“Counting Kangaroos: Fact or Fiction?”

ASSESSING THE RELIABILITY, TRANSPARENCY AND SUSTAINABILITY OF KANGAROO POPULATION ESTIMATES

Kangaroos ALIVE

CONTENTS

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FOREWORD

Australia prides itself on science-based wildlife management. Yet the system governing the world's largest land-based commercial wildlife kill operates largely out of public view, built on population estimates that are increasingly under scrutiny.

State governments justify commercial kangaroo killing by setting quotas based on aerial survey-derived population estimates. The premise is simple: monitor populations, set sustainable quotas, protect the species.

The reality is far more complex. This report examines what happens when we look beyond the official government information. What we find is troubling: population estimates that defy biological plausibility, survey methods so limited they cover less than 1% of commercial killing areas, raw data withheld from public access, and kill quotas that may already exceed what wild populations can sustain.

None of this is accidental. These are systemic failures embedded in the management framework—failures that have persisted despite repeated warnings from scientists and policymakers. The 2022 NSW Parliamentary Inquiry recommended greater transparency and a review of survey methodologies. These recommendations remain unimplemented.

The stakes are high. If current estimates are inflated and quotas unsustainable, Australia risks managing a commercial industry toward ecological collapse while claiming it is evidence-based. Conversely, if populations are genuinely as large as claimed, then the system's opacity serves no legitimate purpose.

Either way, the current approach fails the basic test of credible wildlife management: it cannot be independently verified.

This report is a call for the transparency and rigour that any industry must provide to the public and to independent researchers.

Mick McIntyre
Co-Founder, Kangaroos Alive

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EXECUTIVE SUMMARY

Australia's commercial kangaroo industry kills between 1.6 and 1.8 million animals annually—making it the world's largest land-based wildlife use for meat and skins. Yet serious concerns persist regarding the population estimates that guide commercial kill quotas. This independent assessment identifies critical gaps in reliability, transparency, and sustainability across state-managed kangaroo management plans.

KEY FINDINGS

RELIABILITY IN QUESTION

1. **Biologically implausible growth rates**: Around 20% of annual population estimates in New South Wales, Victoria, and South Australia showed increases of > 30% annually—In some cases far exceeding the natural growth rates of 10–30%.
2. **Minimal survey coverage**: Less than 1% of commercial killing areas were surveyed in New South Wales, Queensland, and Victoria. In Victoria, raw count extrapolations inflated population estimates by up to 500-fold.
3. **Inflated quotas**: These exaggerated estimates directly inflate allowable kill quotas, creating a false sense of sustainability.

TRANSPARENCY FAILURES

1. **Restricted access to raw data:** State environmental agencies do not release raw data aerial survey data, preventing independent verification.
2. **Limited historical data:** Only New South Wales publishes full historical data; other states offer minimal oversight opportunities.
3. **No ecological monitoring:** Kangaroo management plans lack ecological and biodiversity indices to assess broader environmental impacts.

SUSTAINABILITY CONCERNS

1. **Counterintuitive kill patterns:** Decreasing commercial killing in several New South Wales zones persisted despite rising carcass values and shooter numbers, suggesting possible population stress.
2. **Consistently low kills:** Across many areas, low kill numbers may indicate that actual kangaroo populations are significantly smaller than official estimates suggest.
3. **Climate change risk:** Increased drought frequency, combined with rising commercial demand, could push kill levels beyond what populations can sustain.

THE BOTTOM LINE

Population estimates underpinning Australia's kangaroo industry are unreliable, opaque, and potentially unsustainable. Inflated figures and limited survey coverage create a facade of ecological viability that may mask overexploitation.

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ABSTRACT

Four kangaroo species are commercially killed in mainland Australia, yet concern is growing about the accuracy of the population estimates underpinning state administered kangaroo management plans[1] (KMPs). Using publicly available information, we evaluated KMPs and population estimates (as of 2023) across three dimensions: **reliability** (whether population estimates and kill quotas reflect biological reality), **transparency** (the extent to which data and methods are open to independent scrutiny), and **sustainability** (whether current kill levels are ecologically and demographically supportable).

For **reliability**, we found that kill quotas are often set above plausible population growth rates. In NSW, SA, and VIC, about 20% of annual estimates showed biologically implausible population increases, inflating allowable quotas. The implausible increases were particularly common in New South Wales (NSW), Victoria (VIC), and South Australia (SA), which were subject to variable weather conditions, including the Millennium Drought (1997-2009) and the 2017-2019 Drought. Survey coverage was extremely limited, with less than 1% of the commercial killing area surveyed in NSW, QLD, and VIC. In VIC, annual raw count extrapolations inflated estimates by up to 500-fold.

For **transparency**, state based environmental agencies do not release raw aerial survey data, limiting independent evaluation of population estimates. Only NSW published full historical data on population estimates. No KMPs include ecological indices (e.g., plant and fauna biodiversity) to track the broader impacts of commercial killing on landscape integrity.

For **sustainability**, reduced kills in several NSW kangaroo management zones[2] (KMZs) occurred even as carcass values and kill numbers rose, suggesting possible population stress. Adjacent KMZ analyses indicated that red kangaroo movement does not explain the implausible population increases reported in some zones. Overall, consistently low kills across many areas suggest kangaroo populations may be smaller than official estimates indicate.

Low takes and density-dependent trigger points may prevent overkilling. However, this remains to be determined over time. The greatest long-term risk may come from the combined pressures of climate change, particularly increased drought frequency, and rising demand, which could push kills closer to inflated quotas. We recommend that KMPs improve transparency, adopt more precautionary quota-setting, and strengthen the accuracy of population monitoring.

1. Kangaroo management plans designate the conditions under which kangaroo species can be commercially killed in each state. They include a review of kangaroo populations in the State and the methodologies used to estimate their populations.

2. Kangaroo management zones are discrete geographical areas within states for monitoring and commercially killing kangaroos.

