Portfolio Committee No. 7 – Planning and Environment

Inquiry into the health and wellbeing of kangaroos and other macropods in New South Wales

Supplementary questions

Questions for the NSW Department of Planning Industry & Environment (DPIE)

1. When Mr Brill was asked whether the department had abandoned the long-term western district survey methodology in NSW, Mr Brill responded "No". Can the department confirm Mr Brill's consequent advice that:

   (a) The strip count survey methodology that had been used from 1988 until 2015 was changed to a mark/recapture distance sampling methodology in 2016?

   (b) The line transects which had previously "flown … right across the state" from 1988 until 2017 were changed to 56 monitoring blocks in 2018?

ANSWER:

1. (a) The strip counting method was used from 1984 to 2015. In 2016 and 2017 the same survey transects were flown but mark-recapture distance-sampling (MRDS) was used to capture and analyse the results.

b) Yes. However, in 2018 and 2019, 52 monitoring blocks were surveyed and in 2020 and 2021, 56 blocks were surveyed on the western plains.

2. Given that according to Mr Brill the western zone strip count survey methodology used from 1988 to 2015 is no longer being used, and that the survey transects being flown from 1988 to 2017 are no longer being flown, please explain how the old survey methodologies have not been abandoned?

ANSWER:

2. Methods used for aerial survey are regularly reviewed. Adopting advances in data collection and analysis are appropriate. For example, the change from strip transect sampling to mark-recapture distance-sampling (MRDS) has lessened bias and improved precision in estimated population sizes of kangaroos. The change from east-west transects to survey blocks was done to improve occupational health and safety of the survey crew and the public. Thus, the current survey methods have been refined and improved over time to improve safety, and data recording and analysis. Nevertheless, the corrected strip-sampling survey data from 1984–2015 and the MRDS data from 2016 to present form a valuable time-series for scientific study.

3. Mr Brill provided a description of how the distance sampling counting was done, making reference to kangaroo observations being placed into "*bins*" which define distance categories "*from zero to 300m*". Later he stated "*the closer it* [a kangaroo] *is to 300, the more likely they* [the counter] *are to miss it*".

   (a) What are the distance categories used in the current MRDS methodology in western NSW, on each side of the plane?

ANSWER:

3. (a) Distance categories are: 0–50 metres, 50–100 metres, 100–200 metres and 200–300 metres.

4. Mr Brill stated that a correction factor of 1.85 is only applied to Wallaroos. What year was that correction factor introduced?

ANSWER:

4. The correction factor was introduced in 2001. The first helicopter surveys of the Northern Tablelands management zones were carried out in 2001 and 2002. The correction factor for wallaroos was introduced with these surveys. Each report has contained an explanation of its origin and use.

5. What is the maximum annual population growth rate (PGR) for Grey Kangaroo populations when *actual* or observed factors such as juvenile mortality, life-tables and numerous detailed field studies are taken into account:

   (a) Is it around 9-10%, taking into consideration Caughley's r-max 55% *minus* mortality, life-tables and numerous detailed field studies; or is it up to or over 249% per annum (according to previous KMP Manager Payne 2013) or even higher (426%) as is indicated by the department's population estimates?

   (b) If 9-10% is a maximum PGR, how can an aspirational harvest rate of 15% be sustainable given this rate exceeds maximum growth rate for the species? How is this not a critical flaw in the harvest model?

ANSWER:

5. (a)

Population Growth Rate

Population growth rate (also referred to as the rate of increase) is defined as the per capita rate of growth of a population. It tells us whether population size is increasing, stable or decreasing, and indicates how fast it is changing. It is conventionally calculated as

$$\lambda = {}^{N_t}/_{N_{t-1}}$$

where λ = the finite rate of increase, and N refers to the number of individuals in the population at time t.

The finite rate is often converted to an exponential rate to improve interpretation and the ease of use mathematically (Caughley 1977). The advantages of the exponential rate (rather than the finite rate) include: (i) the rate is centred around zero for stable populations; (ii) the sign of the rate immediately indicates if the population is increasing (positive) or decreasing (negative); (iii) increases or decreases of the same magnitude have the same value, so a doubling of the population or a halving of the

population have the same value, apart from the reversal of sign; and (iv) in contrast to finite rates, exponential rates can easily be converted from one unit of time to another (when the annual exponential rate of increase equals x the daily rate equals x/365). For these reasons, the Department refers hereon to the rate of increase as the exponential rate.

This simple method of calculating the rate of increase is the most commonly used method and it compares population abundance (or index of abundance) over two successive points in time. This method calculates the *observed* finite rate of increase and takes into account the influence that resources (such as food availability) and other factors such as predation, have on survival and fecundity. This observed rate is a completely *general measure* of rate of increase and makes no assumptions with respect to sex ratio, the age distribution of the population, that resources are superabundant, or that the rate of increase is constant over the period of measurement. When resources are superabundant, predation is absent and the sex ratio is female biased; survival and fecundity can reach their maximum rates. At this point, the observed rate of increase is the observed *maximum* rate of increase.

This is not the only method for calculating rate of increase. Rate of increase can also be calculated from age or stage-specific survival and fecundity values, commonly arranged into a lifetable. However, age or stage specific values of survival and fecundity are difficult to measure (Gaillard et al. 1998) and are unknown for most kangaroo populations. Even relatively simple measures, such as the sex ratio and age distribution of a population – which are required to estimate rate of increase from a life-table – are unknown for most populations. It is for these reasons that lifetables are rarely used to estimate maximum rate of increase, and doing so usually requires untested assumptions about a population.

In contrast, abundance estimates derived from regular broad-scale surveys are available for all kangaroo populations that are harvested, and therefore the rate of increase can be easily estimated.

Using broad-scale survey data, the rate of increase has been measured (and published in peer-reviewed scientific journals) for many populations of kangaroos. In western NSW, Bayliss (1987) calculated the maximum rate of increase for red kangaroo as 0.34–0.57 (equivalent to finite rates: 1.40–1.77) and for western grey kangaroos as 0.35–0.66 (equivalent to finite rates: 1.42–1.93). In a separate study, Caughley et al. (1984) estimated the maximum rate of increase for reds and western greys as 0.33–0.40 and 0.26–0.30 (equivalent to finite rates: 1.39–1.49 and 1.30–1.35), respectively. Cairns & Grigg (1993) estimated values for red kangaroo populations in South Australia to be between 0.38–0.92 (equivalent to finite rates: 1.46–2.51). For eastern grey kangaroos in the ACT, Banks (2000) estimated the maximum rate of increase to be 0.47–0.55 (equivalent to finite rate: 1.60–1.73).

The highest rates were observed following drought breaking rains (e.g. Bayliss 1987, Cairns and Grigg 1993, Caughley et al. 1984), when the combined effects of an unstable age distribution, imbalanced sex ratio in favour of females and abundant food resulted in an initial rapid rate of increase in the first year after drought-breaking rains, or when predators (primarily foxes) were heavily baited thereby removing predation as a factor (e.g. Banks 2000).

Maximum rates based on assumptions regarding theoretical populations, estimated vital rates and sources of data derived from numerous sites are likely to be highly inaccurate and misrepresent true maximum rates of increase. The claim that the maximum rate of increase of kangaroos is between 0.086–0.095 (equivalent to finite rates of 1.09–1.10) is not supported by empirical data.

Kangaroo management zones in NSW are divided into administrative units. The boundaries of zones are not correlated with underlying vegetation, topographic or climatic factors that may influence the distribution of kangaroos. In addition, there are no administrative boundaries controlling the movement of kangaroos and, with the exception of fences used to control the movement of livestock or exclude pest animals, kangaroos can move freely between zones. Large changes in abundance between years within a zone, that exceed the observed maximum rates of increase described above, have sometimes been observed. These are not unexpected and are most likely associated with changes in the availability of food resources within a zone, as has been observed in South Australia, where broad-scale movement of kangaroos was observed in response to rainfall that stimulated new plant growth (Pople et al. 2010).

(b)

Sustainable harvesting

Caughley (1976, 1977) outlined the principles of sustainable wildlife harvesting. To harvest a sustained yield from a population at steady density, the population must first be manipulated in some way to promote its rate of increase (e.g. it could be reduced below its ecological carrying capacity or its resources could be supplemented). Four theoretical principles can be identified:

- Any harvest reduces population size and the greater the harvest rate, the smaller the population becomes.
- Harvesting theory proposes that populations can be sustainably harvested but must be regulated by some combination of density-dependent reproduction and mortality. Furthermore, harvest mortality is compensated to some extent by lowered natural mortality rates and increased fecundity rates due to resources becoming available when the population size is reduced.
- Rates of harvest may be raised to levels that are unsustainable and, if continued, can cause the extinction of the population.
- Between no exploitation and over-exploitation to extinction there are many levels of sustained yield.

Although these principles were developed with steady state environments in mind, with some modifications they also apply to variable environments. For species such as kangaroos that live in variable environments and have dynamics characterised by periods of 'boom and bust', harvest offtake that tracks changes in population size theoretically and practically reduces the risk of resource depletion (Lande et al. 1997, Aanes et al. 2002).

