased from the Framework)	Indicators	Kangaroo Management Impact Area
Environment and Climate <i>Canberra’s natural environment sustains all life and is climate-resilient; this supports long-term economic sustainability</i>	<ul style="list-style-type: none"> • Healthy and resilient natural environment • Connection to Nature • Climate resilient environment and community 	Environment Economy Welfare (all animals including humans)
Economy <i>Strong farming and tourism business (both rely on environmental sustainability)</i>	<ul style="list-style-type: none"> • Economic performance • Business conditions (of farming sector, nature-based tourism sector) 	Environment Economy Welfare (all animals including humans)
Health <i>Canberrans have good physical and mental health ... including through access to health-promoting environments [such as natural environments]</i>	<ul style="list-style-type: none"> • Overall health • Mental health • Healthy lifestyle 	Welfare (Human)
Social connection <i>Canberrans are connected and supported within our community</i>	<ul style="list-style-type: none"> • Sense of social connection • Levels of volunteering 	Welfare (Human, possibly other animals) Environment (Through the activities of volunteer groups such as Park Care)
Safety <i>Canberrans are and feel safe and secure</i>	<ul style="list-style-type: none"> • Road safety 	Welfare (for people and kangaroos on roads) Environment (kangaroo population size)
Identity and belonging <i>Connection to Canberra, Valuing Indigenous history and culture</i>	<ul style="list-style-type: none"> • Sense of belonging and inclusion • Connection to Canberra • Valuing Indigenous culture 	Environment Welfare (People)
Governance and institutions <i>Canberrans participate and are heard; Government is transparent</i>	<ul style="list-style-type: none"> • Trust in government • Feeling that voice and perspective matter 	Environment Economy (from effective government) Welfare (People)

Recommendation

5.5 Replace 'Social Impacts'; in the Plan with 'One Welfare Impacts', making One Welfare a high-level impact area, on a par with Environmental and Economic Impacts. This would mean that the welfare consequences of management actions (or inaction) for kangaroos, people, other animals, and the environment, can be explicitly and consistently considered within the same framework. This change would recognise recent amendments to the ACT Animal Welfare Act, the development of the ACT Wellbeing Framework, and the One Welfare concept.

6 Have the policies contributed towards achieving the management objectives?

The Review was asked to consider the policies contained in the EGK CNSMP and where possible evaluate the degree to which the policies have achieved the management objectives stated in the plan in the last five years (2017-2022).

This task has been partially accomplished in the sections above; where this is the case, the section(s) above will be referred to.

The 2017 Plan groups a collection of policies, some with their own objectives, into four categories (Kangaroo Welfare, Interactions between human and kangaroos; Managing kangaroo densities; Managing captive populations). The Review deals with each category in turn.

6.1 Kangaroo welfare

The 2017 Plan's policy on kangaroo welfare (section 4.3.1) has an explicit objective:

- *Kangaroo management in the ACT is undertaken in a way that accords with ACT legislation, codes of practice and current Australian standards for animal welfare.*

To support this objective there are a collection of policies relevant to the operation of the management program (e.g., shooter testing, culling season, urban wildlife program, legislation and Codes of Practice); a policy for wildlife care of kangaroos; and a policy for translocation.

6.1.1 Kangaroo Welfare during culling

Culling is carried out to comply with a National Code of Practice for humane shooting of kangaroos and wallabies for non-commercial purposes. However, the ACT has additional regulation and practice designed to enhance welfare outcomes considerably. In particular, shooters must regularly pass a competency test (of shooting accuracy, familiarity with the Code, and macropod identification); audits of operations are undertaken on both the conservation and rural culls; a culling season reduces the risk that large pouch young and small young at foot will be orphaned, the conservation cull occurs only in reserves where conservation benefits are expected; and the overall number of kangaroos to be culled is reduced by culling regularly with small culls.

Humane killing of pouch young remains a sensitive issue for some people. This Review found that the protocols for humanely killing pouch young of different stages that is outlined in the Commercial Code (rather than the Non-commercial Code) was clear, useful, and supported by the available evidence. There may be potential for research to develop alternative methods.

The ACT Government's requirements and practice surrounding kangaroo management are dispersed across regulation and various internal guidelines and processes; there may be value in gathering some of these into a single Standard Operating Procedures document, for transparency and to drive positive change more broadly.

The Plan makes it clear that killing kangaroos without being authorized to do so under the Plan, without a license or by an exception under the Nature Conservation Act, is illegal.

The Plan establishes that kangaroo management must be carried out in accordance with legislation in the Animal Welfare Act 1992, and ministerially approved codes of practice.

The Plan defines animal welfare as “the health, safety and welfare of animals in general, or one or more animals in particular”. [The Review notes that the [Animal Welfare Act 1992](#) has been updated since the 2017 Plan was released and this should be reflected in the revised Kangaroo Management Plan.]

For kangaroo culling, the relevant code of practice is the 'National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes' (NRMMC 2008), which was adopted as an approved Code of Practice (not mandatory) in the ACT from March 2014. This Code deals with killing kangaroos (adults and young) for non-commercial purposes such as conservation management or compassionate euthanasia. This National Code was reviewed by a working group that includes representatives from states/territories, animal welfare organisations, and the kangaroo industry, and there was a public comment process.

There is also a National Code of Practice for humane shooting of kangaroos and wallabies for commercial purposes (AgriFutures 2020). This Code is more recent, was informed by a broad pre-consultation process (Sharp and McLeod 2020), and has several useful advances compared with the older, non-commercial Code. For example, it includes more detailed standard operating procedures for shooting kangaroos and humanely killing joeys. Although commercial shooting does not occur in the ACT, much of the requirements for non-commercial culling in the ACT comply with these more current standards.

The ACT requires shooters to exceed the specifications in the non-commercial Code (although the Code encourages states/territories to "promote measures to ensure competency"), in several ways:

- Having stringent tests for non-commercial shooters, requiring them to pass a shooting accuracy test, a test on the Code, and a macropod identification test every two years. These are considerable improvements over the situation in other states (Wilson and Edwards 2019). If a shooter fails the test, they must wait two years before they can re-sit the test. Based on the consultation carried out for this Review, this lengthy wait to re-sit the test can be problematic for professional shooters as they are unable to work for two years.
- Auditing compliance and performance. Auditing processes are in place to assess compliance with the code during rural and conservation culling.
 - Rural: Pre-COVID, random audits were carried out on about 10% of people holding a licence to shoot kangaroos. During the audit, shooters were assessed for compliance with the non-commercial Code; for the percentage of kill-shots to the kangaroos' heads; for correct checking of pouches and humane killing of pouch young; and for tagging of killed animals. The landholders (if not the shooter) were checked to ensure compliance with conditions. If audits revealed a breach, the case was passed to the Licensing and Compliance team for further action. These processes are described in internal documents. Post-COVID, the ACT Government team are currently assessing whether and how to vary the audit process to make it as efficient and effective as possible.
 - Conservation: Independent veterinary welfare assessments of the ACT Government conservation culling have been conducted in 2013, 2015, 2017, and 2023. These assessments considered compliance with the Code, welfare outcomes for shooting of adults and independent juveniles, and welfare outcomes of humane killing of pouch young (as per the Code). The independent audits are important for maintaining public confidence in the program. An ACT Government vet also assessed the culling program in earlier years.

In the most recent assessment (Atkinson and Hampton 2023), of 144 shot kangaroos, 97% died instantly from a single head shot, 3 animals required two shots (with 28-49 seconds between shots) and two kangaroos escaped after being shot. An additional two animals were missed altogether. There were 56 pouch young associated with the adult females; of these two-thirds were unfurred. Of the 18 furred young, one escaped before it could be euthanised. Apart from the escapee, the pouch young were killed promptly using a concussive blow to the head. These statistics are similar to the results of the earlier assessments (all are available on the Government website).

The proportion of kangaroos that insensible immediately upon the first shot is similar to another study of welfare outcomes for four large macropod species which reported a wounding rate of 0.4% for 279 kangaroos killed during a commercial harvest (McLeod and Sharp 2014); and higher than in some other wildlife shooting and abattoir slaughter of livestock (Hampton and Forsyth 2016; Smith

and Ryeng 2022). A review of all killing methods for large macropods concluded that an accurate shot to the head is least likely to cause suffering to individual kangaroos (Descovich *et al.* 2015).

An earlier assessment of the ACT Government conservation culling (Hampton and Forsyth 2016) measured the duration of stress in sentient young (i.e. the time between being extracted from the pouch and killed), reporting this as 4 seconds. The 2015 assessment also considered the stress imposed on kangaroos standing near to the shot individuals: of 124 kangaroos that were positioned near to shot individuals, only 73% moved away from the shot animal, and only for a short period (median time of 5 seconds).

The welfare outcomes from conservation culling in the ACT study are likely due to the high competence of the shooters, avoiding the use of spotlights (using thermal scopes and night vision instead), using suppressors on the guns, and the habituated nature of the kangaroos which allows for close shooting distances; these features may not be present in all large macropod shooting programs.

In addition to the external audits, it could be worthwhile to reinvigorate the involvement of the government vets in the conservation culling program. The vet(s) should have experience of culling operations and be willing to be part of the team and aim to assist the operation. During planning, they can keep the shooting team abreast of any developments in kangaroo welfare and veterinary science. In the field, a staff vet could help check for pouch young, collect data on demographics of the culled animals, and sample the condition of animals; these data may help inform predictions for population growth over the coming year (Wilson and Coulson 2021). Vets have knowledge that could be valuable at unexpected times during the operation, and they are expert and trusted conduits of information on animal welfare and health for the public.