INTRODUCTION

The commercial kangaroo industry in Australia is the world's largest land-based wildlife use, with 1.6–1.8 million adult kangaroos commercially killed annually (DPIE, 2021; Ramsey and Scroggie, 2021; Department for Environment and Water, 2022; Department Biodiversity Conservation and Attractions, 2023; Queensland Parks and Wildlife Service, 2023a). Because about one third of killed animals are females, an additional ~400,000 dependent joeys are killed as collateral deaths (Ben-Ami et al., 2014). Four species—red kangaroo (*Osphranter rufus*), wallaroo (*O. robustus*), eastern grey kangaroo (*Macropus giganteus*), and western grey kangaroo (*M. fuliginosus*)—are killed across five states (NSW, QLD, VIC, SA, WA). Their products, including meat, pet food, skins, and leather, are consumed domestically and exported internationally (AgriFutures Australia, 2021). While kangaroos are protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Department of Climate Change Energy the Environment and Water, 2025) and state legislations, commercial killing is permitted under licence, subject to the legal requirement of maintaining ecologically viable populations.

Sustainable wildlife use depends on robust monitoring. Both national legislation and international obligations typically (e.g., CITES, IUCN Red List) require credible population estimates and trends to demonstrate ecological viability and ensure legitimacy (IUCN, 2001; Primack, 2006). Yet monitoring involves trade-offs: methodologies must be accurate enough to detect biologically meaningful changes while remaining cost-effective (Lancia et al., 1996).

Kangaroo population estimates are typically derived through aerial surveys covering a small proportion of kangaroo management zones (KMZs) (e.g. Department of Planning and Environment, 2022). Observed counts are corrected for visibility bias, then extrapolated across the broader landscape. Sustainable yield quotas are set as a proportion of these estimates. This system depends on three qualities: **reliability** (whether estimates and quotas reflect biological reality), **transparency** (whether data and methods are available for independent scrutiny), and **sustainability** (whether kills remain ecologically viable under current and future pressures).

Concerns about the reliability of estimates have persisted for decades. A retrospective review of the NSW Kangaroo Management Program concluded that populations are large and commercial killing is sustainable (Lunney et al., 2018). However, it also included historical data showing that annual increases in Red and Eastern Grey Kangaroo estimates exceeded 45–100% in some KMZs, well above the maximum biological growth potential of 10–40% (See review in McCallum, 1995). Concerns have been raised by a number of population estimate assessments (Ben-Ami, 2009; Mjadwesch, 2011; Brooks, 2022). These issues were also highlighted in the NSW Parliamentary Inquiry into the Health and Wellbeing of Kangaroos and Other Macropods (NSW Inquiry), which recommended greater transparency (e.g., releasing raw aerial survey data) and a review of survey methodologies (NSW Government, 2022). To date, these recommendations remain unimplemented.

Independent review and public scrutiny have repeatedly influenced kangaroo management. In 1974, U.S. trade restrictions on kangaroo products (Listing Notice: 39 Fed. Reg. 44990, December 30, 1974) prompted the introduction of systematic monitoring (Lunney, 2010; Boom et al., 2012) and the eventual lifting of restrictions (Delisting Notice: 60 Fed. Reg. 12887, March 9, 1995). Legal challenges have led to the adoption of low-density "trigger points" to prevent overkill (Administrative Appeals Tribunal, 2008). More recently, welfare concerns have prompted debate over male-only kills (KIAA, 2022; RSPCA Australia, 2022) and culminated in the NSW Inquiry.

Against this background, this study provides an independent assessment of the commercial kangaroo killing based on publicly available information, with a focus on **reliability, transparency, and sustainability**. We evaluate the plausibility of population estimates, the adequacy of survey effort, and the accuracy of kill quotas. Using NSW as a case study, we assess kill trends and the potential role of kangaroo movement between KMZs. Finally, we examine the accessibility of information provided by state KMPs to determine whether current monitoring frameworks can support transparent, evidence-based management.

METHODS

We based our assessment on publicly available information from state kangaroo management plans (KMPs) from NSW (Department of Planning and Environment, 2022), QLD (Queensland Parks and Wildlife Service, 2023b), SA (Deparment for Environment and Water, 2020), VIC (Environment Land Water and Planning, 2021), and WA (Department of Biodiversity Conservation and Attractions, 2023), including annual population estimate reports, and commercial kill statistics. These data were supplemented with published demographic studies of the four commercially killed kangaroo species, which we used to derive biologically plausible growth rates independent of aerial survey estimates. By combining state-reported population estimates with independent ecological benchmarks, we evaluated three aspects of the KMPs: (1) **reliability**, by testing whether population estimates and quotas align with known demographic limits; (2) **transparency**, by reviewing the accessibility of data and methodologies; and (3) **sustainability**, by analysing kill outcomes in relation to quotas, industry trends, and potential influences such as migration. State-provided population estimates were interpreted critically as ecological plausibility rather than accepted as fact.

RELIABILITY

POPULATION GROWTH RATES

Sustainable commercial kill quotas must remain below population growth rates to prevent overkill and long-term decline. Growth can be described in several ways: density dependence can depress growth temporarily (R_{low}), while maximal growth (R_{max}) occurs under highly productive conditions following rainfall. Neither is suitable for long-term quota setting. We therefore adopted a conservative mean growth rate (R_{mean})—reflecting average demographic responses to both density dependence and favourable conditions—as the most appropriate benchmark for sustainable kills (McCallum, 1995).

IMPLAUSIBLE POPULATION CHANGES

To test plausibility, we compared annual changes in state-reported population estimates against independent demographic limits. R_{mean} and R_{max} were derived from published demographic studies of the four species, incorporating data on sex ratios, fecundity, recruitment, and survivorship (Table 1). Estimates inferred from aerial surveys were excluded to avoid circularity of potential errors linked to the methodology. State population reports were used to calculate year-to-year changes for each kangaroo management zone (KMZ). Increases greater than 30% were considered implausible (see assessment in Results, Table 2). Declines greater than 50% (outside drought) were also considered implausible, as commercial killing and other mortality factors (e.g., predation, roadkill) cannot account for such losses. During drought, declines up to 40% are possible due to starvation and disease (Caughley et al., 1985).