Harvest quotas are typically 10–17 per cent per annum of conservatively estimated populations. Based on rate of increase of kangaroo populations (see above), the harvest rates employed, and the extensive body of research that supports the sustainability of the current management strategy, the commercial harvest of kangaroos is sustainable. Further, there is no evidence that the viability of any kangaroo population has been affected by commercial harvesting.

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6. What are the maximum population growth rates for populations of Red Kangaroos and Wallaroos, when juvenile mortality and life-tables are taken into account?

   (a) Is it around 14% during good conditions, or is it up to and over 260% per annum (for Wallaroos), or 269% per annum (for Red Kangaroos) as asserted by the department's population estimates?

   (b) How can an aspirational harvest rate of 17% be sustainable given that this rate exceeds the maximum PGR of 14% for the species, according to life tables for the species? How is this not a critical flaw in the harvest model?

ANSWER:

6. (a–b) Please refer to the response to Question 5.

7. If the Department asserts populations actually increase by up to or over 249% pa, or 260% pa, or 269% pa, or 426% pa, please explain the biological/reproductive mechanisms which would make these seemingly biologically impossible rates of population increase possible?

ANSWER:

7. These rates are due to movement of kangaroos into the kangaroo management zone and are not due solely to increases in fecundity and survival.

Kangaroo management zones in NSW are divided into administrative units. The boundaries of zones are not correlated with underlying vegetation, topographic or climatic factors that may influence the distribution of kangaroos. In addition, there are no administrative boundaries controlling the movement of kangaroos, and, with the exception of fences used to control the movement of livestock or exclude pest animals, kangaroos can move freely between zones.

Large changes in abundance between years within a zone, that exceed the observed maximum rates of increase described above, have sometimes been observed. These are not unexpected and are most likely associated with changes in the availability of food resources within a zone, as has been observed in South Australia, where broad-scale movement of kangaroos was observed in response to rainfall that stimulated new plant growth (Pople et al. 2010).

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8. The government's population estimates describe kangaroo populations as crashing by up to and over 80-90% between 2000 and 2010 in the western zones. How does the Department explain

the biologically impossible population recovery rates to pre-drought levels by 2014 (according to the Kangaroo Management Units then manager Wolter (2018) graph, which was reproduced in the KIAA submission), particularly without cessation of shooting during that time, and with drought conditions intensifying during this period.

ANSWER:

8. During the period 2000–2014, the annual rate of increase of red kangaroos ranged from -0.80 to 0.22. The annual rate of increase of grey kangaroos ranged from -0.71 to 0.30. These annual rates of increase are all within the range outlined in the scientific literature (please refer to the response to question 5).

More specifically, the overall rate of increase from 2010 to 2014 for red kangaroos was: 0.21 (lower confidence level [lcl] 0.16, upper confidence level [ucl] 0.25). This is equivalent to a finite rate of 1.23 (or a 23 per cent increase). For grey kangaroos the overall rate of increase was 0.20 (lcl 0.17, ucl 0.23). This is equivalent to a finite rate of 1.22 (or a 22 per cent increase). As stated above, these rates of increase are all within the range outlined in the scientific literature (please refer to the response to question 5)

The method used to calculate rate of increase was based on maximum likelihood estimation of an Exponential Growth Rate State-Space (EGSS) model of stochastic population growth. Full methods are available in Humbert et. al. (2009).

The high capacity for kangaroo populations to recover post-drought is because of their unstable age structure and female-biased sex ratio. In rangelands populations, a short series of consecutive good seasons will see a substantial bounce-back from the effects of a drought. Records show that this happened following both the 1982–83 drought and the millennium drought of 1997–2010 (Figure 1).

For more detail, please refer to the studies cited in the response to Question 5.

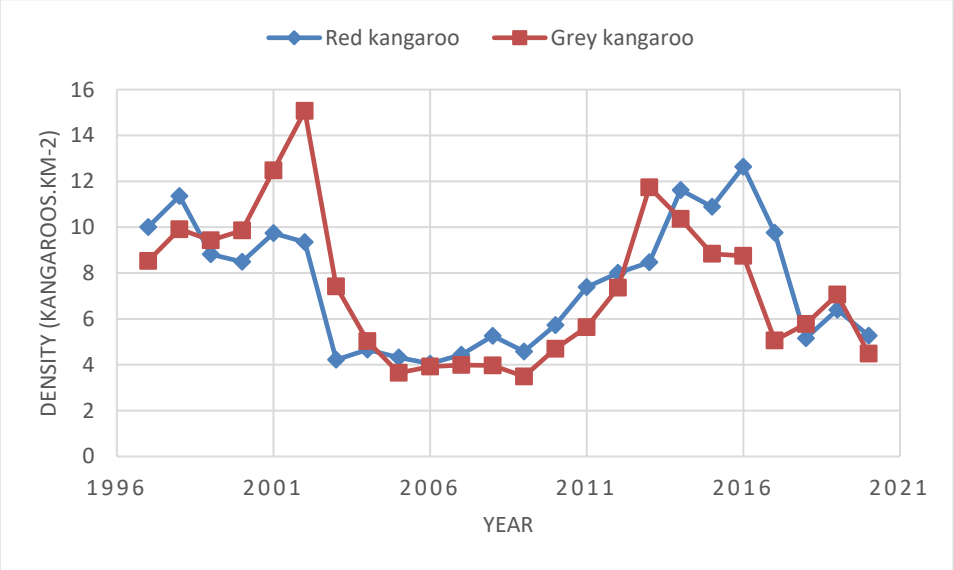

Figure 1: Red and grey kangaroo densities 1997-2000, in the western plains survey area, adapted from 2021 Quota Report.

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9. Is the Department aware that in the 1970s the proposed harvest model prescribed a cessation to shooting during drought, and recommended a post-drought period of no shooting to allow populations to re-build? (*Kangaroos and Men* Symposium, RZS of NSW 1971)

   (a) Why were key recommendations such as these not incorporated into the harvest model that was adopted?

ANSWER:

9–9(a) In the early 1970s, kangaroo harvesting was largely unregulated (Lunney 2010). The conference 'Kangaroos and Men' was organised by the Royal Zoological Society of NSW to discuss current knowledge of kangaroo biology and to raise issues and concerns regarding the management of kangaroos and wallabies. In the proceedings, Newsome (1971) presented some ideas on the management of commercial kangaroo harvesting. These ideas were derived from his experiences in ecological research, primarily studying red kangaroos in Central Australia. On their own, Newsome's ideas cannot be called a harvest model or strategy since he makes no suggestions regarding limiting offtake, no provision for monitoring kangaroo populations and no analysis of the impacts of his ideas on the viability of kangaroo populations. Newsome's suggestions were based largely on the fact that little was known about the ecology of kangaroos and their response to harvesting at the time. This is not the case now.

Current management of commercial harvesting is based on well-studied theoretical models of alternative harvesting strategies and their impacts on population state (e.g. Engen et al. 1997, Lande et al. 1995, Lande and Orzack 1988, Lande et al. 1997, Sæther et al. 1996), simulation modelling of harvesting strategies on kangaroo viability (e.g. Caughley 1987, McLeod et al. 2004, McLeod and Pople 2018) and field data on the impacts of harvesting on kangaroo populations (e.g. Pople 1996, Hacker et al. 2003). The current system of management, referred to as proportional threshold harvesting, incorporates some of the ideas put forward by Newsome, but has done so in a rigorous and evidence-based manner. This strategy has been well studied and is considered relatively safe and efficient for a fluctuating population.

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10. How can continuation of shooting during drought, when populations can decline by up to and over 50% pa, be sustainable?

    (a) How is this not a critical flaw in the harvest model?

ANSWER:

10–10(a) The issue of harvesting during drought has been examined in detail by Pople (2003). The following description draws heavily from his analysis of harvesting impacts on kangaroo populations during drought.

Annual quotas are set for a calendar year that represent a percentage of the population size, estimated annually (in most areas) by aerial survey in the winter of the previous year. Even if the full quotas are taken, the actual rates of harvest will differ from 15–17 per cent because populations rarely remain stable. There is therefore some risk of over- or under-harvest.

If the population halves over 12 months, the actual harvest rate over the year becomes roughly 21 per cent instead of the desired (set by quota) rate of 15 per cent. If the decline is 80 per cent, the annual harvest rate is likely to be around 34 per cent. A doubling of the population will result in a harvest rate of roughly 11 per cent. These actual rates are approximate because they assume constant geometric growth and decline in the population.

In most years, this risk of over- or under-harvest is likely to be small because year-to-year fluctuations are relatively small. On a broad scale, increase in the population will be constrained physiologically by the reproductive capacity of females, and modified by sex ratio and age structure. The maximum rate of increase, even in a male-biased population with few juveniles, will fall short of doubling. However, the rate of decline can be more pronounced as it is unconstrained by an animal's physiology.

In the drought of 1982–83, kangaroos declined by approximately 40 per cent over 12 months in the sheep rangelands of eastern Australia (Caughley, Grigg et al. 1985). However, most of this decline occurred over a shorter period of perhaps four months (Robertson 1986), when possibly the more vulnerable individuals died. Had this period of decline been maintained, the decline over 12 months would have been 80 per cent.