The ACT has additional regulation and practice to improve kangaroo welfare as a resulting of non-commercial shooting:

- The ACT imposes culling seasons. Mixed sex culls can occur only between 1st March and 31st July each year when 8-12 month old young-at-foot are unlikely to be present. Young of this age are old enough to be outside the pouch and evade a follow-up shot if their mother is killed. The assumption is that the orphaned animal is still too young to survive without their mother (Sharp and McLeod 2016). The culling season is effective at reducing the risk of orphaning young of this age because kangaroo breeding in the ACT is strongly seasonal, with pouch emergence timed to coincide with the flush of green grass of spring (Fletcher 2007; Lucas *et al.* 2021). Studies of the age profile of young encountered during culls carried out over multiple years and sites in the ACT show that 8-12 month old juveniles are least likely to be seen between April and June, and most likely to be seen between September and December (Fletcher 2007; Lucas *et al.* 2021). In addition to the mixed-sex cull, on rural land (i.e., not on conservation lands), farmers may also kill males from 1st August to 31st October, but there are constraints placed on the number of males that can be killed (<30% of the number shot in the mixed season).
- In addition to these formal requirements, in the conservation culling program the contracted shooters and ACT Government staff use additional measures to improve welfare outcomes for the kangaroos and the efficiency of the program. For example, shooting is carried out at night, using night-vision and thermal imaging (instead of spotlights), and suppressors on the guns. The procedures covering all aspects of the conservation culling operation are outlined across various documents (e.g., tender documents and contracts), and it could be useful to gather them together in one set of Standard Operating Procedures to communicate how carefully the culling is organised, and to share with professional shooters working on rural lands, and managers in other jurisdictions.
- The ACT favours small, regular (annual) culls, rather than less regular, very large culls. The culling operations aim to bring the population size in reserves down closer to the target densities, then carry out smaller maintenance culls each year instead of less frequent but larger culls. This results in a welfare benefit because fewer animals are killed (section 4.3.3 in the 2017 Plan) when populations are not released to grow exponentially between culls.

- Culling is prioritised across the reserves and is most likely to occur in reserves with greater anticipated conservation benefit to other species. Conversely, culling is less likely when conservation benefits are considered to be less (ACT Government 2023a). This program design feature also reduces the total number of kangaroos that need to be killed.

6.1.1.1 Euthanasia of pouch young

During consultation for this review, some stakeholders voiced concerns over the methods outlined in the non-commercial Code for killing pouch young. The recommended methods are a concussive blow to the head or stunning and decapitation for unfurred young; and a concussive blow to the head for furred young (NRMMC 2008). The specific concern regarding decapitation is that if pouch young develop sentience before fur develops, then decapitation may cause suffering because the brain remains active for a short period after the head is severed. The specific concern about concussive blows is whether it is successful at killing the pouch young all the time. In addition, both decapitation and a concussive blow to the head have a connotation of violence that can be upsetting for some people.

The recommended methods for humanely killing pouch young in the more recently updated Code for commercial shooting of macropods (Australia 2020) are cervical dislocation or decapitation for pouch young under 5 cm long; decapitation for unfurred pouch young larger than 5 cm long; and a concussive blow to the head for partially furred or fully furred pouch young. The commercial Code contains more detailed information on the developmental stages of joeys, and how that affects whether methods are humane or not; and more detailed instructions on how to use each method properly. The Code also states that if the shooter is uncertain about the age and therefore sentience of a pouch young, then they should assume the young is sentient, and use a concussive blow.

Are unfurred young sentient?

Research has shown that brain activity *begins* developing from around the time the eyes begin to open and fur begins to develop in large kangaroos (Diesch *et al.* 2010; Diesch *et al.* 2008; McLeod and Sharp 2014). Thus, cervical dislocation and decapitation for very small pouch young should not cause distress, and these methods – which can be undertaken without removing the young from the pouch or off the teat – do appear to be the most humane way of killing these animals.

Is a concussive blow to the head for partially furred/furred pouch young a humane killing method?

A recent investigation of killing methods for pouch young of all ages concluded that a concussive blow (or ‘blunt trauma’) to the head was the most effective method and least likely to cause suffering (McLeod and Sharp 2014). An alternative method, using a captive-bolt device, was trialled but found to cause poorer welfare outcomes because too many animals were not properly stunned with a single shot when using the device (McLeod and Sharp 2014). Another review of all methods of killing large macropods (of all ages) also concluded that blunt trauma for young kangaroos was acceptable if properly delivered (Descovich *et al.* 2015). The [Australian](#) and American Veterinary Associations both state that blunt trauma, when done correctly by experienced operators, results in rapid death and is therefore an acceptable method of euthanasia (ANVMA 2020).

The issue of how to humanely kill pouch young was also raised as a concern in some submissions to the recent NSW Parliamentary Inquiry into the ‘*Health and wellbeing of kangaroos and other macropods in NSW*’ (NSW Legislative Council 2021). However, other submissions noted that research-based veterinary advice considered this method as the most humane. The Portfolio Committee acknowledged that the killing of joeys (by blunt trauma to the head) was “shocking to many people” (Committee Comment 5.47) but made no recommendations for review of the method.

It therefore seems that a concussive blow to the head/blunt trauma is the most humane way to kill joeys, because it is rapid, effective, and consistent. However, it is very unpalatable to some of the public. The 2020 commercial Code notes that using captive bolts may provide an alternative option for humanely killing pouch young in the future, but that the effectiveness and consistency of this technique is yet to be demonstrated. The 2020 Code also

has more specific instructions about how to deliver the concussive blow to pouch young that are much more useful than the material available in the non-commercial Code. Given the public sensitivity to the killing of pouch young, the ACT Government could encourage and support research to explore whether captive bolts, or some other approach, could potentially replace a concussive blow to the head.

6.1.1.2 Other issues raised during consultation

Euthanasia or humane killing?

Some stakeholders questioned the use of the term ‘euthanasia’ for killing pouch young, and felt that ‘humane killing’ was more accurate. Euthanasia refers to killing to end incurable suffering and is carried out in the best interest of the killed individual. A pouch young (without care) whose mother has been shot is almost certain to die from exposure, starvation, or predation; it may experience emotional distress and fear after the loss of its mother. Thus, killing an orphaned joey could be viewed as an act of mercy, consistent with the meaning of euthanasia. Alternatively, the killing of the mother and the dependent pouch young should be regarded as the same, single event, in which case we should apply the same term of ‘humane killing’ to both mother and pouch young. The research, livestock, and animal rescue/care sectors have been narrowing their use of the term euthanasia, retaining it for only the subset of humane killing scenarios that genuinely involve the relief of suffering because there is no other option. Both the commercial and non-commercial Codes for shooting kangaroos use the term euthanasia for killing pouch young, but the ACT could review its use of the term, and decide to use more specific language in its own documentation.

Including pouch young in culling targets and reports

During consultation, some stakeholders suggested that pouch young numbers should be included both in the cull targets, and the cull reports. The Plan states that pouch young are not counted or shot (section 4.3.1 (h)). In the early years of the program, the number of pouch young killed was not reported. However, this situation changed from 2014, when management reports began reporting pouch young, in response to public feedback. Including pouch young in cull targets does not seem feasible, given managers cannot predict, and shooters cannot know whether adult females are carrying pouch young or not, until they check the pouch after shooting the female.

The 2017 Plan states that cull reports will include the number of adults, subadults and young-at-foot that are independently mobile. There has been some concern that independently mobile young at foot could be orphaned when females are shot [*Animal Liberation ACT & Conservator of Flora and Fauna (Administrative Review) [2014] ACAT 35, No. 48*]. In practice this may be rare, since large young-at-foot should be shot and counted as a culled kangaroo. If it does occur, research suggests that the young kangaroo may survive, but experience emotional distress (McLeod and Sharp 2014).

Recommendations

- 6.1 The Code for non-commercial shooting of kangaroos is 16 years old. The ACT Government should work with counterparts in the other jurisdictions to update the Code, and bring it closer to the standard of the current Code for commercial shooting of kangaroos (dated 2020). The 2020 Code for commercial kangaroo shooting has some useful new material (such as more detailed and updated standard operating procedures appended to the Code) that could be incorporated into a new non-commercial Code. In addition, the pre-consultation approach used in the development of the commercial Code – where stakeholder views were gathered to inform the revision – could also be considered for the non-commercial Code.
- 6.2 In the interim, the ACT Government could consider gathering all the information that guides the current conduct of the conservation culling operation into a single, non-statutory ‘standard operating procedures’ style of document, that can be used to communicate the very high standards and careful operation of the conservation culling program to all shooters working in the ACT, to shooters working in other jurisdictions, and to the public. To inform these SOPs, consider seeking review from the **ACT’s Animal Welfare Advisory Committee**, a body with broad community representation from the animal welfare, farming, veterinary, research, conservation, companion animal, recreational/sporting and environmental legislation sectors.

- 6.3 Consider increasing the involvement of government vet(s), making them integral member(s) of the culling operations, helping to gather additional information on kangaroo demographics and health, and helping to communicate to the public that animal welfare is a primary consideration during the culling.
- 6.4 Explore the potential for further research to improve the effectiveness and consistency of portable non-penetrating captive bolts as an alternative method for humanely killing pouch young of certain ages. If potential exists, then support that research. Similarly, remain aware of further research into the development of sentience in pouch young, and implications for adjusting methods for humanely killing unfurred joeys.
- 6.5 Shooter competency:
- Consider providing shooter competency tests annually instead of every two years. Allow shooters that fail, to re-sit the test the following year; and drop the frequency of retesting to one in 3-5 years, so the overall workload of administering the tests is not increased, yet shooters are able to take the test again sooner.
 - Include the use of night-vision equipment in shooter tests.
 - The current penalties for killing females currently deter landholders from using the male-only culling season; consider modifying penalties to encourage male only culls to occur, whilst maintaining strong discouragement for shooting females out of the mixed-cull season.
- 6.6 Make the ear tags biodegradable.
- 6.7 Consider how to design and manage field audits during rural culls to optimise welfare benefits, make audits a constructive opportunity for two-way exchange, and reduce administrative burdens on farmers and government staff.
- 6.8 The Animal Welfare Act has been updated to recognize animal sentience since the 2017 Plan was released and this should be reflected in the revised Kangaroo Management Plan.
- 6.9 In the revised Plan, and other (new) documents relating to kangaroo management in the ACT, consider replacing the term 'euthanasia' with 'humane killing' for pouch young that are killed because their mothers have been shot during the conservation culling. This is in line with the terminology used in the National Animal Welfare Standards and Guidelines.