TRANSPARENCY

We reviewed the most recent five-year KMP for each state (cited above; as of publication newer plans may have been released), documenting how populations are monitored, what data are released, and whether raw survey information is made publicly accessible. While survey methods differ between years and states, this review focused on the consistency of information available to the public and whether it enables independent scrutiny of population estimates and commercial killing outcomes.

SUSTAINABILITY

CASE STUDY OF COMMERCIAL KILLING OUTCOMES IN NSW

Commercial kill statistics for NSW were collated from annual population estimate reports 1990-2022 (DPIE, 2021). For each KMZ, linear regressions were used to assess long-term kill trends. At the state level, Pearson correlations were used to compare annual kill totals with industry indicators, including the number of commercial shooters, chillers, registered properties, and carcass values to commercial shooterss.

RED KANGAROO MIGRATION IN NSW

Because Red Kangaroos can move up to 30 km in response to rainfall (Dawson, 2012), we assessed whether local migration could explain implausible increases in population estimates. For each KMZ, we applied 10 km and 30 km buffer zones to approximate potential immigration from neighbouring areas. Implausible increases (R > 100%) were tested against concurrent declines (R > 50%) in adjacent KMZs, which would be required if migration were driving the increases. Migration from neighbouring zones with stable or increasing populations was considered unlikely, given adequate local resources and the generally sedentary nature of kangaroos.

RESULTS

DEMOGRAPHIC PARAMETERS AND SUSTAINABLE YIELD ASSUMPTIONS

We first assessed whether the demographic parameters and sustainable yield quotas used by state Kangaroo Management Programs (KMPs) are biologically plausible. Growth rates were derived from published estimates of female proportion in populations, reproductive rates, fecundity, recruitment, and survival. The resulting intrinsic growth rates (R_{mean}–R_{max}) ranged from 0.12 to 0.31 across the four commercially killed species (Table 1). We note that the mean growth rates (R_{mean}) for all species (12%-13%) are at the low end of the sustainable yield quotas currently applied, which are typically set between 10–20% of the estimated population size. Therefore, it is likely that commercial kill quotas typically exceed the species' biological capacity for replacement. Red Kangaroos showed higher potential fecundity due to embryonic diapause, which enables rapid post-drought reproduction and provides a reproductive "head start" compared with other species.

Table 1. Demographic parameters, derived growth rates, and sustainable yield quotas for commercially killed kangaroos.

Species	Prop. ♀	Repro. ♀	Young/♀/yr	Recruitment	Adult survival	Commercial kill survival	R_{mean}–R_{max}	Sustainable yield quotas (%)
Red	0.5–0.6	0.75–0.951,2	1.1–1.22,7,9	0.33–0.502	0.95	0.95	0.12–0.318	20 (SA11, QLD12) 17 (WA13, NSW14)
Eastern Grey	0.5–0.6	0.75–0.953	1.0–1.19	0.38–0.50	0.95	0.95	0.13–0.28	15 (NSW, SA, QLD) 10 (VIC16)
Western Grey	0.5–0.6	0.75–0.954	0.9–1.19	0.38–0.50	0.95	0.954	0.12–0.288	15 (WA, NSW, SA)
Wallaroo	0.5	0.75–0.955	1.0–1.19	0.38–0.60	0.95	0.97	0.13–0.29	15 (NSW, SA, QLD)

Notes:

- Prop. ♀ - proportion of females in the population; Repro. ♀ - proportion of reproductive females; Young/♀/yr – births per female per year; Recruitment = annual proportion of reproductive adults joining the population; Adult survival – annual proportion of adults surviving natural mortality; Harvest survival – Annual proportion of adults surviving the commercial kill.
- R = F/Pop × Rep F × Young/F/yr × Recruitment × Adult survival × Harvest survival.
- Red Kangaroos have reproductive anoestrus under adverse climatic conditions.
- References: 1(Kirkpatrick, 1965), 2(Bilton and Croft, 2004),3Banks(Banks, 2001),4(Arnold et al., 1991),5(Ashworth, 1995),6(Coulson et al., 2014),7(Newsome, 1965),8(Bayliss, 1985),9(Dawson, 2012),10(Bergeron et al., 2022),11(Deparment for Environment and Water, 2020),[12](Queensland Parks and Wildlife Service, 2023b),[13](Department of Biodiversity Conservation and Attractions, 2023),[14](Department of Planning and Environment, 2022), [16](Environment Land Water and Planning, 2021)

IMPLAUSIBLE POPULATION CHANGES

To test reliability, we compared state-reported population estimates against demographic limits. Despite the demographic constraints above, large interannual changes in estimated population size were common across all states. Using thresholds of >30% increase (beyond R_{max}) or >50% decrease (outside major drought) in a single year as implausible, we found that up to 47% of annual estimates fell into this category, depending on species and region (Table 2). These anomalies cannot be explained by natural demographic processes and suggest that estimation error is widespread.

In NSW, implausible estimates were common in semi-arid Western Plains KMZs: 38% for Red Kangaroos and 47% for Grey Kangaroos. By contrast, estimates in temperate eastern KMZs showed implausibility rates of only 2% (Eastern Grey Kangaroo) and 8% (Wallaroo). In QLD (semi-arid zones), implausibility rates were lower but still evident: 8% for Red Kangaroo, 11% for Eastern Grey Kangaroo, and 20% for Wallaroo. SA showed 25% implausible estimates for both Red and Western Grey Kangaroos, while VIC (semi-arid KMZs) had 39% implausible increases for Eastern Grey Kangaroos. No data were publicly available for WA. The implausible increases were particularly common in NSW, VIC, and SA (Fig. 1), which were subject to variable weather conditions, including two notable and catastrophic drought events in NSW between 1990 and 2022 (Bureau of Meteorology, 2025). In QLD there relatively few cases of implausible population changes, with the difference being the much larger KMPs and the tri-annual population estimate.

Table 2. Plausibility of population estimate changes by species and state. Implausible = population increase >30% or decrease >50% compared with previous year. The total amount of survey data (Years) and the number of surveyed KMZs provide the sample size. At the time of writing population estimates were not available for WA.