Harvest mortality can be additional to natural mortality or compensatory (Anderson and Burnham 1976). The latter results from some animals being harvested that would have died anyway. For a fluctuating population of herbivores, mortality tends to be additive during population increases when pasture is abundant and compensatory during declines in drought (Pople 1996). Harvesting will therefore have a greater effect on a population's rate of increase when it is increasing than during drought. Harvesting is unlikely to be completely compensatory or completely additive as there will be

potential survivors of drought that may be harvested and there is invariably natural mortality even when food is abundant.

Populations can be harvested during a drought because there is compensatory mortality. Animals that would likely have perished during a drought are harvested, and those that remain have more resources, which improves their survival. Furthermore, kangaroo harvesters are highly selective in the animals they shoot, preferring to shoot kangaroos with body weight above 25–30 kilograms (Hacker et al. 2004). During extended droughts animals with large body size are more likely to die because their food demand is higher while food availability is low. Having a small body size is an advantage during drought because food requirements are lower and smaller individuals are less likely to be targeted by harvesters. Additionally, harvesters cease shooting in areas when harvesting becomes economically unviable (Choquenot et al. 1998). This occurs during drought due to a combination of lower density and small body size of kangaroos. This occurred recently in the Tibooburra kangaroo management zone, when no shooting of eastern and western grey kangaroos occurred despite quota being available. In addition, the proportional threshold harvesting strategy includes strong trigger points based on population state, which stop harvesting if population size declines to a low level. Results from simulation models support the finding that the proportional threshold harvesting policy provides an adequate safeguard against overharvesting during drought (McLeod and Pople 2018).

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11. If kangaroo populations are in decline, for example during drought, and if quotas are set based on the previous year's count:

    (a) Doesn't this mean quotas will be over-allocated?

    (b) Does it not follow that the "critical threshold" at which shooting is discontinued will continually decrease, resulting in the continued shooting of kangaroos and the reinstatement of shooting at ever lower densities?

(c) How is this not a critical flaw in the harvest model?

ANSWER:

11. (a–c) Please see the response to Question 10.

12. If populations are in decline, and if populations are kept at low density by continuous shooting, does this mean that the "long-term average" density will also be decreasing?

(a) If the long-term average is decreasing, does this mean that the "critical threshold" at which harvest rates are reduced or discontinued will also be decreasing?

(b) If the "critical threshold" is continually decreasing, does this mean that shooting of kangaroos and the reinstatement of shooting will occur at ever lower densities?

(c) If shooting is permitted at ever decreasing densities, how is this not a critical flaw in the harvest model?

ANSWER:

12. Hypotheses about the long-term trend in populations can be tested by examining the average rate of increase of a population over a long period of time. Evidence of a population in decline would be indicated by the average being negative and significantly different to zero. Conversely, evidence of a long-term increase would be indicated by a positive average that was significantly greater than zero. Finally, evidence of a stable population trend would be indicated by the average being not significantly different to zero.

The long-term surveys of kangaroo populations in NSW provide the data to test these hypotheses. A recent study used multivariate autoregressive state-space models to examine spatial and temporal patterns in kangaroo populations in NSW and Queensland (McLeod et al. in press). The results indicated that over the 30–35 year time series of kangaroo abundances, the long-term growth rate of all populations was not significantly different to zero, indicating that there has not been an overall decline in the abundance of kangaroos in areas where kangaroos are harvested.

As there is evidence that populations of kangaroos are not in decline, parts (a), (b) and (c) of this question are redundant.

References

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13. Please explain how it is appropriate to use animals counted in non-shooting areas such as national parks and reserves to formulate density estimates which are then applied to surrounding farming/shooting landscapes that often return low or zero-counts of kangaroos, according to the raw data?

(a) If it is considered appropriate to use animals observed in national parks to generate densities applied to farmland or zero-counted landscapes, please detail why the survey design team discontinued flying over national parks and other conservation reserves in western NSW in 2018?

ANSWER:

13. (a) From 1984 to 2017, kangaroos on the western plains of NSW were surveyed along transects that followed the 15' and 45' parallels for each one-degree of latitude. This systematic layout of transects sampled land-use categories in proportion to occurrence. By chance alone, transects crossed reserves, including national parks, which made up approximately five per cent of the survey effort. There is no evidence that the relatively small proportion of reserves included in the surveys biased the counts.

In 2018, the survey was redesigned, and reserves were excluded from the survey areas. This change was made after consultation with community groups and scientists who are considered experts in survey design and analysis.

14. If it is not appropriate to use animals from national parks to generate densities applied to farmland, as suggested by the exclusion of national parks from the western districts survey sample in 2018, are there any valid population estimates for western NSW for the period 1988-2017?

ANSWER:

14. Yes, the population estimates for 1988–2017 are still valid. Please refer to the response to question 13 for further explanation.

15. How is it appropriate to continue industrial-scale shooting of Australian wildlife with no valid scientific baseline data or population estimates for areas in which kangaroos are shot?

ANSWER:

15. Commercial harvesting of kangaroos is regulated by Commonwealth and state legislation. Kangaroo populations are regularly monitored, and quotas are set at sustainable levels. Monitoring of populations has been undertaken recurrently in NSW for 40 years and represents one of the best long-term datasets in the world (Lunney et al., 2018). Monitoring has been based on standardised and scientifically peer-reviewed methods and provides a time-series against which trends and the viability of populations throughout their present ranges are assessed. There is no scientific evidence that the viability of any kangaroo population in NSW is at risk.

References

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. doi:10.7882/AZ.2018.040

16. More specifically, how is it appropriate to continue shooting kangaroos given unambiguous and long term decline in the government data sets in many regions, and given that historically population estimates have been based on using kangaroos from within non-shooting areas (including national parks), to form a representation of populations in harvest zones across the KMZs?

ANSWER:

16. The Department rejects the inference in the question that there is *'unambiguous and long-term decline in the government data sets in many regions'*. The long-term data sets do not support that statement. Across the continent, kangaroo numbers go down with drought and increase in response to wetter seasons with abundant resources. This phenomenon is most apparent in the rangelands.

Hypotheses about the long-term trend in populations can be tested by examining the average rate of increase of a population over a long period of time. Evidence of a population in decline would be indicated by the average being negative and significantly different to zero. Conversely, evidence of a long-term increase would be indicated by a positive average that was significantly greater than zero. Finally, evidence of no long-term change in population size would be indicated by the average being not significantly different to zero.

The long-term surveys of kangaroo populations in NSW provide the data to test these hypotheses. A recent study used multivariate autoregressive state-space models to examine spatial and temporal patterns in kangaroo populations in NSW and Queensland (McLeod et al. in press). The results indicated that over the 30–35 year time series of kangaroo abundances, the long-term growth rate of all populations was not significantly different to zero, indicating that there has not been an overall decline in the abundance of kangaroos in areas where kangaroos are harvested.

With regard to the tablelands commercial kangaroo management zones, numbers in the tableland management zones have generally increased from survey to survey up until the recent drought. Eastern grey kangaroo numbers fell quite markedly in the South East Tablelands zone and the Central Tablelands zones as a result of the drought. In the Northern Tablelands, where it appears that the drought may not have been as severe, eastern grey kangaroo numbers remained relatively constant over the period 2016–2019. Officially, the drought occurred in 2017–2019.

References

McLeod, S. R., Finch, N., Wallace, G., and Pople, A. R. (in press). Assessing the spatial and temporal organization of kangaroo populations in eastern Australia using multivariate autoregressive state-space models. *Ecological Management & Restoration* **n/a**.

17. Was the (then) OEH Kangaroo Management Unit or its contractors made aware of the errors regarding sampling conservation areas in Dec 2013 when the NSW Scientific Committee was advised of this error in a supplementary submission to the 2011 nomination of kangaroos tothe threatened species list?

    (a) If not, why not?

ANSWER:

17–17(a) Review of the NSW Scientific Committee Final Determinations, available online here, shows that proposals to list the eastern grey kangaroo, western grey kangaroo, red kangaroo and common wallaroo as a Vulnerable species in Part 1 Schedule 2 of the *Threatened Species Conservation Act 1995* or Threatened Species Conservation Regulation 2010 were all rejected in May 2015, because the species did not meet any of the criteria for listing of vulnerable species in the Threatened Species Conservation Regulation 2010.

The time-series data used to monitor population size and variations by the Kangaroo Management Program shows population fluctuations without directional change in population size. These long-term data show the proposals had no basis or evidence.

It is unclear what sampling errors the Parliamentary Committee is referring to in this question. The only use of the word 'error' in each of the four determinations is to state that, *'Even allowing for the presence of immature animals, sampling uncertainty and experimental* ***error****, it is highly likely that the total number of mature* [Macropus sp.] *individuals is not low or moderately low.'*

The citation of December 2013 in the determinations by the NSW Scientific Committee for the eastern grey kangaroo, western grey kangaroo and red kangaroo references the 2013 Quota Report published by the Department (then known as the Office of Environment and Heritage; OEH) and primarily authored by then manager Ms N. Payne.

The highly reputable independent scientists of the NSW Scientific Committee did not identify any errors when they published their determinations, and this is likely why the departmental Kangaroo Management Unit was not advised of 'errors regarding sampling conservation areas'. The committee rejected the proposed nominations.