6.1.2 Kangaroo welfare in wildlife caring and translocations

The 2017 Plan does not support translocations, or the release of hand-reared kangaroos, because of poor welfare outcomes for kangaroos, and some risks to humans (from hand-reared kangaroos). Research since 2017 on the outcomes of large macropod translocations corroborates this position.

The Plan outlines the welfare arguments against hand-rearing and releasing kangaroos in the ACT (welfare concerns for the individual kangaroo, risk that hand-reared males could later injure people when they are mature, risk to resident kangaroos). There is a licence to export 35 kangaroos that come into care in the ACT, into NSW, each year. The Plan notes that there is no justification for hand-rearing and release on conservation grounds as the eastern grey kangaroo is an abundant species.

The Plan does not support alternative actions to culling that have poor welfare outcomes for individual kangaroos, including translocation of kangaroos. Kangaroos to be moved must be captured and sedated, transported, then released to a novel site, steps that each present risks of distress, injury, and death from various mechanisms. Research carried out since the 2017 Plan was published corroborates this assessment (e.g. Cowan *et al.* 2020; Thompson *et al.* 2022).

In addition, translocations can not be carried out on the scale required to keep kangaroo populations at lower levels, they are resource-intensive, and there are no/few suitable release sites. Since eastern grey kangaroos are not threatened, there is no conservation justification for translocations.

6.1.3 Kangaroo welfare considerations only partially, or not, considered by the 2017 Plan

The 2017 Plan focussed mainly on kangaroo welfare during culling. In the revised Plan, if the recommendation of adding 'One Welfare' as an impact area is adopted, then the kangaroo welfare considerations of other actions can also be explicitly considered. These include fertility treatment, fencing, inaction when high density kangaroo populations starve during drought conditions, and kangaroo-vehicle collisions.

6.1.3.1 Fertility control treatment

The Plan has supported research into fertility control methods that avoid poor welfare outcomes. The ACT Government has invested in research to develop, and assess the welfare outcomes, of dart-delivered immuno-contraceptive techniques that do not require the kangaroo to be immobilised, which is stressful and involves risk of injury and death.

Although fertility control treatment can reduce the number of kangaroos that are killed, it may not be considered ethical from an animal rights perspective.

6.1.3.2 Welfare outcome from exclusion fencing and barrier fencing

Large fenced enclosures may affect kangaroo movement. Kangaroos could get caught in large or small exclusion fences. Alternatively, the use of fencing to protect grazing sensitive areas can reduce the need to kill kangaroos by excluding them, or by allowing fertility treatment to be used on the small enclosed kangaroo population. Barrier fences along roads can reduce the number of collisions with vehicles. Road barrier fences can restrict kangaroo movements. If poorly designed, they can act as funnels, directing kangaroos to sections of roads and creating a collision hotspot (Cope and Herbert 2023).

6.1.3.3 Poor welfare outcomes when high density populations face food shortage

Herbivore populations that lack top-down predation pressure are often characterised by marked population fluctuations. Episodes of greater food availability (for example, after good rain) causes numbers to increase but the population eventually overshoots their food supply, especially if conditions change (for example, to a dry spell). The population crash that follows has poor welfare outcomes for individual kangaroos, affecting young and old animals most strongly (Bergeron *et al.* 2023; Wilson and Edwards 2019).

Eastern grey kangaroos are reported to experience mass die-offs, when low food, increased disease burdens, and low overnight temperatures combine to increase mortality rates, especially in sub-adults (Coulson 2007; Fletcher 2006b; Portas and Snape 2018; Wilson and Coulson 2021) but also in adults (Brandimarti *et al.* 2021; Hunter and Hunter 2019). Subadults in higher density populations in the ACT have been shown to have lower bone marrow fat and blood metrics (such as haematocrit, red cell count, albumin, etc), making them more vulnerable to die off events from starvation, hastened by disease, or predation, during winter and early spring when food shortages are most likely (Fletcher 2006b; Portas and Snape 2018).

Culling could improve welfare outcomes if it reduces suffering across individual kangaroos exposed to starvation (Hampton *et al.* 2019). Note that Fletcher (2007) suggests that mass starvation is a natural process, and should not be a reason to cull. That statement makes sense in large protected areas like Namadgi NP. However, in the managed kangaroo populations of Canberra Nature Park, where welfare outcomes from management actions is a critical factor in decision-making, then it makes sense to consider welfare more comprehensively, across all management decisions to act, or not act.

Wilson and Coulson (2021) suggest that early intervention to cull animals when populations begin to increase would improve welfare outcomes for individual kangaroos, and/or reduce the number of kangaroos that need to be killed in a later intervention, because intervening later would mean killing more kangaroos. They describe the relationships between the direction of population change (increasing or decreasing) with female reproductive rate (higher when population is increasing) and adult sex ratio (even when population is increasing; female biased when population is decreasing because of differential male mortality), and suggest these markers could be used to help gauge the likely population trajectory in the near future.

6.1.3.4 Poor welfare outcomes from high rates of vehicle collisions during dry conditions

Collisions between vehicles and kangaroos increase when conditions are dry, because kangaroos move more widely and cross roads in search of food, and may cluster along road verges to access the forage there. The effect is accentuated when the kangaroo densities neighbouring the road are high (Cope and Herbert 2023; Herbert *et al.* 2021). In the ACT, around 2600-5800 kangaroos are killed annually by collisions with vehicles, and thousands more are injured (some of which may also die) (see [Sections 5.2](#) and [5.6](#)). Although reducing collision rates is not a justification for culling, it is possible that the overall consequentialist welfare outcomes from culling (where some kangaroos are shot humanely and fewer kangaroos and people are involved in collisions) are greater than those from not culling (where more kangaroos and people are involved in road collisions) (Hampton *et al.* 2019).

6.2 Interactions between humans and kangaroos

The 2017 Plan's policy on managing interactions between humans and kangaroos has an explicit objective:

- Kangaroo management and community education minimise negative encounters between people and kangaroos in the ACT.

This review is unable to assess whether this response has been effective at reducing the incidence of conflict between people and kangaroos. If the occurrence of such events is low, then discerning change is challenging.

The Plan states the incidents between kangaroos and people are few, and mainly arise when unrestrained dogs harass kangaroos. The ACT government has established an 'urban wildlife program' to support welfare of kangaroos, by euthanising injured animals, and sharing information about kangaroos and their welfare, and people's responsibilities with respect to welfare, including by controlling their pet dogs.

Commented [SL48]: Check with....Claire?

Commented [WC49R48]: Yes, happy with this

6.3 Managing kangaroo densities

This group of policies outline the Plan's position on the menu of approaches for controlling kangaroo populations. It establishes that professional shooting is the most humane way to kill independently mobile kangaroos, and that the ACT would work to advance the use of fertility control as a viable population management method for specific circumstances. This last commitment has resulted in field deployment of contraception.

The 2017 Plan's policy on managing kangaroo densities (section 4.3.3) has two objectives:

- Kangaroo densities in the ACT are managed according to the management objectives for the land on which the populations occur.
- Methods of managing kangaroo densities in the ACT are based on the best available scientific knowledge, animal welfare and cost effectiveness.

6.3.1 Methods of culling

This section of the Plan contains information on options for killing kangaroos, and considers that shooting is the most humane option. However, capture darts followed by hand-delivered lethal injections may be used in areas where shooting is not possible. Orally ingested poison is not to be used. The point is made that regular, smaller culls result in fewer kangaroos being killed than irregular, much larger culls (this point is noted also in the section 6.1 Kangaroo Welfare).

6.3.2 Fertility control

The Plan summarises the available approaches for fertility control at that time, and commits to continuing to support and conduct research on fertility control, as has happened since the late 1990s. As noted in section [3.1.3.4 Fertility control target](#), this research has been very successful, and has resulted in the inclusion of

contraception as a population management tool in three reserves, with expansion to additional reserves being planned.

6.3.3 Environmental modification

This collection of policies addresses the options for managing kangaroo densities with broad-scale ecological manipulations of the environment, such as increasing tree cover, reducing water sources, encouraging top-down population regulation from dingoes, and exclusion by fencing. Most of these options are not viable or useful in the reserves of Canberra Nature Park, except in exceptional circumstances such as the large fenced area of Mulligan's Flat-Goorooyarroo, or using long lengths of fencing to edge a road.

However, at smaller scales, modification could be effective. Using piles of coarse woody material, or small fenced plots, or even carcasses, to exclude kangaroo grazing from small areas, can have marked effect on species richness at those sites (Barton *et al.* 2011; Barton *et al.* 2016; Manning *et al.* 2013; McIntyre *et al.* 2019; Smith *et al.* 2023). Allowing the grass in some small patches to become so thick that kangaroos avoid eating it is another example of small-scale manipulation. The use of environmental modification at small scales is discussed in this Review at [Section 3.2.11](#).

6.4 Managing captive populations

This policy deals with the issues of enclosed populations of kangaroos in a logical way and makes the responsibilities of managers of such areas clear.

This policy does not have an explicit objective. The policy deals with situations where kangaroos are enclosed by a fence. When emigration is impossible, and some sources of mortality (such as road collisions) are eliminated populations can grow very quickly, and kangaroo welfare could be poor (Herbert *et al.* 2021; Mawson *et al.* 2016). In areas greater than 100 ha, that population is to be managed as a wild population, but in smaller areas the kangaroos must be managed as a captive population. In these cases, the landholder must seek a licence to keep and prepare a management plan, and must control breeding mainly by controlling breeding rather than culling. The management should aim to maintain the ecological (including soil) and cultural values of the site. Site owners/managers can apply to remove all kangaroos from small, fenced areas.

The requirement to use fertility control rather than culling makes sense when the population is small, and females are not emigrating into the area. In addition, there are likely to be human safety concerns about using guns in small areas, potentially surrounded by suburbs. The Review spoke to three site managers of large, fenced areas (>100 ha); the kangaroos in these areas were all managed as wild populations, with varying levels of management advice/support (for example, for kangaroo counts, or monitoring threatened species) from the ACT Government.