State	Species	Years	Years	KMZs	Increases >30%	Decreases > 50%
NSW	Red Kangaroo	1990-2022	30	8	80	20
	Grey Kangaroo	"	30	14	73	20
	Wallaroo	"	30	3	8	0
QLD	Red Kangaroo	2013-2022	10	3	1	1
	Grey Kangaroo	"	10	3	2	2
	Wallaroo	"	10	3	5	1
SA	Red Kangaroo	2018-2022	5	16	14	6
	Western Grey Kangaroo	"	5	16	13	8
	Wallaroo	"	5	16	0	2
VIC	Eastern Grey Kangaroo	2020-2022	3	6	7	0

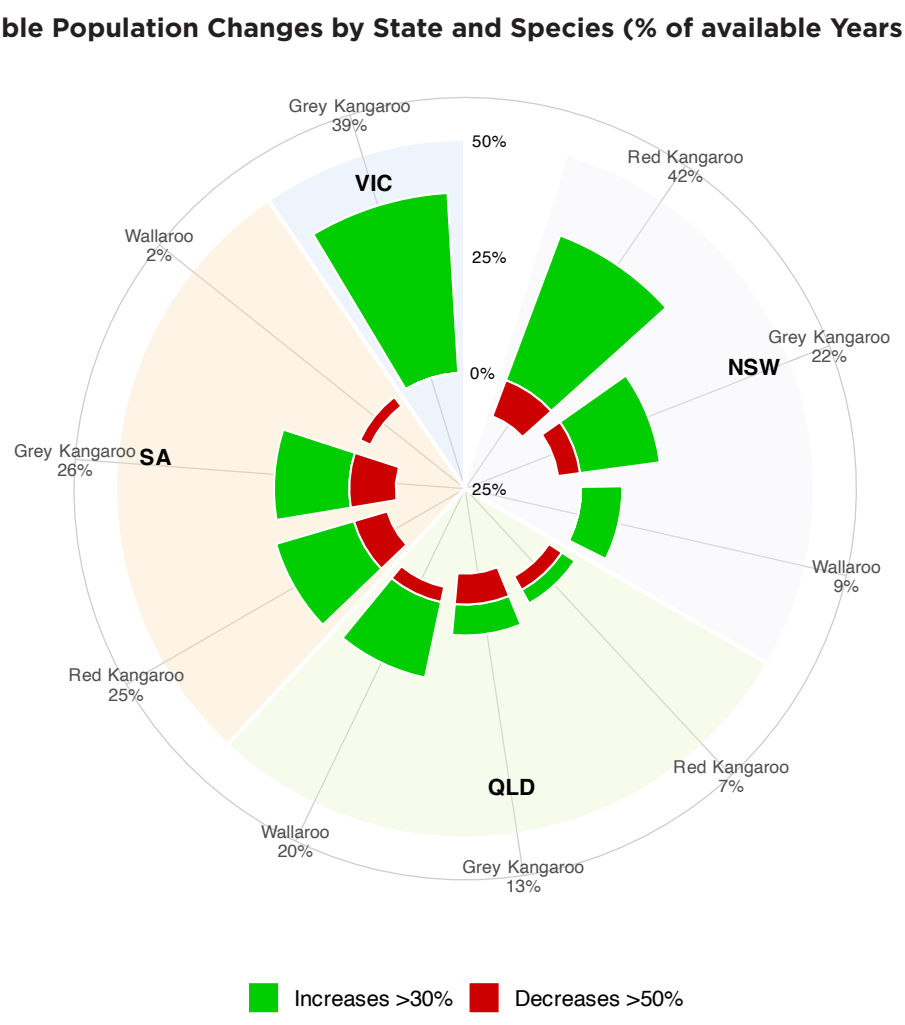

Figure 1. Implausible population changes (y axis) by state and species. The green and red percentages are the implausible increases and decreases, respectively, relative to the plausible occurrences across a particular state and its KMZs for the years in which we had available data (see Table 2). Total implausible changes in populations between successive years are noted as percentages below each species label.

TRANSPARENCY OF KANGAROO MANAGEMENT PLANS

Transparency was generally low across all KMPs. None of the states published raw aerial counts, limiting independent scrutiny. Survey frequency ranged from annual (NSW western plains) to once every 2–3 years (WA, SA), and survey intensity was low. For example, in NSW, QLD, and VIC, less than 1% of the commercial kill area was directly surveyed in any given year (Table 3). Moreover, ecological indices that might track landscape-level consequences of harvesting (e.g., vegetation condition, predator-prey dynamics) were absent from all programs. The different survey methods and frequency make it difficult to compare the efficacy of population estimates over time. Moreover, the use and type of correction factors varied between states.

Table 3. Summary of survey methodologies and transparency across state kangaroo management programs.

State	Survey Frequency	Survey Method / Transport	Area Surveyed(%)	Correction Factors	Transparency (Primary & Secondary Data)	Trigger points
NSW	Annual in western KMZs; every 3 years in eastern KMZs	Aeroplane surveys (western KMZs) Helicopter surveys (eastern KMZs)	0.5%	No correction factors since 2016, except for Wallaroos.	Primary data not public; full 30-year secondary dataset available	Long term mean +2 SD
QLD	Every 3 years	Aeroplane surveys calibrated by ground surveys	0.2%	No correction factors since 2016	Secondary data online for ~10 years; no primary data	Long term mean +2 SD
SA	Biannual	Helicopter and automobile surveys depending on site	Not reported	Correction factors applied for habitat & weather	Secondary data online for ~5 years; no primary data	Long term mean +2 SD
VIC	Annual	Helicopter surveys; stratified by habitat type	0.4%	Sampling effort adjusted by habitat type	Only recent secondary data online; no primary data	Long term mean +2 SD
WA	Every 3 years	Aeroplane surveys	Not reported	Correction factors for habitat & weather	No primary or secondary data publicly available	Long term mean +2 SD

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COMMERCIAL KILLING SUSTAINABILITY

Despite potentially inflated population estimates, realised commercial kills were consistently low relative to quota. In NSW between 2010–2021, annual take was typically 10–43% of the quota, depending on species (Fig. 2). Only Wallaroos exceeded 50% of quota in more than one year. This discrepancy suggests that actual population densities may be substantially lower than those implied by official estimates, or that economic constraints (e.g., access, market demand) are limiting commercial shooterss' ability to meet quotas.