18. Is it legitimate science to state kangaroo monitoring surveys did *not* fly over national parks and state forests in western NSW (see Cairns *et al* 2009 and 2012), when mapping of the raw data along transects confirms non-shooting conservation areas were in fact overflown?

    (a) How did the extrapolation of animals counted in national parks inflate asserted numbers in each of the surveys up to 2018, when overflying national parks and reserves was abandoned?

    (b) Please provide the mathematics describing the role dropping of transects over national parks and reserves played in the decline described by the Population Estimates in 2018?

ANSWER:

18. Up to and including 2017, the east-west transects across western NSW did intersect some national parks. This crossover was random: there was no plan to selectively survey or to avoid the national park estate.

Surveying national park estate does not invalidate the results. Many kangaroos come and go between national park estate and private land. Stakeholders tend to have divergent views; for example, NSW Farmers advocates including national parks in the surveys.

(a) Whether there was any inflatory or deflatory effect associated with surveying national park estate has not been assessed. The proportion of national park estate that the transects intersected was relatively small (around 4.9 per cent at its peak) and approximately in proportion to the survey area that was covered by national park estate. The graph below (Figure 2) shows the change in proportion of the western plains surveys that was national park estate over time.

(b) The Department believes the change from including small areas of national park on the transects to avoiding national parks completely has a negligible effect on population estimates. Year-to-year variation in populations would far exceed any effect surveying national parks, or not, may have.

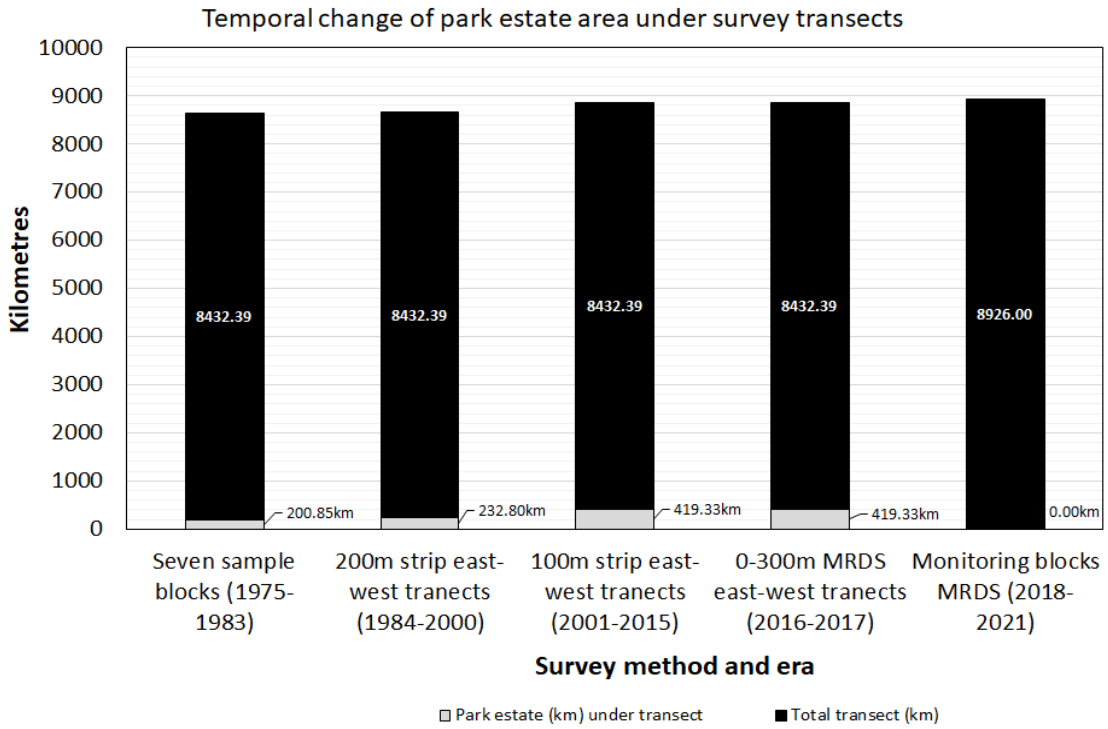

Figure 2: Temporal changes in the park estate covered by survey transects.

19. Given that survey team sampled national parks in the central tablelands in 2008 and 2011, when the survey reports stated that they did not fly over conservation areas, why did the OEH-KMU re-engage the consultants is they failed to provide valid baseline and subsequent results for the kangaroo survey program?

ANSWER:

19. The 2008 and 2011 surveys were the first surveys conducted in the Central Tablelands. Survey transects are adjusted by the flight planners to ensure they remain within the boundaries of the kangaroo management zone. There may have been a small amount of accidental overlap with national parks in 2008, however, this was eliminated for the 2011 survey and for the subsequent 2014 survey. In addition, in most circumstances, kangaroos move freely between the national park estate and private land, so it is not invalid to survey national park land, particularly where that park is relatively small near private land.

The Department rejects the inference in the question regarding the expert contractor. The level of expertise and quality of work provided by the contractor, Dr Cairns, is impressive. Dr Cairns has not failed to provide sufficient and accurate population estimates and has an expert understanding of population ecology and surveys. The Department has attached Dr Cairns' publication record (Tab S1).

20. Is it normal practice for the Kangaroo Management Unit to re-engage consultants who have failed to deliver valid data and results?

ANSWER:

20. The Department rejects the basis of the question. Dr Cairns has always and continues to meet the contact requirements and delivers expert analysis of tablelands surveys and program support.

21. Has the department ever done a stratified analysis of the survey data by land-use and/or vegetation type, in order to verify whether population estimates from the extrapolated / official population estimates match results from a stratified analysis?

    (a) If not, why not?

ANSWER:

21–21(a) The tablelands surveys are stratified on the basis of landscape characteristics, land use and gross macropod density. Full explanations are available in the numerous reports written by Cairns et al.

In the western plains, multimodel inference (Burnham and Anderson 2002) is used to determine covariates that contribute to improving the fit of the mark-recapture distance-sampling (MRDS) analysis. Analyses use post-stratification of a large number of covariates including but not limited to: vegetation cover, land use, and bioregion. The Government is examining the usefulness of model-based estimates using density surface models (Miller et al. 2013) to estimate density between survey blocks.

References

Burnham, K. P., and Anderson, D. R. (2002). 'Model Selection and Multimodel Inference'. (Springer: New York.)

Miller, D. L., Burt, M. L., Rexstad, E. A., and Thomas, L. (2013). Spatial models for distance sampling data: recent developments and future directions Ed O. Gimenez. *Methods in Ecology and Evolution* **4**, 1001–1010. doi:10.1111/2041-210X.12105

22. With regard to assertions about the sustainability of the industry, the Mjadwesch submission has graphed the government's commercial Eastern Grey Kangaroo Take in the Central Tablelands North and South zones (as an example):

    (a) Does the department agree that the commercial killing in the Central Tablelands and other eastern zones escalated from 2017-18, as evidenced by the sharp increase in Take in these areas?

    (b) How does this Take increase correspond to NPWS rangers directing landholder shooting towards commercial utilization, as directed by the regulating office?

    (c) According to Cairns *et al* (2018) and Cairns *et al* (2020), between 2017 and 2020 the reported population halved in the Central Tablelands zone. At the same time shooting increased three- to five-fold as described by the Take graphs provided by Mr Mjadwesch:

        (i) Does the department agree this data shows the population is crashing while the harvesting is escalating?

        (ii) Explain how this is a good example of a sustainable commercial wildlife exploitation program?

        (iii) If a 50% decrease in a population, corresponding to a three- to five-fold increase in killing is considered sustainable, what rate of population decline vs offtake would the department consider to be unsustainable?

ANSWER:

22.

(a) Yes, the data shows an increase in harvest levels in the Central tablelands from around 2017–18.

(b) The Department does not have data on the number of referrals from NPWS rangers. However, it is more likely a result of decreased harvest rates in the western parts of the state that were severely drought affected at that time.

(c)

(i) The Department does not agree that the population is 'crashing'.

(ii) The commercial kangaroo management program annually surveys populations on the western plains and triennially surveys populations in the higher rainfall tablelands areas. Conservative quotas are set based on these surveys. To date the proportion of the quota (and therefore the population) harvested on the tablelands is relatively low.

(iii) It is not valid to compare percentage decreases in population with percentage increases in harvest levels. Each parameter should be compared back to the same baseline, the population, for example. The Department would reduce the quota to 10 per cent of population when the surveyed population falls below 1.5 standard deviations below the mean and to zero quota when the population falls below two (2) standard deviations below the mean.

23. Mr Quirk said, in reference to applications for non-commercial permits in the wake of the 2019-2020 fires: "*We have taken a very cautious approach about any non-commercial permit requests in the Eastern Division in those areas where fires occurred and they are all being subject to site inspections and checking. Interestingly, we are not getting a lot of applications.*" Mr Quirk consequently stated "*in the commercial zone we often recommend to farmers a range of options, but one of the options we suggest to them is that they use commercial harvesters*".

(a) Is it possible the Eastern Division is not receiving many non-commercial applications to kill kangaroos because the department has been implementing a policy to urge landholders to use commercial shooters?