7. Is kangaroo culling for a conservation outcome justified?

The Review assessed the ACT Kangaroo Management program against a set of seven international consensus principles for ethical wildlife control in conservation programs, finding the program mostly adheres to the principles. Using the framework is a reminder that other threats to the ecological integrity of grassy ecosystems (fire regimes, invasive species, fragmentation) should be managed to the extent possible; that kangaroo management must be justified (on environmental grounds); that management must have clear and achievable outcome-focussed objectives; that overall welfare (least harm to least animals) is considered; that the diversity of human values is considered; that management is well-planned; and that kangaroos are not labelled in a way that scape-goats them for a situation not of their making.

As described in section 5.5 [Trauma to people](#), killing native animals for conservation purposes poses a valid moral and ethical challenge, because people value animals and nature in diverse ways. Broadly, a person’s values may align with conservation-centric, animal rights-centric, welfare-centric perspectives, or some combination of these. As the natural world is reduced and degraded, the potential for discord between conservation, welfare, and animal rights perspectives is increasing in frequency; at the same time, the morality of considering non-human animal interests in decisions, including conservation decisions, continues to be explored (Schapper *et al.* 2022).

Dubois *et al.* (2017) propose a framework, with seven principles, to support decisions about controlling native species in situations of conflict with humans (where conflict could cover a range of issues) that is rational, evidence-based, and ethical because it considers and weighs the needs, benefits, and costs from various perspectives. The authors suggest this framework could lessen controversy over wildlife control, although they note that it will not remove controversy if stakeholders want decisions to be made solely based on one set of rights, such as the right of a farmer to guard their livelihood against any animals, or the rights of animals to live without intervention from people.

Another approach to place killing animals for conservation into a moral framework was explored recently in Woinarski (2018), who developed a set of principles to guide decision-making by adapting a rubric designed originally to identify when war is ‘just’. The principles outlined in Woinarski are slightly more detailed, and pertain to a narrower set of circumstances, than those proposed by Dubois *et al.*, but the two frameworks substantially overlap. The seven principles of Dubois *et al.* (2017), with some additional detail drawn from Woinarski (2018), are listed in Table 5, against a column that evaluates how the ACT Kangaroo Management Plan rates against these principles.

Table 5. An assessment of the ACT Kangaroo Management program against principles for ethical wildlife control, based on (Dubois *et al.* 2017; Woinarski 2018). The table asks: Is the conservation culling of eastern grey kangaroos predicated on a benefits to the environment? The table also considers the rural cull against the framework.

Principle	ACT Kangaroo Management – performance against the principle	Areas for improvement
1. Modify human practices: Address the ultimate factors responsible for the ecological imbalance to the extent possible.	<i>Conservation and Economic</i> <ul style="list-style-type: none"> The ultimate factors of the ecological imbalance - of urban and agricultural expansion, causing habitat loss, fragmentation, removal of dingos, dispossession of Indigenous people, invasive species, nutrient loading, proliferation of water points, and changed fire regimes - are mostly impossible or impractical to wind back. 	Further adjustments to human practice could include: <ul style="list-style-type: none"> Ensure that kangaroo management is one part of integrated management in (and off) reserves, and other threats are being managed as effectively as possible. Reconnect habitat fragments and allow kangaroos to move between these areas, possibly spreading some of the grazing pressure. Consider the needs of biodiversity, including kangaroos, during urban expansion.

Principle	ACT Kangaroo Management – performance against the principle	Areas for improvement
		<ul style="list-style-type: none"> Take a more cross-tenure approach to environmental management, so kangaroos and other species are managed more effectively in a fragmented landscape.
<p>2. Justification for control: Is there compelling evidence that eastern grey kangaroos have a significant detrimental impact on people, property, livelihoods, ecosystems, other animals.</p>	<p><i>Conservation</i></p> <ul style="list-style-type: none"> Given the current distribution of habitat fragments, and their ecological condition, high or low levels of kangaroo grazing can now contribute to further ecological degradation, and further decline and extinction risk in other native species. Preventing such extinctions has a justifiable ethical basis, because species have intrinsic values and rights to exist; because future human generations have the right to experience the diversity of the natural world in the way previous generations have; and because further erosion of nature diminishes Country for Indigenous Australians. <p><i>Economic</i></p> <ul style="list-style-type: none"> High densities of kangaroos (especially in dry conditions) adversely affect economic viability of farms. 	
<p>3. Clear and achievable outcome-based objectives: Are there net conservation, economic benefits, which are clearly expressed, monitored, with information used to adapt management?</p>	<p><i>Conservation</i></p> <ul style="list-style-type: none"> Kangaroo management for conservation outcomes has clear and achievable objectives for grass layer condition and thus the viability of several threatened species; the outcomes (for the grass layer) are monitored; implementation is adapted based on evidence. <p><i>Economic</i></p> <ul style="list-style-type: none"> Economic outcomes for farmers are assumed based on past research, but not directly monitored or used to adapt management. 	<ul style="list-style-type: none"> Monitor the response of grazing sensitive species. Periodically monitor kangaroo density in reserves other than Canberra Nature Park to provide the broader context in which the kangaroo management sits. Add strategic monitoring of grass layer condition and kangaroo density at priority locations on rural land.
<p>4. Overall welfare: Control should be humane, and cause the least harm to the least number of animals. Options other than killing should be assessed.</p>	<p><i>Conservation and economic</i></p> <ul style="list-style-type: none"> Culling operations are carried out to minimise pain and suffering to kangaroos. The ACT Government is exceeding national standards and is committed to continuous improvement. Culling may result in the least harm to the least number of animals: managing populations to lower densities may reduce overall harm by preventing mass starvation of kangaroos (when food is short); by retaining habitat for grass-dependent animals that are affected by heavy grazing; and by reducing the number of people and kangaroos involved in kangaroo-vehicle collisions. Welfare outcomes of non-culling options have been assessed and mostly 	<ul style="list-style-type: none"> Welfare outcomes (for people, kangaroos, other animals) have not been holistically articulated, monitored, or evaluated, although most of the building blocks are in place. Adding One Welfare as a high level impact area with clear objectives and desired outcomes would allow management decisions to act (or not to act) to be weighed up more consistently and comprehensively.

Principle	ACT Kangaroo Management – performance against the principle	Areas for improvement
	<p>considered worse (e.g. translocations of large macropods have poor outcomes). Contraception may be useful in limited situations, and exclusion (using fences, or logs) may be possible in small areas.</p> <ul style="list-style-type: none"> • Culling, and fertility control, may cause emotional suffering to people with an animal-rights perspective, or a kin relationship (Indigenous) to the animal; people may worry about pain and suffering during a cull; some people form attachments to kangaroo individuals that are culled. 	
<p>5. Social acceptability: The management plan should consider the range of community values</p>	<p><i>Conservation</i></p> <ul style="list-style-type: none"> • The management plans present a comprehensive range of conservation, economic, and social issues and perspectives. • Plan was open for public comment, and its performance is subject to regular review. • The annual operation of the plan is transparent, with monitoring results and culling targets available on the government website. 	<ul style="list-style-type: none"> • Engage the Traditional Custodians, and other Indigenous Canberra families, in the development and implementation of the Plan. • Facilitate broad community engagement into the process for revising the Plan.
<p>6. Systematic planning No ad hoc culling</p>	<p><i>Conservation</i></p> <ul style="list-style-type: none"> • A comprehensive management plan is in place, supported by law and policy, and by a thorough research program with extensive collaboration to the research sector. <p><i>Economic</i></p> <ul style="list-style-type: none"> • Planning occurs at property level, with a 1-2 year horizon. • Culling is regulated and audited. 	<ul style="list-style-type: none"> • Add a strategic assessment of spatial variation in kangaroo density, to inform where control is a priority.
<p>7. Decision-making by specifics rather than labels: Focus management on the specific issue, rather than negatively labelling kangaroos</p>	<ul style="list-style-type: none"> • The management focus on maintaining the grass layer at a certain height is appropriate (compared to reducing the density of 'overabundant' kangaroos, which is less appropriate). • Terms that categorise kangaroos negatively could lead to poorer welfare or ethical outcomes. For example, best to avoid terms such as 'pest' (in the context of farms). The 2017 Plan mostly achieves this. 	

Recommendations

7.1 Consider using the international principles for ethical wildlife control (or something similar) when revising the management plan; note these principles guide ethical management for conservation outcomes, but some stakeholders may have values that conflict with the conservation-centric value in this framework.

7.1 Kangaroo conservation culling in the context of other mortality, and overall population size

Of the direct anthropogenic causes of kangaroo mortality, culling on rural lands affects the largest number of kangaroos (~9100 per year), followed by road kills (midpoint 4200, range 2600 - 5800 per year), then conservation culls (~2000 per year). Therefore, of mortality caused directly by humans (conservation cull, rural cull, road kills), the conservation cull represents 13%. The Review did not estimate the number of kangaroos displaced (and thus probably killed) by urban expansion.

There are about 6 million eastern grey kangaroos in NSW west of the Divide. The Review estimates that there are about 122,500 eastern grey kangaroos in the ACT, of which most are in the large protected areas in the west and south of the ACT (43%) and on rural lands and government horse paddocks (26%). Canberra Nature Park and other lands managed for conservation contain about 26% of the population, and 5% is on Commonwealth land and in plantations (1%). Conservation culling therefore kills less than 2% of the ACT kangaroo population every year, road kills around Canberra affect around 3%, and rural culls affect 76% (stressing these figures are very approximate).

Given the ethical complexities of killing kangaroos for environmental benefits (previous section), it may be useful to compare the extent of mortality caused directly by human action covered in this plan: culling for conservation, culling for economic benefits, and accidental mortality from collisions with vehicles on roads.

Culling for conservation:

- Since 2018, the kangaroo populations in 15 to 16 KMUs have been estimated each year, returning an average density (given the area sampled, usually around 8300 ha, but varies between years) of 1.35 kangaroos per ha.
- Annually, culling has occurred at reserves within 4 to 8 KMUs, with 1041 to 4035 independently mobile kangaroos killed each year (**mean = 1997**), and an additional 362 to 1603 (mean = 769) pouch young killed each year.
- The culls remove about 18% of the independently mobile kangaroos in the reserves within the 15-16 KMUs.