Despite quotas being under-filled, commercial kill numbers of all species have increased across most KMZs since 2010, including both arid and temperate zones. Only three KMZs showed declining take (see "-" slope, Appendix 1). Industry expansion is likely to have contributed to the increases as carcass prices to chillers doubled after 2018 (coinciding with the removal of the historic fauna dealer licence cap), and the number of commercial shooters and chiller operators also rose.

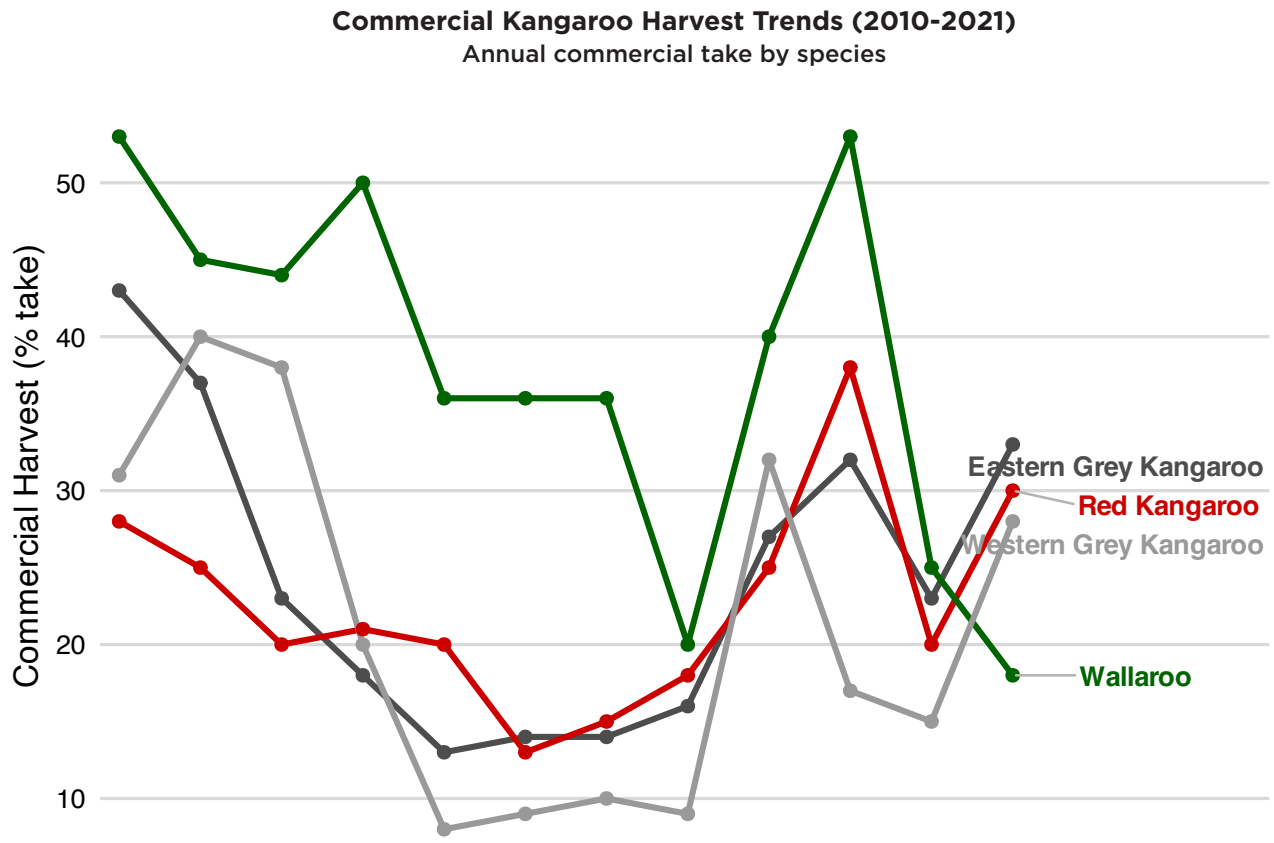

Figure 2. Commercial kills take as percentage of quota in NSW (2010–2021).

INDUSTRY INDICES AND COMMERCIAL KILLING TRENDS

To test whether commercial kill levels tracked industry dynamics in NSW, we analysed correlations between annual take and indices such as carcass prices, number of commercial shooters, and number of chiller operators. Commercial kill levels were strongly correlated with prices ($r = 0.77$, $p = 0.026$) and moderately correlated with commercial shooters numbers ($r = 0.54$, $p = 0.038$), but showed no or only weak relationship to quotas or chiller density (Table 4). These findings reinforce that commercial killing take is primarily demand-driven rather than biology-driven.

Table 4. Correlations between commercial killing take of all species and industry indices, NSW (2010–2021).

Variable	Pearson's r	df	F	p-value
Prices (AUD/kg)	0.77	1	8.56	0.026
Chiller operators	0.38	1	1.69	0.223
Commercial shooters	0.54	1	6.55	0.038
Quota	0.03	1	0.01	0.938

MIGRATION AND MOVEMENT EXPLANATIONS OF ESTIMATES

We examined whether migration between adjacent Kangaroo Management Zones (KMZs) might account for anomalous population increases (Fig. 3). Buffer analyses showed that, on average, 31% of KMZ area overlapped with a 10 km buffer of neighbouring KMZs, leaving on average 69% potentially unaffected by migration (Table 5). For larger semi-arid KMZs with red kangaroos, an average of 57% overlapped with a 30 km buffer of neighbouring KMZs, leaving on average 43% of the KMZ too far from neighbouring zones to explain changes in annual population increases or decreases.