ANSWER:

23. (a) No. The east coast of NSW falls in the non-commercial zone, which is not open to commercial harvest. As stated by Mr Quirk, the option to engage a commercial harvester is only available for properties in one of the commercial zones. However, in the commercial kangaroo harvest areas it is possible that some landholders have elected to give permission to professional kangaroo harvesters to harvest on their property rather than applying for a licence to cull kangaroos.

24. In discussing threats to the commercial industry the NSW Kangaroo Management Advisory Panel (KMAP) Minutes #30 (28 March 2018) concluded the "*highest risk* [to the commercial industry] *is to lose faith in information regarding sustainable populations and harvesting*".

Lunney *et* al's 2018 paper, *Four decades of research and monitoring the populations of kangaroos in New South Wales: one of the best long-term datasets in Australia* was subsequently published in December 2018 in *The Australian Zoologist.* It described the NSW program as having produced "*one of the best long-term datasets in Australia… and indeed the world because of their consistency in data collection over such a large scale for four decades"*.

(a) What is the Department's response to the KMAP's conclusion, and does the Department agree with it?

(b) How did the KMAP's conclusion contribute to the writing of that paper?

(c) What funding or other role did the Department have in that paper, given that Lunney and other coauthors were/are employees of OEH and DPI (and Qld Dept Agriculture) and include other roles such as KMAP member, designer of kangaroo surveys, former and acting managers of the commercial kangaroo program?

(d) Given that evidence of errors in the survey program, errors in the harvest model and decline in data sets have not shaken the faith of the program managers, what evidence would the Department need to see to "lose faith in information regarding sustainable populations and harvesting"?

(e) Does the Department agree with the Lunney *et al* paper's statement that the long-term datasets are based on "*consistency in data collection…for four decades*" and that "*counting* [in the western districts] *has been consistent over the same area since the beginning of surveys in 1975*"?

ANSWER:

24.

(a) The Department agrees that it is important to ensure data on sustainable populations and harvesting is robust and credible.

(b) It did not contribute. The paper was initiated by Dr Lunney in 2016, prior to the KMAP meeting in 2018.

(c) The Department did not provide funding for the work, although some of the authors were employees of the Department. Staff from the kangaroo management program co-authored the publication. Contribution to the paper was part of normal staff roles in OEH.

(d) The Department rejects the premise of the question.

(e) Yes, the Department agrees that the long term kangaroo monitoring dataset over the commercial kangaroo management zones in NSW is one of the best broadscale wildlife monitoring data sets in Australia or perhaps even the world.

25. Does the Kangaroo Management Task Force receive government funding; if yes, how much?

ANSWER:

25. The Kangaroo Management Task Force does not receive any funding from the NSW Government.

26. As part of a discussion about the Kangaroo Management Task Force, KMAP Minutes #32 state "*There is a fact sheet on the Kangaroo being the most dangerous animal in Australia – how many people they kill each year*".

(a) Who produced the "*fact sheet*" referred to?

(b) How many people do kangaroos directly kill every year?

ANSWER:

26.

(a) The statement likely references the Road Safety fact sheet produced by the Kangaroo Management Taskforce in 2019. That fact sheet was in a draft form at the time of KMAP meeting #32.

(b) The Department does not know how many people kangaroos directly kill each year. The factsheet referred to in response (a) states that 18 Australian deaths were caused by kangaroos between 2000 and 2010.

27. After the 2019-20 bushfires:

(a) How many tags for commercial harvesting were issued in bushfire affected areas?

(b) How many were used?

(c) How many were returned?

Please provide by each kangaroo management zone.

ANSWER:

27. (a–c) The bushfires mainly occurred along the eastern edge of the following commercial kangaroo management zones; Glen Innes-13, Armidale-9, Upper Hunter-14, Central Tablelands North-48, Central Tablelands South-49, and South East-16. They generally affected only small proportions of each of these zones as shown by the map comparing the commercial kangaroo management zones with the burnt areas in 2019–20 summer and national park estate.

The requested data is for each zone for all of the 2020 calendar year is as follows:

Commercial kangaroo management zone	Number of allocated tags	Number harvested	Number of tags returned
Armidale - 09	41,650	34,187	3,239
Central Tablelands North - 48	38,350	33,801	2,689
Central Tablelands South - 49	26,300	24,236	1,409
Glen Innes - 13	27,050	21,210	3,008
Southeast NSW - 16	63,000	58,033	2,673
Upper Hunter - 14	27,200	21,593	4,221
Total	**223,550**	**193,060**	**17,239**

28. Why is the percentage take of the quotas consistently so low?

ANSWER:

28. A combination of factors affect harvest levels at any particular time. These include demand, availability of other work for kangaroo harvesters, kangaroo numbers (low numbers due to drought or higher numbers due to good seasons), kangaroos being scattered and in less accessible country following good rainfall, and boggy conditions on properties due to above average rainfall.

Young and Morris (1985) and Ampt and Baumber (2006) provided comprehensive reviews of external issues affecting kangaroo harvesting, as did McLeod and Hacker (2020).

References

Young, M. D. (Michael Denis) & Morris, G. J & CSIRO. Division of Wildlife and Rangelands Research (1985). *Economic and administrative influences on kangaroo management in NSW: final report*. C.S.I.R.O. Division of Wildlife & Rangelands Research, [Deniliquin, N.S.W.]

Peter Ampt, Alex Baumber; Building connections between kangaroos, commerce and conservation in the rangelands. *Australian Zoologist* **33**, 398–409. doi: https://doi.org/10.7882/AZ.2006.014

McLeod S. R., Hacker R. B. (2020) Balancing stakeholder interests in kangaroo management – historical perspectives and future prospects. *The Rangeland Journal* **41**, 567–579. https://doi.org/10.1071/RJ19055

29. Given in the inquiry hearing you did not quite clarify whether or not you do not think kangaroos as a species are in any danger, could you confirm in writing your view on this?

ANSWER:

29. In NSW, all kangaroo species that can be commercially harvested are classified as species of 'Least Concern' by the International Union for Conservation of Nature's Red List of Threatened Species (Ellis et al., 2015a; Ellis et al., 2015b; Munny et al., 2015; Burbidge et al., 2015).

The International Union for Conservation of Nature's Red List of Threatened Species is the world's most comprehensive information source on the risk status of animal, fungus and plant species. These species of kangaroo are listed as Least Concern because they are widely distributed, have large population sizes, occur in a number of protected areas, and are not in decline. A similar conclusion was reached in 2015 by the NSW Threatened Species Scientific Committee when they rejected a proposal to list these species as threatened.

References

Ellis, M., van Weenen, J., Copley, P., Dickman, C., Mawson, P., and Woinarski, J. (2015a). IUCN Red List of Threatened Species: Macropus rufus. IUCN Red List of Threatened Species. Available at: https://www.iucnredlist.org/en [accessed 12 July 2021]

Ellis, M., Menkhorst, P., van Weenen, J., Burbidge, A. A., Copley, P., Denny, M. J. S., Zichy-Woinarski, J., Mawson, P., and Morris, K. (2015b). IUCN Red List of Threatened Species: Macropus robustus. IUCN Red List of Threatened Species. Available at: https://www.iucnredlist.org/en [accessed 12 July 2021]

Munny, P., Menkhorst, P., and Winter, J. (2015). IUCN Red List of Threatened Species: Macropus giganteus. IUCN Red List of Threatened Species. Available at: https://www.iucnredlist.org/en [accessed 12 July 2021]

Burbidge, A., Menkhorst, P., Ellis, M., and Copley, P. (2015). IUCN Red List of Threatened Species: Macropus fuliginosus. IUCN Red List of Threatened Species. Available at: https://www.iucnredlist.org/en [accessed 12 July 2021]

30. Given that by your reporting, in Tibooburra if the quota of 2020 was reached then there would have only been 77 individual kangaroos left meaning this species is facing regional extinction due to mismanagement (Population estimate 2020 = 6859, quota was 6782), could you please explain how the 2020 quota could have even been set?

ANSWER:

30. The Department rejects the premise of the question. In 2020, there were no tags allocated and no kangaroos harvested in the Tibooburra commercial kangaroo management zone.

6782 is the combined eastern and western grey kangaroo quota set for 2020. The western grey kangaroo quota was set at 10 per cent of the population (Quota = 972) and the eastern grey kangaroo quota was set at 15 per cent of the population (Quota = 5796).

The Tibooburra Kangaroo Management Zone covers the north-western limit of natural range in NSW for these species, and consequently the population size of these species is always low. Eastern grey kangaroos are predominant in more easterly parts of NSW and the western greys are predominant in more southern parts of NSW. When conditions are favorable, kangaroo populations may be both breeding and migrating, resulting in large increases in population estimates. Conversely, during drought animals may move out of the management zone, reflected in a decline in population size.

31. For the Tibooburra 2020 quota, was anybody checking the numbers to determine if the quota was close to the estimated population?

    (a) Is the same person responsible for the entire table or are they merged documents?

    (b) How were these values missed?

    (c) If the lowest threshold is 10% did the person responsible for setting this quota look at the value for 2020?