Culling for farm economic benefit:

- The number of kangaroos reported as shot on rural lands has varied from 3878 to 14,569 (**mean 9077**) between 2015 and 2022.

Death by vehicle collision:

- The number of road-killed kangaroos has averaged 2600 (from ranger callout data) to 5800 (from public survey), since 2015. The midpoint of these two figures is 4200. The ranger callout density is an underestimate, the public survey records may be inflated if people recall collisions that occurred longer than three years ago, or outside the ACT. Neither source count the kangaroos that left the collision site and died later from injuries.

These figures indicate that most kangaroos are killed on rural lands, followed by road collision, then conservation culls. However, another way of looking at this is to consider the proportion killed in terms of their relevant population sizes, because these kangaroos are living in different areas (albeit with some overlap). Table 6 shows the numbers killed, their relevant overall population size and therefore the proportion. Considering the figures in this way, it still seems that the greatest proportion of kangaroos are killed on rural lands, then on conservation land, and then on roads.

Table 6. The number of independently mobile kangaroos killed in conservation culls, rural culls, and by vehicle collisions; and the proportion this represents out of the relevant total population. (Details in Appendix 1).

Mortality source	Average N. kangaroos killed (years)	Population total with rationale, and assessment of uncertainty		Kangaroo mortality as % of population
cull	1997 (2018-2023)	11,250	Population in reserves with culls over last 5 years (8310 ha), with average density 1.35/ha. High certainty: based on annual kangaroo count and cull data, and the areas of reserves are measured.	18%
rural	9077 (2015-2023)	30,300	Population on rural lands (39,500 ha), with density 0.77/ha. Low certainty: data on density are few and old; and culling numbers may be inaccurately reported.	30%
road	4200 (2015-2023)	76400	Low certainty: data on number of collisions is extrapolated from surveys of 600 people and incomplete callout data; overall kangaroo population used is based on the approximate population of kangaroos in ACT minus those in Namadgi, Tidbinbilla, Cotter.	6%

To put these numbers in a broader context, the Review carried out some rough calculations, summarised in Table 7.

- The total population of eastern grey kangaroos in the commercial harvest zones (i.e., west of the Divide) is close to 6 million, but this number fluctuates with weather conditions (NSW DPE 2023).
- The harvest zone that surrounds the ACT contains about 1.4 million eastern grey kangaroos.
- Using density data from empirical studies in different parts of the ACT, the Review estimates – approximately – that there are 122,400 eastern grey kangaroos in the ACT, with most of these in the large contiguous protected areas (43%), and on rural lands and government horse paddocks (26%). About 26% of the ACT population is in Canberra Nature Park and other lands managed for conservation (and 9% are managed), 5% is on Commonwealth land, with 1% in plantations.

Thus, conservation culling kills less than 2% of the ACT kangaroo population annually, road kills affect about 3%, and rural culls affect about 7% (stressing these figures are very approximate).

Table 7. The number of kangaroos, and their density, in different land tenure/uses, a confidence rating for the estimate, and the source for the estimates. Note that in some cases these estimates are very approximate, especially those for rural lands, and protected areas in the ACT that are not Canberra Nature Park.

Location and Statistic	Population size	Density	Confidence rating	Source
NSW				
Population size of EG kangaroos in NSW commercial harvest zones (everywhere west of the Divide; 688,004 km ²)	5,880,000	0.86/ha	high	(NSW DPE 2023) (Lunney <i>et al.</i> 2018) Quota is 14-15%, and actual harvest is <3% of population
Population size of EG kangaroos in NSW Southeast Tableland commercial harvest zone (surrounds ACT), 40,705 km ²	1,428,800	0.35/ha	high	(NSW DPE 2023) (Lunney <i>et al.</i> 2018) Quota is 15%, and actual harvest is <1% of population
ACT	Population size % of total ACT population			

Population size of EG kangaroos in the ACT (2358 km ²)	122,400 100%			Based on adding estimated populations of rural land; horse paddocks; plantation; Canberra Nature Park (split into those where kangaroos are managed and not managed); other land managed as reserves; Namadgi-Tidbinbilla-Cotter (split into grasslands, grassy woodlands, forests using vegetation mapping data, each with different density estimates); Commonwealth land with grassy ecosystems.
Population size of EG kangaroos in Canberra Nature Park and reserved land where kangaroos are managed (83.1 km ²)	11,200 9%	1.35/ha in	high	average density of years 2018-2023
Population size of EG kangaroos in Canberra Nature Park and reserved land where kangaroos are not managed (115.9 km ²)	20,300 17%	1.75/ha	moderate	Use density from unmanaged areas with count data; smaller sample than for managed areas
Population size of EG kangaroos on rural lands (395 km ²)	30,300 25%	0.77/ha	low	From old empirical data (ACT Government 2010; NSW DPE 2023; Perry and Braysher 1986); and the density on rural land in the KMUs (two estimates)
Population size of EG kangaroos in horse paddocks (9.7km ²)	865 1%	0.89/ha	moderate	Based on limited count data
Population size of EG kangaroos in Namadgi-Tidbinbilla-Cotter (1200 km ²)	52,500 43%	0.1 to 3.2/ha	low	<ul style="list-style-type: none"> • 36 km² grassy areas with 3.2 roos/ha, (ACT Government 2010; Banks <i>et al.</i> 2000; Fletcher 2006b) plus recent WLT data (1 estimate). • 199 km² grassy woodlands with 1.6/ha (density set at 50% of the estimates for grasslands) • 958 km² forests with 0.1 roos/ha
Population size of EG kangaroos on Commonwealth land with grassy ecosystems(45 km ²)	6080 5%	1.35/ha	moderate	Assuming densities similar to CNP
Plantation (112km ²)	1120 1%	0.1/ha	low	Young successional stages contain suitable feeding habitat; all stages provide cover.

Recommendation

7.1 These estimates for kangaroo population sizes across the ACT are uncertain, because of the paucity of data on kangaroo densities from rural lands and the large protected areas that are not Canberra Nature Park (i.e., Namadgi NP, Tidbinbilla NR). Obtaining density estimates from these areas, periodically, would help to understand the broader context in which kangaroo management is operating. Recommendation 4.3 was for an assessment of spatial variation in kangaroo density on rural lands, followed by an ongoing monitoring program carried out around every 5 years or another ecologically sensible interval. Here, the recommendation is to integrate this with periodic surveys on the large, reserved areas in the west and south of the ACT. This information will help contextualise the intensive management in Canberra Nature Park, and provide an overall status assessment of one of the ACT's iconic species.

8. References

- ACT Auditor-General (2021) ACT Auditor-General's Report: Land Management Agreements Report No. 1 / 2021. ACT Audit Office. (Canberra, Australia)
- ACT Conservator of Flora and Fauna (2020) Biodiversity Research and Monitoring Implementation Report 2017-19. Environment, Planning and Sustainable Development Directorate. ACT Government. (Canberra, Australia)
- ACT Government (2010) ACT Kangaroo Management Plan. Parks, Conservation and Lands, Department of Territory and Municipal Services, ACT Government. (Canberra, Australia)
- ACT Government (2017a) ACT native grassland conservation strategy and action plans. Environment, Planning and Sustainable Development. (Canberra, Australia)
- ACT Government (2017b) Eastern Grey Kangaroo: Controlled Native Species Management Plan. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2017c) Estimating kangaroo density: A comparison of methods for Eastern Grey Kangaroos in the peri-urban environment - DRAFT. Environment and Planning Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2017d) Nature Conservation (Translocation of Native Flora and Fauna) Conservator Guidelines. Notifiable instrument NI2017-650 (Conservator of Flora and Fauna, ACT Government: Canberra, Australia)
- ACT Government (2019a) Draft Herbage Mass Management Guidelines for Lowland Grassy Ecosystems of the ACT. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2019b) Ecological Guidelines for Fire, Fuel and Access Management Operations. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2020) ACT Wellbeing Framework. Treasury and Economic Development Directorate. (Canberra, Australia)
- ACT Government (2021a) Canberra Nature Park Reserve Management Plan. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2021b) Government Response to ACT Auditor-General's Report No. 1 of 2021 - Land Management Agreements The Legislative Assembly for the ACT. (Canberra, Australia)
- ACT Government (2022) Caring for Dhawura Ngunnawal: A natural resource plan for the ACT 2022-2042. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2023a) Eastern Grey Kangaroo Conservation Management Advice. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- ACT Government (2023b) Wildlife Callouts Heatmap 2016-2022; Up To July 2022.)
- ACT Government (undated) Estimating kangaroo density: A comparison of methods for eastern grey kangaroos in the peri-urban environment DRAFT. Environment, Planning and Sustainable Development Directorate. (Canberra, Australia)
- AgriFutures (2020) National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes. AgriFutures Australia Publication No. 20-126. AgriFutures Australia. (Wagga Wagga, Australia)
- ANVMA (2020) AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. American Veterinary Medical Association. (Schaumburg, IL, USA)
- Review of the ACT EGK CNSM Plan /p. 103*

Atkinson J and Hampton JO (2023) Animal welfare assessment of kangaroo culling: ACT 2023. *Ecotone Wildlife* 1448-5494.