Table 5. Migration buffer areas for NSW KMZs, calculated at either 10 or 30 km (only for KMZs with red kangaroos) from the boundary of each KMZ to account for potential movement of eastern and red kangaroos between KMZ, respectively. The percentage of each KMZ potentially unaffected by potential migration into buffer areas between adjacent KMZs is presented. Th

KMZ	Zone	KMZ Area (km^2)	10 km Buffer Area (km^2)	KMZ Area (-10 km buffer) (%)	30 km Buffer Area (km^2)	KMZ Area (-30 km buffer) (%)
Armidale	9	16,386	8,211	50%		
Glen Innes	13	20,999	8,207	61%		
Upper Hunter	14	14,726	5249	64%		
Central Tablelands North	48	30,236	8,290	73%		
Central Tablelands South	49	23,358	8,424	64%		
South East Tablelands	16	51,950	16,198	69%		
Broken Hill	2	91,337	16,997	81%	43,065	53%
Cobar	6	40,415	10,201	75%	24,857	38%
Bourke	7	55,005	11,082	80%	28,451	48%
Coonabarabran	10	61,689	11,016	82%	29,215	53%
Lower Darling	4	56,759	13,937	75%	34,302	40%
Narrabri	8	65,779	11,377	83%	30,692	53%
Tibooburra	1	55,071	12,109	78%	29,777	46%
Griffith North	11	105,347	53,297	49%	74,060	30%
Griffith South	12	105,347	55,424	47%	75,715	28%
Average		52,958	35,668	69%	20,008	43%

However, comparisons of implausible increases (>100%) with concurrent declines (>50%) in neighbouring KMZs revealed very few such cases (Table 6). This indicates that dispersal cannot plausibly explain the frequency or magnitude of estimation anomalies. For NSW out of 36 KMZ cases with >100% increases, only 2 coincided with adjacent declines >50%. Similar patterns were found in QLD, SA, and VIC. Thus, large-scale migration between KMZs cannot plausibly explain the inflated estimates. Moreover, if migration had occurred at this scale, ~70% of the increase would need to be concentrated within buffer zones, producing unrealistically high local densities.

Table 6. The likelihood of migrations. Within the table: "Implausible population increases (>100%), implausible decreases (>50%)".

State	Red Kangaroo	Grey Kangaroo	Wallaroo	Total
NSW	16,0	17,2	1,0	34,2
QLD	0,0	0,0	2,0	2,0
SA	4,0	3,0	NP	7,0
VIC	NP	1,0	NP	1,0

Note: Values = (number of KMZs with implausible increase, number with adjacent >50% decline). NP = not present.

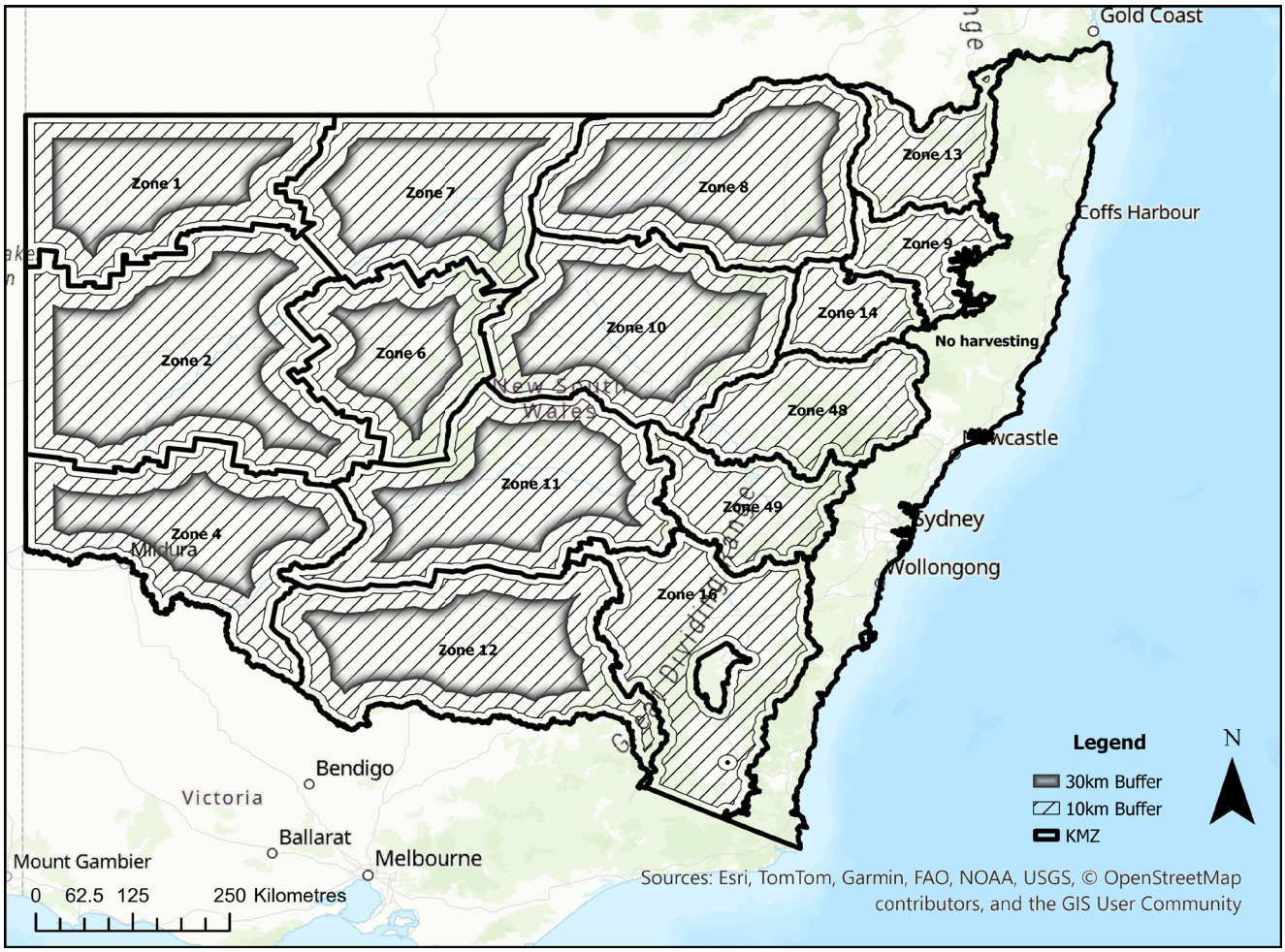

Figure 3. New South Wales Kangaroo Management Zones (KMZs) labelled by zone number. Ten-kilometre migration buffer areas are shown in white, with the remaining zone areas represented by dashed outlines. For zones containing Red Kangaroos, areas unaffected by the 30-km migration buffer are shaded grey.