ANSWER:

31–31(c) It is not valid to compare 2020 quotas with 2020 population estimates. Quotas for 2020 are set in late 2019 (based on 2019 population estimates), approximately 8–9 months prior to the 2020 surveys commencing and approximately 10–11 months before the 2020 population estimates are available. There was no allocation and harvest in the Tibooburra zone. The Department was monitoring allocation (and harvest) levels throughout the year.

32. Can you please explain how the population of Red kangaroos in Tibooburra was allowed to decline from 1,567,598 in 2016 to 344,619 in 2018 as per the NSW Commercial Harvest Management 2017 -21 Quota Report?

ANSWER:

32. A decline in population of this nature is consistent with the boom-and-bust population cycles that kangaroos experience, particularly in lower rainfall semi-arid areas such as the Tibooburra Zone. This decline occurred most likely due to drought during 2016, 2017 and 2018. The red kangaroo harvest in the Tibooburra zone as a proportion of the population was just 2.8 per cent in 2016, 2.4 per cent in 2017, and 1.5 per cent in 2018, suggesting commercial harvesting had little impact. In addition, independent research in Sturt National Park that is not subject to harvesting showed those populations followed similar trends. The Sturt National Park populations fell from around 100 kangaroos per square kilometre in mid-2017 to almost zero in mid-2018.

33. Given that throughout the period (2016-2018) the quota for red kangaroos in Tibooburra was sustained at 17%, could the department please provide the exact value that the population needed to fall to in order to stop the quota?

ANSWER:

33. The zero quota threshold density, and the zero quota population threshold for red kangaroos in Tibooburra commercial kangaroo management zone is shown in the table below for the years 2016–2018.

Year	Zero Quota Threshold Density (kangaroos/km$^{2)}$	Zone Area (km^2)	Zero quota population threshold (kangaroos)	Population Estimate (kangaroos)	Quota level set for following year
2016	6.69	54,848	366,933	1,567,598	17%
2017	6.81	54,848	373,515	1,135,531	17%
2018	6.31	54,848	346,091	344,619	0%

The average densities and standard deviations used to calculate the thresholds are available in the quota report each year.

Note the thresholds vary slightly from year to year due to the effect of the previous year's population estimate.

34. Referring to Tibooburra again for the Grey kangaroo, if the population declined from 184,002 in 2018 to 48,502 in 2019, that is a percentage drop of 73.6%, could the department please explain how a quota of 14% could have been set for the following year given this percentage drop?

    (a) Could the department please provide the EXACT figure the population would have needed to decline to in order to stop the quota and avoid the 6,782 (2020) quota even being set?

ANSWER:

34–34(a) Quotas are set using a 'Proportional Threshold' harvesting strategy, whereby population densities more than two standard deviations below the long-term mean lead to zone closures and population densities between 1.5 and two standard deviations below the long-term mean lead to a reduced quota (10 per cent). The density thresholds are unique for red kangaroos and grey kangaroos within each zone. This is a robust and objective method of setting density thresholds and reflects the nature of kangaroo populations across time.

The lower density threshold for grey kangaroos in Tibooburra in 2019 using all years of data was 0.62. In terms of population, any estimate less than 34,006 would have led to a zone closure for grey kangaroos. This threshold is not based on an arbitrary decision, it is informed purely by population data for grey kangaroos in the Tibooburra region, collected since 1984. Furthermore, it is an objective demonstration that it is not statistically 'unusual' for a population drop such as that referenced to occur for grey kangaroos in Tibooburra.

35. Given your submission acknowledges that the statistical methods used to monitor populations are the "best available" for broad scale wildlife, while the University of Adelaide showed that the use of drones to count wildlife is up to 96% more accurate than by aerial survey using humans, could you please provide evidence of your claim that "there would be no drone that could do it in any sort of time frame that was achievable"?

ANSWER:

35. In NSW, kangaroo populations are monitored by aerial survey using either fixed-wing aircraft or helicopters, and survey data are analysed using either mark-recapture distance sampling or multivariate distance sampling to estimate kangaroo population sizes. The equipment and methods used for collecting data are appropriate for broad-scale surveys of wildlife. Although drones are suitable for some small-scale surveys of wildlife, limitations such as their restricted range make them unfeasible for broad-scale surveys. The example referred to in the question from the committee is based on findings by Hodgson et al. (2018). Hodgson et al. compared counts derived from photographs taken from a drone hovering over replica seabirds (plastic duck decoys) against counts taken by ground observers. The results of Hodgson et al. are not comparable to a broad-scale aerial survey of kangaroos.

However, there is one study that directly compares survey results derived from a drone with the results based on conventional distance sampling using a helicopter. Gentle et al. (2018), conducted a direct comparison of a long-range drone with concurrent helicopter surveys in Queensland, and found that the drone under-estimated macropod density by between 87–97 per cent, compared with counts by experienced human observers in a helicopter. The helicopter surveys were also less expensive and more time efficient, partly because post-flight data processing took more time after drone surveys.

References

Gentle, M., Finch, N., Speed, J., and Pople, A. (2018). A comparison of unmanned aerial vehicles (drones) and manned helicopters for monitoring macropod populations. *Wildlife Research* **45**, 586–594. doi:10.1071/WR18034

Hodgson, J. C., Mott, R., Baylis, S. M., Pham, T. T., Wotherspoon, S., Kilpatrick, A. D., Segaran, R. R., Reid, I., Terauds, A., and Koh, L. P. (2018). Drones count wildlife more accurately and precisely than humans. *Methods in Ecology and Evolution* **9**, 1160–1167. doi:10.1111/2041-210X.12974

36. Given that you stated that "we are constantly looking at new technology and what might be available to us in the future", could you please provide evidence of what "new technology" you have investigated and the results with specific application to population estimates for Red, Eastern and Western grey kangaroos and wallaroos?

ANSWER:

36. As a departmental unit responsible for broadscale monitoring of wildlife, the Commercial Kangaroo Management Program (KMP) operates within an adaptive management framework. This means that monitoring methods are optimised over time, where improvements can be made. Before any decision to optimise methods, evidence and practicalities for and against the proposed change are reviewed.

Some examples of KMP adopting new technology to refine monitoring methods include:

- Its trial and now use of the Cessna 208 Caravan aircraft instead of the Cessna 206. The 208 is technologically more advanced and has a greater carrying capacity than the 206. In addition to the pilot, the 208 can seat an air observer to monitor for hazards, one or two wildlife observers in training, and four wildlife observers. This enabled a mark-recapture monitoring component and led to the implementation of mark-recapture distance-sampling (MRDS) in the western plains.
- Strips and bins were previously demarcated using string tied to the strut of the wing. In the

Cessna 208 the KMP has developed a frame with fixed distance classes and height adjusted to remove any effect of parallax error between front and rear observers.

- Since 2016, observations have been recorded directly onto Panasonic Toughpad tablets.
- Toughpads are fitted with GPS units and all animals are 'marked' and 'recaptured' with a spatial reference and time stamp. The previous method relied on human memory to enumerate observations.
- XBOX Wolverine game controllers (with the fastest response time from controller to computer available) are used to record observations onto the logger program developed for the Toughpad.

37. Could you please justify how aerial surveys involving multiple humans in the aircraft are more cost-effective compared to more accurate methods such as imagery (camera in the plane) while also providing all costs relating to the MRDS methods?

ANSWER:

37. The premise of the question is incorrect. The use of imagery is not more accurate than trained human observers. The human eye has greater resolution than any camera that could be deployed. Currently, if cameras are used instead of trained human observers, the imagery, which is of a poorer quality than the actuality, still needs to be reviewed by human analysts.

In recent years, Lethbridge et al. (2019) have used thermal imagery for large scale aerial fauna surveys. Unfortunately, their thermal imagery work could not differentiate between Macropus (grey) and Osphranter (red) kangaroo species. The work covers less area per unit distance (smaller effective strip width) and does not facilitate independent observation to correct for perception bias. It does, however, attempt to account for availability bias (objects present but not visible) and, when compared to human observers, resulted in a 30 per cent increase in the population estimate. The automated component of the algorithm resulted in 97.6 per cent of detections as false positives, thus all footage was reviewed manually, increasing the time and effort involved. The thermal camera yielded data from an effective strip width of 67 metres.

Other major technical progress is the accessibility and increased payload capability of unmanned aerial vehicles (UAV). UAVs effectively monitor small sea bird colonies in a homogenous landscape (on a sandy beach) (Hodgson et al., 2018), although they are not yet useful for broadscale surveys (Ezat et al., 2018; Fang et al., 2016). Gentle et al., (2018) tested the efficacy of long-range UAV against manned helicopter counts of kangaroos and found 'helicopter surveys were less expensive and more efficient and cost effective, requiring less flight and data processing time than UAS [unmanned aerial systems] surveys'. KMP will continue to review the evidence as it arises around the usefulness of UAV in broadscale aerial survey.

There is some momentum behind developing machine learning algorithms to automate detection using satellite imagery. Duporge et al. (2020) achieved comparable results between humans and automated detection using Worldview satellite imagery (30 cm^2 pixel) to detect large African elephants in open country. However, this study does not compare ground and automated counts and there are doubts about its applicability to NSW kangaroo surveys. This is because very high-resolution satellite imagery is only effective for vertebrate counts in high contrast and open habitats (La Rue et al., 2017). Additionally, objects must be at least two pixels in size for detection (Shannon (1949) as cited in Wang et al., 2019). Since the best available spatial resolution is 30 square centimetres, we can only identify kangaroos greater than 60 square centimetres in diameter. The cost of the imagery is promising (estimated to be between $14 and $27 USD per square kilometre (Wang et al., 2019)). Costs should decrease with the growth of the remote sensing industry.