Australia Co (2020) National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes. AgriFutures Australia. (Canberra, Australia)

AWS (2020) Carcass Utilisation in the ACT - a Discussion Paper. A report to ACT Environment, Planning and Sustainable Development Directorate. Australian Wildlife Services. (Canberra, Australia)

Banks PB, Newsome AE, and Dickman CR (2000) Predation by red foxes limits recruitment in populations of eastern grey kangaroos. *Austral Ecology* 25, 283-291

Barton PS, Evans MJ, Foster CN, Pechal JL, Bump JK, Quaggiotto M-M, and Benbow ME (2019) Towards quantifying carrion biomass in ecosystems. *Trends in Ecology & Evolution* 34, 950-961

Barton PS, Manning AD, Gibb H, Wood JT, Lindenmayer DB, and Cunningham SA (2011) Experimental reduction of native vertebrate grazing and addition of logs benefit beetle diversity at multiple scales. *Journal of Applied Ecology* 48, 943-951

Barton PS, McIntyre S, Evans MJ, Bump JK, Cunningham SA, and Manning AD (2016) Substantial long-term effects of carcass addition on soil and plants in a grassy eucalypt woodland. *Ecosphere* 7, e01537

Bennett A, Duncan DH, Rumpff L, and Vesk PA (2020) Disentangling chronic regeneration failure in endangered woodland ecosystems. *Ecosphere* 11, e02998

Bergeron R, Pigeon G, Forsyth DM, King WJ, and Festa-Bianchet M (2023) Post-weaning survival in kangaroos is high and constant until senescence: Implications for population dynamics. *Ecology* 104, e3963

Bowman DMJS and Legge S (2016) Pyrodiversity—why managing fire in food webs is relevant to restoration ecology. *Restoration Ecology* 24, 848-853

Brandimarti ME, Gray R, Silva FR, and Herbert CA (2021) Kangaroos at maximum capacity: health assessment of free-ranging eastern grey kangaroos on a coastal headland. *Journal of Mammalogy* 102, 837-851

Brown GW, Dorrough JW, and Ramsey DS (2011) Landscape and local influences on patterns of reptile occurrence in grazed temperate woodlands of southern Australia. *Landscape and Urban Planning* 103, 277-288

Brunton E, Brunton A, Hohwieler K, Ogbourne S, and Conroy G (2022) Spatial genetic structure and gene flow of the eastern grey kangaroo (*Macropus giganteus*), in a rapidly urbanising landscape. *Global Ecology and Conservation* 38, e02273

Caughley G, Shepherd N, and Short J (1987) 'Kangaroos: their ecology and management in the sheep rangelands of Australia.' (Cambridge University Press: Melbourne, Australia)

Ceballos G, Davidson A, List R, Pacheco J, Manzano-Fischer P, Santos-Barrera G, and Cruzado J (2010) Rapid decline of a grassland system and its ecological and conservation implications. *PLoS one* 5, e8562

CoA (2023) Draft National Recovery Plan for Four Grassland Earless Dragons (*Tympanocryptis* spp.) of Southeast Australia. Commonwealth of Australia. (Canberra, Australia)

Cope H and Herbert C (2023) Understanding Wildlife-Vehicle Collisions. Stage 3 Funded Activity Report. School of Life and Environmental Sciences, University of Sydney. (Sydney, Australia)

Coulson G (1989) The effect of drought on road mortality of macropods. *Wildlife Research* 16, 79-83

- Coulson G (2007) Exploding kangaroos: assessing problems and setting targets. In 'Pest or Guest, the Zoology of Overabundance'. (Ed. CR Dickman, D Lunney, P Eby, P Hutchings, and S Burgin) pp. 174-181. (Royal Zoological Society of New South Wales: Mossman, NSW, Australia)
- Coulson G (2010) Independent peer review of the ACT Kangaroo Management Plan. University of Melbourne. (Melbourne, Australia)
- Coulson G, Snape MA, and Cripps JK (2021) How many macropods? A manager's guide to small-scale population surveys of kangaroos and wallabies. *Ecological Management & Restoration* **22**, 75-89
- Cowan M, Blythman M, Angus J, and Gibson L (2020) Post-release monitoring of western grey kangaroos (*Macropus fuliginosus*) relocated from an urban development site. *Animals* **10**, 1914
- Croft DB and Witte I (2021) The perils of being populous: Control and conservation of abundant kangaroo species. *Animals* **11**, 1753
- Cullen B, Eckard R, Callow M, Johnson I, Chapman D, Rawnsley R, Garcia S, White T, and Snow V (2008) Simulating pasture growth rates in Australian and New Zealand grazing systems. *Australian Journal of Agricultural Research* **59**, 761-768
- DCCEEW (2023a) Approved Conservation Advice for the Native Temperate Grasslands of the South Eastern Highlands. Department of Climate Change, Energy, the Environment and Water. (Canberra, Australia)
- DCCEEW (2023b) Approved Conservation Advice for the White Box-Yellow Box -Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Department of Climate Change, Energy, the Environment and Water. (Canberra, Australia)
- Descovich K, McDonald I, Tribe A, and Phillips C (2015) A welfare assessment of methods used for harvesting, hunting and population control of kangaroos and wallabies. *Animal Welfare* **24**, 255-265
- Diesch T, Mellor D, Johnson C, and Lentle R (2010) Developmental changes in the electroencephalogram and responses to a noxious stimulus in anaesthetized tammar wallaby joeys (*Macropus eugenii eugenii*). *Laboratory Animals* **44**, 79-87
- Diesch TJ, Mellor DJ, Johnson CB, and Lentle RG (2008) Responsiveness to painful stimuli in anaesthetised newborn and young animals of varying neurological maturity (wallaby joeys, rat pups and lambs). *AATEX* **14**, 549-552
- Dimond WJ, Osborne WS, Evans MC, Gruber B, and Sarre SD (2012) Back to the brink: population decline of the endangered grassland earless dragon (*Tympanocryptis pinguicolla*) following its rediscovery. *Herpetological Conservation and Biology* **7**, 132-149
- Dixon KM, Cary GJ, Worboys GL, Banks SC, and Gibbons P (2019) Features associated with effective biodiversity monitoring and evaluation. *Biological Conservation* **238**, 108221
- Dorrrough J, Ash J, and McIntyre S (2004) Plant responses to livestock grazing frequency in an Australian temperate grassland. *Ecography* **27**, 798-810
- Dorrrough J, McIntyre S, Brown G, Stol J, Barrett G, and Brown A (2012) Differential responses of plants, reptiles and birds to grazing management, fertilizer and tree clearing. *Austral Ecology* **37**, 569-582
- Dorrrough J, Moxham C, Turner V, and Sutter G (2006) Soil phosphorus and tree cover modify the effects of livestock grazing on plant species richness in Australian grassy woodland. *Biological Conservation* **130**, 394-405
- Driscoll DA (2017) Disturbance maintains native and exotic plant species richness in invaded grassy woodlands. *Journal of Vegetation Science* **28**, 573-584

- Dubois S, Fenwick N, Ryan EA, Baker L, Baker SE, Beausoleil NJ, Carter S, Cartwright B, Costa F, Draper C, Griffin J, Grogan A, Howlad G, Jones B, Littin KE, Lombard AT, Mellor DJ, Ramp D, Schuppli CA, and Fraser D (2017) International consensus principles for ethical wildlife control. *Conservation Biology* **31**, 753-760
- Dunne B and Doran B (2021) Spatio-temporal analysis of kangaroo–vehicle collisions in Canberra, Australia. *Ecological Management & Restoration* **22**, 67-70
- Fischer J, Lindenmayer DB, and Cowling A (2004) The challenge of managing multiple species at multiple scales: reptiles in an Australian grazing landscape. *Journal of Applied Ecology* **41**, 32-44
- Fletcher D (2006a) Population dynamics of eastern grey kangaroos in temperate grasslands. (University of Canberra, Canberra, Australia)
- Fletcher D (2006b) What process limits the high-density populations of eastern grey kangaroos at Gudgenby and other local sites? Unpublished report. University of Canberra. (Canberra, Australia)
- Fletcher D (2007) Managing Eastern Grey Kangaroos *Macropus giganteus* in the Australian Capital Territory: reducing the overabundance-of opinion. In 'Pest or Guest: the zoology of overabundance'. (Ed. D Lunney, P Eby, P Hutchings, and S Burgin) pp. 117-128. (Royal Zoological Society of New South Wales: Mosman, NSW, Australia)
- Foster CN, Banks SC, Cary GJ, Johnson CN, Lindenmayer DB, and Valentine LE (2020) Animals as agents in fire regimes. *Trends in Ecology & Evolution* **35**, 346-356
- Foster CN, Barton PS, and Lindenmayer DB (2014) Effects of large native herbivores on other animals. *Journal of Applied Ecology* **51**, 929-938
- Fuhlendorf SD, Engle DM, Kerby J, and Hamilton R (2009) Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. *Conservation Biology* **23**, 588-598
- Gibson-Roy P and Delpratt J (2015) The restoration of native grasslands. In 'Land of Sweeping Plains: Managing and restoring the native grasslands of south-eastern Australia'. (Ed. N Williams, A Marshall, and J Morgan) pp. 331-388. (CSIRO Publishing: Melbourne, Australia)
- Goldin SR and Hutchinson MF (2013) Coarse woody debris modifies surface soils of degraded temperate eucalypt woodlands. *Plant and Soil* **370**, 461-469
- Gordon I and Snape M (2019) Kangaroo Management Research Workshop Summary Report. ACT Government. (Canberra, Australia.)
- Gordon I, Snape M, Fletcher D, Howland B, Coulson G, Festa-Bianchet M, Caley P, McIntyre S, Pople T, and Wimpenny C (2021) Herbivore management for biodiversity conservation: a case study of kangaroos in the Australian Capital Territory (ACT). *Ecological Management & Restoration* **22**, 124-137
- Gordon IJ, Gregorini P, and Evans MJ (2023) Herding the Literature: Trends in Large Mammalian Herbivore Grazing and Foraging Ecology Research over the Past Three Decades. *Rangeland Ecology & Management*
- Gordon IJ, Hester AJ, and Festa-Bianchet M (2004) The management of wild large herbivores to meet economic, conservation and environmental objectives. *Journal of Applied Ecology* **41**, 1021-1031
- Gott B (2008) Indigenous use of plants in south-eastern Australia. *Telopea* **12**, 215-226
- Hampton JO, Arnemo JM, Barnsley R, Cattet M, Daoust P-Y, DeNicola AJ, Eccles G, Fletcher D, Hinds LA, and Hunt R (2021) Animal welfare testing for shooting and darting free-ranging wildlife: a review and recommendations. *Wildlife Research* **48**, 577-589

Hampton JO and Forsyth DM (2016) An assessment of animal welfare for the culling of peri-urban kangaroos. *Wildlife Research* **43**, 261-266

Hampton JO, Warburton B, and Sandøe P (2019) Compassionate versus consequentialist conservation. *Conservation Biology* **33**, 751-759

Hangar J and Nottidge B (2009) Queensland Code of Practice for the Welfare of Wild Animals Affected by Land-Clearing and Other Habitat Impacts; and Wildlife Spotter/Catchers. Australian Wildlife Hospital, Australia Zoo Wildlife Warriors Worldwide Ltd. (Beerwah, Australia)