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DISCUSSION

Our review highlights a substantial discrepancy between population growth values derived from aerial survey–based extrapolations and those calculated from demographic field studies. Aerial surveys in western NSW have suggested mean growth rates (R_{mean}) of 0.25–0.30 for Grey and Red Kangaroos (Caughley et al., 1984), while ground-based demographic analyses consistently indicated much lower values of 0.12–0.13. Even when we applied generous assumptions to fecundity, sex ratios, and recruitment (Table 1), the demographic R_{mean} remained well below those implied by aerial data. Given that most state Kangaroo Management Programs (KMPs) apply commercial kill quotas of 15–20% (although 10% in VIC), the risk of quotas exceeding biologically plausible growth rates is evident. In the context of highly variable kangaroo dynamics (McLeod, 1997), conservative sustainable yield values are essential to ensure both recovery during favourable periods and resilience during declines.

Across states, biologically implausible population estimates were common, affecting more than 25% of estimates (except in WA, where data were unavailable). Implausible increases (>30%) accounted for about 20% of cases, while implausible declines (>50%) made up roughly 5%. Although rapid growth can occur after rainfall and severe declines during drought (Caughley et al., 1985), we accounted for these extremes in our thresholds. The implausible increases were particularly common in NSW, VIC, and SA, which were subject to variable weather conditions, including the Millennium Drought (1997-2009) and the 2017-2019 Drought (Bureau of Meteorology, 2025). Since the environmental and climatic conditions six months prior to surveying are the best predictor of subsequent population dynamics (Jonzen et al., 2010), these findings suggest that sampling methods rather than environmental variability may explain these anomalies. Possible explanations include undetected fine scale rainfall events, or detection bias (from aerial surveys) of kangaroos during drought when vegetation is relatively sparse. Alternative counting methodologies may produce more accurate results. For example, thermal counting by drones has been found to be more accurate than by people (Witt et al., 2020), has been used to detect kangaroos (Juillard et al., 2025), and is now used to count koalas in NSW (NSW Government, 2023).

Another possible cause of implausible estimates, both increases and decreases, could be the relatively low survey effort. As Caughley (1977) demonstrated, accurate estimates (<5% error) in arid NSW would require survey coverage of 25% (Red Kangaroos) or 8% (Eastern Grey Kangaroos) of the landscape. In contrast, current survey intensity is <1% in NSW, QLD, and VIC. Victoria illustrates this mismatch clearly: in 2022, just 5,947 Grey Kangaroos were observed across 970 km^2 of transects (0.4% of the

state), yet extrapolations yielded a statewide estimate of 2.36 million (Moloney et al., 2022). Such low effort relative to large and heterogeneous landscapes makes population estimates highly sensitive to extrapolation errors. Interestingly, even in VIC, where habitat stratification is incorporated, implausible estimates were still common (39%), highlighting the additional influence of unmeasured ecological variability (e.g., habitat, predation, competition, disease) on spatial demographic heterogeneity.

Red Kangaroo migration provides only limited scope for reconciling these anomalies. While individuals can migrate 10–30 km in response to rainfall (Dawson, 2012), buffer analyses of NSW KMZs revealed migration was a plausible explanation in only 2 of 36 cases of >100% annual increases. Moreover, if migration were driving overestimates, it would more likely produce underestimated densities in adjacent KMZs rather than the extreme increases observed. Thus, it is unlikely that migration explains the widespread prevalence of biologically implausible estimates, although more research could be done to test this more thoroughly.

Commercial kill statistics provide an additional lens on population dynamics (Cattadori et al., 2003; Thomaidis et al., 2022). In NSW since 2010, realised commercial kills have consistently fallen well below quotas (10–43%). While this could reflect overestimation of population size, it may also be shaped by industry demand. Correlation analyses showed that take was positively related to carcass price and number of commercial shooters, but not to quota levels, suggesting that economics, rather than biology, drives effort. Nevertheless, declining commercial killing trends in several KMZs, despite rising prices and number of commercial killers, suggest that local populations may be under stress. Given that take data integrate harvester behaviour with biological availability, further scrutiny of these local declines is warranted.

Transparency represents another critical weakness in current management. Primary survey data are not publicly released in any state, and secondary data (long-term population estimates) are inconsistently available. This is despite long-term surveys of other fauna being publicly accessible (e.g., the Eastern Australian Waterbird Survey, Kingsford et al., 2020). Where data have been requested by independent researchers (e.g., NSW GIPA requests), records were often incomplete or provided in unusable formats (e.g., hand-written sheets). Without public access to raw counts, population estimates cannot be independently verified. This lack of transparency is compounded by methodological inconsistency: survey effort, frequency, and correction factors that vary not only between states but sometimes within states across years (Table 3). In QLD, ground surveys are used to calibrate aerial surveys undertaken every three years, while in SA surveys are conducted biannually from helicopters or automobiles depending on site conditions. In NSW, surveys occur annually in the arid tablelands but only every three years in eastern temperate KMZs, while Victoria varies sampling effort by habitat type.

Transparency is further compromised by variation in the application of correction factors (see Table 3): since 2016, NSW and QLD have abandoned their use (except with Wallaroos in NSW), whereas SA and WA continue to apply habitat- and weather-based adjustments. These inconsistencies not only undermine the comparability of estimates but also elevate risks in critical periods: notably, the lack of annual surveys in low rainfall zones that are most prone to drought (<600 mm rainfall) in QLD, SA, and WA (Fig. 3) increases the probability of commercial kills exceeding sustainable yields, given the well-documented rapid population crashes of kangaroos under drought conditions (Caughley et al., 1985; Pople, 2008). Importantly, overkill is mitigated by density determined trigger points that determine a decreasing or cessation of commercial killing.