Many of these technologies sound useful and appealing, but there are always practical constraints and

trade-offs associated with the adoption of new technology that must be closely considered as part of the decision-making process in any adaptive management framework. Remote monitoring of flora and fauna is an active area of research that the KMP continues to review.

Mark-recapture distance-sampling (MRDS) is used for the fixed wing surveys of the western plains. The western plains surveys cost approximately $260,000 per year.

References

Duporge, I., Isupova, O., Reece, S., Macdonald, D.W. and Wang, T., 2020. Using very-high-resolution satellite imagery and deep learning to detect and count African elephants in heterogeneous landscapes. *Remote Sensing in Ecology and Conservation*. DOI: 10.1002/rse2.195

Ezat, M.A., Fritsch, C.J. and Downs, C.T., 2018. Use of an unmanned aerial vehicle (drone) to survey Nile crocodile populations: A case study at Lake Nyamithi, Ndumo game reserve, South Africa. *Biological Conservation* **223**, 76–81.

Fang, Y., Du, S., Abdoola, R., Djouani, K. and Richards, C., 2016. Motion based animal detection in aerial videos. *Procedia Computer Science* **92**, 13–17.

Gentle, M., Finch, N., Speed, J. and Pople, A., 2018. A comparison of unmanned aerial vehicles (drones) and manned helicopters for monitoring macropod populations. *Wildlife Research* **45**, 586–594.

Hodgson, J.C., Mott, R., Baylis, S.M., Pham, T.T., Wotherspoon, S., Kilpatrick, A.D., Raja Segaran, R., Reid, I., Terauds, A. and Koh, L.P., 2018. Drones count wildlife more accurately and precisely than humans. *Methods in Ecology and Evolution* **9**, 1160–1167.

LaRue, M.A., Stapleton, S. and Anderson, M., 2017. Feasibility of using high-resolution satellite imagery to assess vertebrate wildlife populations. *Conservation biology* **31**, 213–220.

Lethbridge, M., Stead, M. and Wells, C., 2019. Estimating kangaroo density by aerial survey: a comparison of thermal cameras with human observers. *Wildlife Research* **46**, 639–648.

Office of Environment and Heritage (NSW) 2017, New South Wales Commercial Kangaroo Harvest Management Plan 2017–2021, Office of Environment and Heritage, Department of Planning and Environment (NSW), Sydney

Shannon, C.E., 1949. Communication in the presence of noise. *Proceedings of the IRE* **37**, 10–21.

Wang, D., Shao, Q. and Yue, H., 2019. Surveying wild animals from satellites, manned aircraft and unmanned aerial systems (UASs): a review. *Remote Sensing* **11**, p.1308.

38. If the department have determined that MRDS is the best method, could they please explain how a more cost-effective method of using cameras in planes is not being used when this would clearly save the government money?

ANSWER:

38. The use of cameras in place of human counters would not be cheaper than the current methods given the current level of development of camera technology for surveying wildlife. Use of cameras would require significant further investment into the technology and development of software to process the imagery, in addition to a large amount of post capture human effort to record the numbers of animals. Human counters outperform cameras, thermal or otherwise, particularly when surveying multiple species. Lethbridge et al., (2019) trialed an automated kangaroo recognition program and reported that 97.6 per cent of observed kangaroos were false positives (kangaroos that did not exist). Differentiation between red and grey kangaroos is not possible with camera technology at this stage.

References

Lethbridge, M., Stead, M. and Wells, C., 2019. Estimating kangaroo density by aerial survey: a comparison of thermal cameras with human observers. *Wildlife Research* **46**, 639–648.

39. Could the department please justify the reasons for using triennial surveys, and if it is to save costs, confirm if they would use cameras if they would show costs and allow for annual, more accurate population estimates?

ANSWER:

39. In arid and semi-arid regions, kangaroo numbers can change rapidly over a short period of time, particularly in response to unfavourable climatic conditions such as drought, which can result in a rapid depletion of available feed and significant mortality and population decline. In more mesic environments, such as the tablelands and slopes of NSW, these processes can still occur, but at a much slower pace than in the arid and semi-arid regions. For this reason, triennial surveys are both ecologically and cost effective in detecting changes in population numbers in the eastern zones.

Pople (2008) discusses these issues in greater detail.

Regarding the use of cameras, please see the response to question 36.

References

Pople A.R (2008) Frequency and precision of aerial surveys for kangaroo management (Wildlife Research 35(4): 340-348)

40. Could the department please explain how the sample space of less than 1% for the entire Western zone represents sufficient size to make an accurate extrapolation for the entire zone?

ANSWER:

40. An important goal of wildlife abundance surveys is to determine the level of effort that provides an unbiased estimate, with a level of precision (confidence) that is useful for management. Hence, the goal of a survey design is to allocate the appropriate resources (effort and cost) to each of the components of the survey, the number and size of sampling units, and the amount of monitoring effort to allocate to each unit.

There are two principal considerations when determining survey effort: the minimum sample size for reliable estimation; and what precision is required to meet survey objectives.

There are two components to sample size: the number of transects in the design; and the number of animals (or groups of animals) detected. Buckland et al. (2001) recommend a minimum 10–20 replicate transects to allow reliable estimation of variance of encounter rate. In the western plains survey, 56 blocks and 446 transects are surveyed, which greatly exceeds the minimum recommendation. With respect to the minimum number of detections, Buckland et al. (2001) suggest that at least 60–80 detections are made to reliably estimate the detection function. For the surveys conducted since adopting mark-recapture distance-sampling (MRDS), the number of animal groups detected exceed the recommended minimum by at least an order of magnitude for all species in all years (e.g. red kangaroos: 4145, 3168 and 2799; grey kangaroos: 3216, 2220 and 1186, respectively for the years 2018, 2019, and 2020). The sample sizes recorded have exceeded the minimum requirements defined in Buckland et al. (2001, 2005, 2015) and the Department is confident that the estimated detection functions were sufficient for reliable estimation.

A useful measure of precision is the coefficient of variation (CV), which represents a standardised measure of dispersion. Based on simulations of a kangaroo population, Pople (2008) found that a survey with high precision (CV = 0.2) provided essentially the same information with respect to

population state as a survey with perfect precision (i.e. CV = 0.0). Even lower levels of precision (e.g. CV = 0.5) were adequate to detect change in the simulated population, particularly with respect to the risk of the population falling below an arbitrarily set threshold in abundance. Using MRDS, the CV of total population size is less than 0.15, while the average CV of individual Kangaroo Management Zones is approximately 0.2 for red kangaroos and 0.3 for grey kangaroos.

The survey effort for the western plains satisfies both requirements for determining satisfactory survey effort to estimate the abundance of kangaroos: the sample size comfortably exceeds the minimum required for reliable estimation of the detection function; and the precision of the counts is sufficient to meet survey objectives.

References

Buckland, S. T. (2001). 'Introduction to Distance Sampling: Estimating Abundance of Biological Populations'. (Oxford University Press.)

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. (2004). 'Advanced Distance Sampling: Estimating abundance of biological populations'. (OUP Oxford.)

Buckland, S. T., Rexstad, E. A., Marques, T. A., and Oedekoven, C. S. (2015). 'Distance Sampling: Methods and Applications'. (Springer International Publishing: Cham.) doi:10.1007/978-3-319-19219-2

Pople, A. R. (2008). Frequency and precision of aerial surveys for kangaroo management. *Wildlife Research* **35**, 340. doi:10.1071/WR07066

41. Could the department please justify the random locations of the transects used in the Western zone given that literature[i] cited below demonstrates that hunters are likely to be restricted to accessing areas within a few kilometres of roads, which constitutes access to only a fraction of the total population meaning increased harvesting could then result in an undesirable clustering of harvest in specific areas?

ANSWER:

41. The purpose of the survey is to provide an unbiased and precise estimate of population size for red kangaroos, eastern grey kangaroos and western grey kangaroos. Following recommendations for survey design (Buckland et al. 2001, 2004, 2015), the KMP followed a design-based, two-stage sampling strategy, with blocks randomly selected within kangaroo management zones and block sample size stratified by zone area. Within each block, eight transects were systematically positioned in a zig-zag pattern (Strindberg and Buckland 2004). This design in combination with mark-recapture distance-sampling (MRDS) provides unbiased estimates of population size with acceptable precision for the purpose of the survey.

References

Buckland, S. T. (2001). 'Introduction to Distance Sampling: Estimating Abundance of Biological Populations'. (Oxford University Press.)

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. (2004). 'Advanced Distance Sampling: Estimating abundance of biological populations'. (OUP Oxford.)