Henderson T, Vernes K, Körtner G, and Rajaratnam R (2018) Using GPS technology to understand spatial and temporal activity of kangaroos in a peri-urban environment. *Animals* **8**, 97

Herbert CA, Snape MA, Wimpenny CE, and Coulson G (2021) Kangaroos in peri-urban areas: A fool's paradise? *Ecological Management & Restoration* **22**, 167-175

Hoffmann AA, Miller AD, and Weeks AR (2021) Genetic mixing for population management: From genetic rescue to provenancing. *Evolutionary Applications* **14**, 634-652

Hone J (2007) 'Wildlife damage control.' (CSIRO Publishing)

Hone J and Snape M (2024) Bias and precision of predicted densities of kangaroo populations. *Ecological Management and Restoration* **in review**

Howland B, Stojanovic D, Gordon IJ, Manning AD, Fletcher D, and Lindenmayer DB (2014) Eaten out of house and home: impacts of grazing on ground-dwelling reptiles in Australian grasslands and grassy woodlands. *PLoS one* **9**, e105966

Howland BW, Stojanovic D, Gordon IJ, Fletcher D, Snape M, Stirnemann IA, and Lindenmayer DB (2016a) Habitat preference of the striped legless lizard: implications of grazing by native herbivores and livestock for conservation of grassland biota. *Austral Ecology* **41**, 455-464

Howland BW, Stojanovic D, Gordon IJ, Radford J, Manning AD, and Lindenmayer DB (2016b) Birds of a feather flock together: Using trait-groups to understand the effect of macropod grazing on birds in grassy habitats. *Biological Conservation* **194**, 89-99

Hunter JT and Hunter VH (2019) High macropod populations at Look At Me Now Headland, North Coast NSW: implications for endangered *Themeda triandra* grasslands on coastal headlands. *Cunninghamia* **19**, 97-106

IUCN SSC (2013) Guidelines for reintroductions and other conservation translocations. IUCN SSC Re-Introduction Specialist Group. (Gland, Switzerland)

Juillard LQ and Ramp D (2022) The Impacts of Drought on the Health and Demography of Eastern Grey Kangaroos. *Animals* **12**, 256

Kennedy BP, Boyle N, Fleming PJ, Harvey AM, Jones B, Ramp D, Dixon R, and McGreevy PD (2022) Ethical Treatment of Invasive and Native Fauna in Australia: Perspectives through the One Welfare Lens. *Animals* **12**, 1405

Leahy L, Legge S, Tuft K, McGregor HW, Barmuta LA, Jones ME, and Johnson CN (2016) Amplified predation after fire suppresses rodent populations in Australia's tropical savannas. *Wildlife Research* **42**, 705-716

Lee E, Klöcker U, Croft DB, and Ramp D (2004) Kangaroo-vehicle collisions in Australia's sheep rangelands, during and following drought periods. *Australian Mammalogy* **26**, 215-226

Legge S, Lindenmayer DB, Robinson N, Scheele B, Southwell D, and Wintle B (2018) 'Monitoring Threatened Species and Ecological Communities.' (CSIRO Publishing: Melbourne, Australia)

Review of the ACT EGK CNSM Plan /p. 107

- Legge S, Smith JG, James A, Tuft KD, Webb T, and Woinarski JCZ (2019) Interactions among threats affect conservation management outcomes: Livestock grazing removes the benefits of fire management for small mammals in Australian tropical savannas. *Conservation Science and Practice*, e52
- Lindenmayer DB and Likens GE (2010) 'Effective ecological monitoring.' (CSIRO Publishing: Melbourne)
- Lucas Z, Pulsford S, Wimpenny C, and Snape M (2021) Seasonal breeding of the Eastern Grey Kangaroo provides opportunities for improved animal welfare in kangaroo management. *Ecological Management & Restoration* **22**, 138-140
- Lunney D, Purcell B, McLeod S, Grigg G, Pople T, and Wolter S (2018) Four decades of research and monitoring the populations of kangaroos in New South Wales: one of the best long-term datasets in Australia. *Australian Zoologist* **39**, 784-800
- Lunt ID, Eldridge DJ, Morgan JW, and Witt GB (2007) A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia. *Australian Journal of Botany* **55**, 401-415
- Lunt ID and Spooner PG (2005) Using historical ecology to understand patterns of biodiversity in fragmented agricultural landscapes. *Journal of Biogeography* **32**, 1859-1873
- Manning AD, Cunningham RB, and Lindenmayer DB (2013) Bringing forward the benefits of coarse woody debris in ecosystem recovery under different levels of grazing and vegetation density. *Biological Conservation* **157**, 204-214
- Mavromihalis J, Dorrrough J, Clark S, Turner V, and Moxham C (2013) Manipulating livestock grazing to enhance native plant diversity and cover in native grasslands. *The Rangeland Journal* **35**, 95-108
- Mawson PR, Hampton JO, and Dooley B (2016) Subsidized commercial harvesting for cost-effective wildlife management in urban areas: a case study with kangaroo sharpshooting. *Wildlife Society Bulletin* **40**, 251-260
- McDougall A, Milner RN, Driscoll DA, and Smith AL (2016) Restoration rocks: integrating abiotic and biotic habitat restoration to conserve threatened species and reduce fire fuel load. *Biodiversity and Conservation* **25**, 1529-1542
- McGregor HW, Legge S, Jones ME, and Johnson CN (2015) Feral cats are better killers in open habitats, revealed by animal-borne video. *PLoS one* **10**, e0133915
- McIntyre S (2005) Biodiversity attributes of different sward structures in grazed grassland. *Ecological Management & Restoration* **6**, 71-73
- McIntyre S, Cunningham R, Donnelly C, and Manning A (2015) Restoration of eucalypt grassy woodland: effects of experimental interventions on ground-layer vegetation. *Australian Journal of Botany* **62**, 570-579
- McIntyre S, Heard K, and Martin T (2003) The relative importance of cattle grazing in sub-tropical grasslands: does it reduce or enhance plant biodiversity? *Journal of Applied Ecology* **40**, 445-457
- McIntyre S, Mclvor JG, and Heard KM (2004) 'Managing & conserving grassy woodlands.' (CSIRO Publishing: Melbourne, Australia)
- McIntyre S, Nicholls A, Graff P, and Stol J (2019) Experimental reintroduction of three grassland forbs to assess climate-adjusted provenancing, grazing protection and weed control. *Australian Journal of Botany* **66**, 628-639
- McIntyre S, Stol J, Harvey J, Nicholls A, Campbell M, Reid A, Manning A, and Lindenmayer D (2010) Biomass and floristic patterns in the ground layer vegetation of box-gum grassy eucalypt woodland in Gorooyarroo and Mulligans Flat Nature Reserves, Australian Capital Territory. *Cunninghamia* **11**, 319-357

- McIntyre S and Tongway D (2005) Grassland structure in native pastures: links to soil surface condition. *Ecological Management & Restoration* **6**, 43-50
- McLeod SR and Sharp TM (2014) Improving the humaneness of commercial kangaroo harvesting. Rural Industries Research and Development Corporation. (Canberra, Australia)
- Meers BT and Adams R (2003) The impact of grazing by Eastern Grey Kangaroos (*Macropus giganteus*) on vegetation recovery after fire at Reef Hills Regional Park, Victoria. *Ecological Management & Restoration* **4**, 126-132
- Micromex (2023) Attitudes and Opinions of ACT Residents Regarding Kangaroos and their Management. Micromex Research and ACT Government. (Canberra, Australia)
- Morgan JW (2015) Biomass management in native grasslands. In 'Land of Sweeping Plains: Managing and restoring the native grasslands of south-eastern Australia'. (Ed. N Williams, A Marshall, and J Morgan) pp. 201-222. (CSIRO Publishing: Melbourne, Australia)
- Morgan JW (2021) Overabundant native herbivore impacts on native plant communities in south-eastern Australia. *Ecological Management & Restoration* **22**, 9-15
- Morgan JW and Williams SG (2015) The ecology and dynamics of temperate native grasslands in south-eastern Australia. In 'Land of Sweeping Plains: Managing and restoring the native grasslands of south-eastern Australia'. (Ed. N Williams, A Marshall, and J Morgan) pp. 331-388. (CSIRO Publishing: Melbourne, Australia)
- Morris T and Letnic M (2017) Removal of an apex predator initiates a trophic cascade that extends from herbivores to vegetation and the soil nutrient pool. *Proceedings of the Royal Society B: Biological Sciences* **284**, 20170111
- Neave H and Tanton M (1989) The effects of grazing by kangaroos and rabbits on the vegetation and the habitat of other fauna in the Tidbinbilla Nature Reserve, Australian Capital Territory. *Wildlife Research* **16**, 337-351
- NRMCC (2008) National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes. Natural Resource Management Ministerial Council, Department of the Environment, Water, Heritage and the Arts. (Canberra, Australia)
- NSW DPE (2023) 2024 Quota Report NSW Commercial Kangaroo Management Program. State of NSW and Department of Planning and Environment. (Sydney, Australia)
- NSW Legislative Council (2021) Health and wellbeing of kangaroos and other macropods in New South Wales. Parliament of NSW Inquiry. Portfolio Committee No. 7, Planning and Environment. (Sydney NSW)
- O'Loughlin L (2024) Effectiveness of kangaroo management in achieving target population densities and grass structure. A CEMP Priority Management Evaluation: Preliminary Results Report. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, ACT)
- O'Loughlin L, Keighley M, and Wimpenny C (2023) Has the last 15 years of kangaroo management in the ACT achieved its key objectives? Poster presentation at the Australasian Wildlife Management Society Conference, 5th-7th December 2023, Melbourne.
- Pahl L (2020) Macropods, feral goats, sheep and cattle. 1. Equivalency in how much they eat. *The Rangeland Journal* **41**, 497-518
- Parkes J and Forsyth D (2013) Review of eastern grey kangaroo counts and derivation of sustainable density estimates in the Australian Capital Territory. Kurahaupo Consulting. (Christchurch, New Zealand)