Finally, ecological indices are entirely absent from KMPs, despite the central role of large herbivores in ecosystem functioning (Gross, 2016; le Roux et al., 2020). Incorporating measures such as grazing pressure, nutrient cycling, soil disturbance, or mortality dynamics would allow for a more holistic assessment of kangaroo management that extends beyond simple population counts. Empirical evidence already demonstrates kangaroos' ecological influence, including their role in nutrient redistribution and water filtration through "hip-holes" (Eldridge and Rath, 2002), contributions to carbon and nutrient cycling via pellet deposition (Kobayashi et al., 2011), and their shaping of vegetation dynamics and resource patch use (Ramp and Coulson, 2002, 2004; Maguire et al., 2005). Fire history also alters grass species composition and nitrogen availability, which in turn influences kangaroo foraging patterns and dietary selectivity (Murphy and Bowman, 2007). Ignoring these ecological functions constrains management to a narrow framing of kangaroos as merely "overabundant" resources, rather than recognising them as integral agents in maintaining ecosystem processes. Accordingly, future kangaroo management should embed ecological indices alongside population estimates, using them as part of quota setting and monitoring frameworks to ensure that management decisions account for both population sustainability and ecological integrity.

CONCLUSION

This review assessed the **reliability, transparency, and sustainability** of Australian kangaroo management programs. We found that:

Reliability is undermined by sustainable yield estimates that exceed ground-based demographic growth rates, implausible year-to-year population estimates that included occurrence after drought (particularly in western NSW), and by low survey coverage.

Transparency is low, with no release of raw data and inconsistent survey methodologies across states.

Sustainability is threatened where low realised commercial kills may reflect not only market limits but also low actual abundance in some zones.

At present, the low proportion of quotas taken and density dependent trigger points should provide a buffer against over killing. However, this remains to be determined over time. Rising demand or extended droughts could expose the risks of inflated population estimates and high sustainable yield quotas.

RECOMMENDATIONS

We propose the following improvements:

STRUCTURAL REFORMS:

1. Transition from "commercial killing management" to **coexistence management** where no commercial killing occurs, with farmer support (including compensation) in drought periods.
2. Make **all primary (raw counts) and secondary (estimates)** data publicly available, both retroactively and in real time.
3. Submit methodologies for **independent peer review** to ensure credibility.

IMMEDIATE CHANGES:

- Reduce sustainable yield quotas to **<10%**, aligning with demographic R_{mean} values (12–13%).
- Increase the proportion of each KMZ that is directly surveyed, with more frequent coverage in semi-arid zones.
- Incorporate **ecological indices** (e.g., grazing impacts, mortality, nutrient cycling) into KMPs.
- Reconfigure KMZs into **smaller, ecologically meaningful units**, enabling more precise surveys and reducing reliance on correction factors.
- Suspend commercial killing in **semi-arid KMZs during drought** and ensure annual surveys in all such zones.

Together, these steps would improve the accuracy, transparency, and ecological grounding of kangaroo management programs, ensuring that both kangaroo populations and the landscapes they shape are managed responsibly in the face of increasing environmental and commercial pressures.

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Appendix 1. Annual kill numbers by KMZ in NSW, 2010–2021, with trend slopes and R^2 values.

KMZ	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	R2	Slope
C/T South	15,755	17,970	8,372	9,677	6,093	2,695	6,388	16,755	23,691	23,401	24,236	22,770	0.31	1204
C/T North	20,394	21,524	13,337	10,176	11,701	15,223	12,040	14,322	23,400	42,879	33,801	25,847	0.32	1567
[3]Griffith South	-	-	-	-	-	-	-	-	-	-	29,371	57,634		
Griffith North	5,733	23,181	39,091	38,177	34,072	34,341	28,756	46,938	80,180	106,762	54,661	50,157	0.49	5205
SE NSW	43,102	34,889	18,385	7,351	6,399	6,851	4,291	5,176	10,918	30,977	58,033	56,320	0.08	1585
Upper Hunter	12,309	10,431	6,070	6,205	8,316	8,864	12,976	12,515	23,248	34,181	21,593	20,931	0.54	1727
Glen Innes	27,023	16,601	14,825	9,416	9,021	11,936	11,203	10,528	24,043	32,137	21,210	20,188	0.08	575
Coonabarabran	49,433	67,161	54,301	52,706	58,325	63,493	65,168	88,097	112,108	125,783	50,657	60,361	0.19	3007
Armidale	21,029	19,223	13,721	11,012	12,399	11,643	15,242	14,787	22,373	37,745	34,187	31,315	0.43	1692
Narrabri	79,849	53,336	40,294	58,960	66,494	61,933	49,635	52,568	65,707	67,057	33,162	22,762	0.25	-2247
Bourke	11,354	19,973	16,031	2,102	12,288	13,559	19,885	33,494	34,392	15,964	11,166	11,268	0.01	212
Cobar	13,038	9,972	12,598	7,625	4,059	6,883	7,929	9,983	12,579	01	01	3,9711	0.41	-818
Lower Darling	29,401	17,304	13,030	24,365	28,434	23,552	23,599	26,882	39,349	39,988	44,926	46,608	0.67	2464
Broken Hill	67,251	52,645	60,299	66,571	74,534	66,849	70,282	83,735	103,372	74,367	52,183	64,857	0.01	987
Tibooburra	14,372	18,697	24,390	24,303	22,904	28,002	31,057	38,846	18,436	01	01	2,2961	0.21	-1575
Total	410,043	382,907	334,744	346,646	355,039	355,824	358,451	454,626	593,796	631,241	469,186	497,285		
Prices (AUD)/kg		0.64-0.75	0.75	0.60	0.60		0.70			1.10-1.20	1.30-1.40	1.31-150		
Chiller operators	143	148	128	83	87	73	91	105	1272	121	149	139		
Commercial shooters			496	338	298	281	324	365	424	502	557	571		
Properties			3647	3152	3046	2965	2878	3142	4269	2988	2777	2775		

[1]Killing limits on one or more species. [2]The removal of the historic cap on fauna dealer licenses in 2018 probably influenced increases in carcasses prices, chillers, and hunters. [3]The Griffith South KMZ was established in 2020 by dividing up Griffith North.