- Perry R and Braysher M (1986) A technique for estimating the numbers of eastern grey kangaroos, *Macropus giganteus*, grazing a given area of pasture [vertebrate pest]. *Australian Wildlife Research (Australia)*
- Pinillos RG, Appleby MC, Manteca X, Scott-Park F, Smith C, and Velarde A (2016) One Welfare—a platform for improving human and animal welfare. *Veterinary Record* **179**, 412-413
- Plaisir C-A, King WJ, Forsyth DM, and Festa-Bianchet M (2022) Effects of rainfall, forage biomass, and population density, on survival and growth of juvenile kangaroos. *Journal of Mammalogy* **103**, 491-502
- Portas TJ and Snape MA (2018) Factors influencing sub-adult mortality events in Eastern Grey Kangaroos (*Macropus giganteus*) in the ACT. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- Price JN, Good MK, Schultz NL, Guja LK, and Morgan JW (2019) Multivariate drivers of diversity in temperate Australian native grasslands. *Australian Journal of Botany* **67**, 367-380
- Price JN, Schultz NL, Hodges JA, Cleland MA, and Morgan JW (2021) Land-use legacies limit the effectiveness of switches in disturbance type to restore endangered grasslands. *Restoration Ecology* **29**, e13271
- Pringle RM, Abraham JO, Anderson TM, Coverdale TC, Davies AB, Dutton CL, Gaylard A, Goheen JR, Holdo RM, and Hutchinson MC (2023) Impacts of large herbivores on terrestrial ecosystems. *Current Biology* **33**, R584-R610
- Prober SM, Byrne M, McLean EH, Steane DA, Potts BM, Vaillancourt RE, and Stock WD (2015) Climate-adjusted provenancing: a strategy for climate-resilient ecological restoration. pp. 65. (Frontiers Media SA)
- Prober SM and Thiele KR (2005) Restoring Australia's temperate grasslands and grassy woodlands: integrating function and diversity. *Ecological Management & Restoration* **6**, 16-27
- Prober SM, Thiele KR, and Speijers J (2013) Management legacies shape decadal-scale responses of plant diversity to experimental disturbance regimes in fragmented grassy woodlands. *Journal of Applied Ecology* **50**, 376-386
- Prowse TA, O'Connor PJ, Collard SJ, and Rogers DJ (2019) Eating away at protected areas: Total grazing pressure is undermining public land conservation. *Global Ecology and Conservation* **20**, e00754
- Pulsford S and Snape MA (2019) Kangaroo management on a localised scale: an evaluation of effectiveness. Unpublished report, Research Report Series. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)
- Rawlings K, Freudenberger D, and Carr D (2010) 'A guide to managing box gum grassy woodlands.' (Commonwealth of Australia)
- Ripple WJ, Beschta RL, Fortin JK, and Robbins CT (2014) Trophic cascades from wolves to grizzly bears in Yellowstone. *Journal of Animal Ecology* **83**, 223-233
- Robinson J and Grace J (2022) Eastern Grey Kangaroos in Canberra Nature Park: Population estimates and culling history 2009-2022. Unpublished report.
- SCECCB (2022) Inquiry into environmental volunteerism. Report 6, 10th Assembly. (Legislative Assembly for the Australian Capital Territory Standing Committee on Environment, Climate Change and Biodiversity: Canberra, Australia)
- Schapper A, Visseren-Hamakers IJ, Humphreys D, and Bliss C (2022) Mainstreaming the animal in biodiversity governance: Broadening the moral and legal community to nonhumans. In 'Transforming Biodiversity Governance. Earth Systems Governance.'. (Ed. IJ Visseren-Hamakers and MTJ Kok) pp. 179-199. (Cambridge University Press: Cambridge, UK)

Scroggie MP, Peterson GN, Rohr DH, Nicholson E, and Heard GW (2019) Disturbance has benefits as well as costs for fragmented populations of a cryptic grassland reptile. *Landscape Ecology* **34**, 1949-1965

Seymour F (2023) Statutory review of the eastern grey kangaroo controlled native species management plan: Preliminary comments. Animal Protectors Alliance.

Sharp S, Garrard G, and Wong N (2015) Planning, documenting and monitoring for grassland management. In 'Land of Sweeping Plains: Managing and restoring the native grasslands of south-eastern Australia'. (Ed. N Williams, A Marshall, and J Morgan) pp. 115-162. (CSIRO Publishing: Melbourne, Australia)

Sharp T and McLeod S (2016) Kangaroo harvesters and the euthanasia of orphaned young-at-foot: Applying the theory of planned behaviour to an animal welfare issue. *Animal Welfare* **25**, 39-54

Sharp TM and McLeod SR (2020) The development of a new code of practice for the commercial harvesting of kangaroos. AgriFutures Australia. (Wagga Wagga, Australia)

Shumack S (1977) 'An autobiography; or, Tales and legends of Canberra pioneers.' (Australian National University Press: Canberra, Australia)

Smith A (2018) Movement patterns of eastern grey kangaroos (*Macropus giganteus*) in relation to road infrastructure. (University of Sydney, Sydney, Australia)

Smith AL, Barrett RL, and Milner RN (2018) Annual mowing maintains plant diversity in threatened temperate grasslands. *Applied Vegetation Science* **21**, 207-218

Smith KJ, Evans MJ, Gordon IJ, Pierson JC, Stratford S, and Manning AD (2023) Mini Safe Havens for population recovery and reintroductions 'beyond-the-fence'. *Biodiversity and Conservation* **32**, 203-225

Smith SD and Ryeng KA (2022) Developments in the Quantitative Assessment of Welfare Outcomes in Hunted Mammals Subject to Shooting. *NAMMCO Scientific Publications* **12**

Snape M, Caley P, Baines G, and Fletcher D (2018) Kangaroos and Conservation: Assessing the effects of kangaroo grazing in lowland grassy ecosystems. Environment, Planning and Sustainable Development Directorate, ACT Government. (Canberra, Australia)

Snape MA, Fletcher D, and Caley P (2021) Species composition, herbage mass and grass productivity influence pasture responses to kangaroo grazing in a temperate environment. *Ecological Management & Restoration* **22**, 16-23

Spooner PG and Briggs SV (2008) Woodlands on farms in southern New South Wales: a longer-term assessment of vegetation changes after fencing. *Ecological Management & Restoration* **9**, 33-41

Stobo-Wilson AM, Murphy BP, Crawford HM, Dawson SJ, Dickman CR, Doherty TS, Fleming PA, Gentle MN, Legge SM, Newsome TM, Palmer R, Rees MW, Ritchie EG, Speed J, Stuart J-M, Thompson E, Turpin J, and Woinarski JCZ (2021) Sharing meals: Predation on Australian mammals by the introduced European red fox compounds and complements predation by feral cats. *Biological Conservation* **261**, 109284

Thompson GG, Thompson SA, and Pusey A (2022) Poor welfare outcomes resulting from poor management decisions in a translocation of western grey kangaroos (*Macropus fuliginosus*). *Pacific Conservation Biology* **29**, 130-140

Travers SK and Berdugo M (2020) Grazing and productivity alter individual grass size dynamics in semi-arid woodlands. *Ecography* **43**, 1003-1013

Travers SK, Eldridge DJ, Dorrrough J, Val J, and Oliver I (2018) Introduced and native herbivores have different effects on plant composition in low productivity ecosystems. *Applied Vegetation Science* **21**, 45-54

Review of the ACT EGK CNSM Plan /p. 111

Viggers K and Hearn J (2005) The kangaroo conundrum: home range studies and implications for land management. *Journal of Applied Ecology* **42**, 99-107

Vivian L and Godfree R (2014) Relationships between vegetation condition and kangaroo density in lowland grassy ecosystems of the northern Australian Capital Territory: analysis of data 2009, 2010 and 2013. CSIRO. (Canberra, Australia)

Weeks AR, Stoklosa J, and Hoffmann AA (2016) Conservation of genetic uniqueness of populations may increase extinction likelihood of endangered species: the case of Australian mammals. *Frontiers in Zoology* **13**, 1-9

Westgate MJ, Likens GE, and Lindenmayer DB (2013) Adaptive management of biological systems: a review. *Biological Conservation* **158**, 128-139

Wiggins NL, Williamson GJ, McCallum HI, McMahon CR, and Bowman DM (2010) Shifts in macropod home ranges in response to wildlife management interventions. *Wildlife Research* **37**, 379-391

Willi Y, Kristensen TN, Sgrò CM, Weeks AR, Ørsted M, and Hoffmann AA (2022) Conservation genetics as a management tool: The five best-supported paradigms to assist the management of threatened species. *Proceedings of the National Academy of Sciences* **119**, e2105076119

Wilson GR and Edwards M (2019) Professional kangaroo population control leads to better animal welfare, conservation outcomes and avoids waste. *Australian Zoologist* **40**, 181-202

Wilson M and Coulson G (2021) Early warning signs of population irruptions in Eastern Grey Kangaroo (*Macropus giganteus*). *Ecological Management & Restoration* **22**, 157-166

Wimpenny C (2022) Project Plan: Integrating the use of GonaCon Immunocontraceptive Vaccine into the Eastern Grey Kangaroo Management Program. Conservation Research and Evaluation, Resilient Landscapes, Parks and Conservation Service; Environment, Heritage and Water Division; ACT Government. (Canberra, Australia)

Wimpenny C, Hinds LA, Herbert CA, Wilson M, and Coulson G (2021) Fertility control for managing macropods—Current approaches and future prospects. *Ecological Management & Restoration* **22**, 147-156

Wimpenny C, Howland B, and Fletcher D (2015) A simple but useful map of vegetation structure in and near Canberra. Technical Report 33. Environment and Planning Directorate, ACT Government. (Canberra, Australia)

Woinarski J (2018) Killing Peter to save Paul: an ethical and ecological basis for evaluating whether a native species should be culled for the conservation benefit of another native species. *Australian Zoologist* **40**, 49-62

Zenger K, Eldridge M, and Cooper D (2003) Intraspecific variation, sex-biased dispersal and phylogeography of the eastern grey kangaroo (*Macropus giganteus*). *Heredity* **91**, 153-162