Buckland, S. T., Rexstad, E. A., Marques, T. A., and Oedekoven, C. S. (2015). 'Distance Sampling: Methods and Applications'. (Springer International Publishing: Cham.) doi:10.1007/978-3-319-19219-2

Strindberg, S., and Buckland, S. T. (2004). Zigzag survey designs in line transect sampling. Journal of

Agricultural, Biological, and Environmental Statistics **9**, 443–461.

42. Given you stated with reference to the Tibooburra zone that "we count them in June-July each year" could the department please demonstrate that the current methodology takes into consideration seasonal variation, either mathematically in the modelling or with surveys that are conducted during each season? If the latter, then why is that not done for Tibooburra?

ANSWER:

42. Surveys of the western plains commercial kangaroo management zones occur in winter because the visibility of kangaroos during daytime in winter is higher than any other season. The higher detectability provides greater confidence in the population estimates. Surveys are completed in the same season for consistency of data over time. The scientific evidence is that kangaroo populations on the western plains have a positive correlation with pasture biomass, which is directly correlated with rainfall, regardless of the season. That is, kangaroo populations are not seasonal, but rather respond (increase and decrease) in relation to available feed resources.

43. Could the department please provide specific reference to the use of the correction factor for the population estimates in Wallaroos as this work was established in Queensland, was only evident during Autumn, and therefore the correction factor should only be applied to any survey work conducted in Autumn in that location where the correction factor was established? *As has been previously mentioned this correction factor was not derived in NSW but is applied in NSW.*

ANSWER:

43. Clancy, T. F., Pople, A. R. & Gibson, L. A. (1997). Comparison of helicopter line transects with walked line transects for estimating densities of kangaroos. Wildlife Research **24**, 397–409.

44. Could the department please justify how the correction factor for Wallaroos is being applied given it was established in 1997 in Queensland which is not the same zone or state of the Northern Tablelands (NSW) and has NOT been validated in the zone where it being applied? Statistically the correction factor is not applicable to a different zone with many different covariates.

ANSWER:

44. Two studies have been undertaken to address the problem of wallaroo/euro detectability. Neither of these were conducted in the Northern Tablelands, but each produced similar outcomes. This provides some confidence with regard to applying a correction to wallaroo data obtained in the NSW tablelands surveys.

Further, the Clancy et al.(1997) surveys were done in Queensland, in a partially cleared woodland landscape that could be compared to the partially cleared agricultural/grazing landscapes of the NSW tablelands and slopes.

References

Clancy, T. F., People, A. R., Gibson, L. A., (1997). Comparison of Helicopter Line Transects with Walked Line Transects for Estimating Densities of Kangaroos Australian Wildlife Research **24**, 397–409.

45. Could the department please explain how multiple quota reports were published with the incorrect values for the Wallaroo populations, as the "correction factor" had not been applied

backdating to 2008?

ANSWER:

45. In some instances, there was misinterpretation regarding whether the correction factor had been applied to wallaroo population data. When the error was discovered, it was corrected, and the Department published a correction on its website with the quota reports. In this case, the correction affected the 2007, 2016 and 2019 surveys.

46. Given the department stated that "the best available advice to us, and the robustness", could the department please explain the mathematical robustness of determining the population estimates with specific reference to the Northern Tablelands where ONLY 508 animals were sighted yet the population estimated was 296 555?

ANSWER:

46. The 508 animals were observed on 412.5 square kilometres of transect area. Adjusting these raw counts for detectability and translating the ensuing densities to the survey areas produces this total population estimate.

This process is explained in each of the tablelands populations reports available on the Department's website. The procedure has a solid scientific background to it.

47. Could the department please clarify how in the table[ii] below the total Wallaroo population estimate adds to give 299,190 however in table 49 of the 2021 quota report the total population estimate is 296,555?

ANSWER:

47. The consultant has confirmed there was a data entry error in the calculation of the initial population estimate that was used in the quota report. This error was resolved prior to publication of the final report. The error is 0.88 per cent of the corrected population estimate.

48. Given on page 15 of the 2021 quota report it is stated "In 2004, the quotas for wallaroos in the Northern Tablelands were changed from 5% to 15% of the population estimate because of the more rigorous scientific basis to survey and estimation methods", could the department please statistically justify what the "more rigorous scientific basis" was and what evidence they had to apply these methods?

ANSWER:

48. This change was made because population estimates for wallaroos based on aerial surveys had become available. Prior to this, quotas were set more conservatively because population estimates were calculated from ground surveys undertaken in the late 1990s (Southwell et al., 1995).

The aerial surveys gave a much better coverage of the Northern Tablelands commercial kangaroo management zones and therefore much greater confidence in the population estimate.

Reference

Southwell, C. J., Weaver, K. E., Cairns, S. C., Pople, A. R., Gordon, A. N., Sheppard, N. W. and Broers, R. (1995). Abundance of macropods in north-eastern New South Wales, and the logistics of broad-scale ground surveys. *Wildlife Research* **22**, 757–766.

49. Could the department please justify the use of the MRDS method with specific reference to Fewster & Pople[iii] on kangaroos and how the department takes into consideration all factors affecting detectability in the modelling, providing a list of all factors and the sample size that was used for this modelling, as well as the assumptions which were checked to ensure that the models statistically converged?

ANSWER:

49. In the reference provided, Fewster and Pople (2008) are referring to 'Mark-Recapture' (MR) survey methods. MR is a unique fauna survey method that addresses observer bias. MR is distinguished from mark-recapture distance-sampling (MRDS) because it does not incorporate a 'Distance-Sampling' (DS) component. The Department uses MRDS because it addresses both observer bias and the decrease in detection with distance from the transect line, encountered in aerial surveys (Caughley, 1974).

Fewster and Pople (2008) also investigated ways in which DS is best incorporated into the MR modelling process. They concluded that there is a 'strong endorsement of the point-independence method for MRDS sampling. The point-independence method is conclusively favoured by Akaike's Information Criterion (AIC) and goodness-of-fit tests. Additionally, its theoretical foundations are stronger and more credible'.

In accordance with the evidence and recommendation provided by Fewster and Pople (2008), the Department employs a point-independence method for MRDS sampling.

Regarding how the Department takes into consideration all factors affecting detectability in the modelling:

- It uses a randomised sampling design that covers areas in excess of a kangaroo's home range – this addresses the probability that a home range intercepts the sampling space.
- It samples large distances in the early morning and late afternoon in winter – this addresses the probability that the animal is present within the survey area during the survey period.
- Multiple covariates are tested in the modelling process – this addresses the probability that the animal is available to be detected given its presence within the sampled area.
- Independent detection probabilities are estimated within and between observers – this addresses the probability that an animal is detected given that it is present and available.

Both hazard-reduction and half-normal key functions are tested using various combinations of covariates including, but not limited to observer, cluster size, distance, management zone, session, bearing, vegetation class and fractional cover. As mentioned, data are collected by pairs of observers and models are specified as 'point-independence', providing the greatest level of rigour (Fewster and Pople 2008).

The sample size used in the modelling varies from year to year, depending on population density. The number of groups of kangaroos positively identified in 2020 in the western plains surveys was 3985. AIC values are compared to determine the most parsimonious model and quantile-quantile plots are used to check for normality. Any models that fail to converge produce an error message notifying the analyst that models have failed to converge, and an alternative model is sought.

References

Fewster, R.M. and Pople, A.R., 2008. A comparison of mark–recapture distance-sampling methods applied to aerial surveys of eastern grey kangaroos. Wildlife Research **35**, 320–330.

Caughley, G., 1974. Bias in aerial survey. The Journal of Wildlife Management **38**, 921–933.

50. Could you please mathematically justify how MRDS is the most statistically appropriate method given MRDS modelling requires large sample sizes "that can be cost prohibitive, limiting the

utility for long term monitoring of populations"? [iv]

ANSWER:

50. Department surveys obtain sample sizes large enough to justify the use of mark-recapture distance-sampling (MRDS). Buckland et al., (2001) suggest a minimum sample size of 60 to 80 individuals, whereas Walsh et al., (2010) and Thompson, Peirce and Mangipane (2010) (as referenced by Schmidt et al., (2017)) suggest sample sizes of greater than 150 are needed. Department surveys obtain sample sizes exceeding the recommended minimum. For example, for the surveys conducted since adopting MRDS, the number of animal groups detected exceeded the recommended minimum by at least an order of magnitude for all species in all years (e.g. red kangaroos: 4145, 3168 and 2799; grey kangaroos: 3216, 2220 and 1186, respectively for the years 2018, 2019, and 2020). The sample sizes recorded exceed the minimum requirements defined in Buckland et al. (2001, 2005, 2015) and the KMP is confident that the estimated detection functions were sufficient for reliable estimation.

Furthermore, Schmidt et al's work on monitoring brown bear populations should be interpreted with great caution and should not be used as a basis for questioning. The work has been openly criticised and discredited in peer reviewed articles by Becker and Christ (2019) for failing to account for undetected bears and differences in detection probabilities (also see Becker and Herreman, 2021).

Department surveys account for undetected kangaroos and differences in detection probabilities through the use of MRDS. Sample sizes are large and collected on time and on budget. The Department stands by the fact that MRDS is the most statistically appropriate method.

References

Becker, E. and Christ, A., 2019. Rejection of Schmidt et al.'s estimators for bear population size. Ecology and evolution **9**, 6157–6164.

Becker, E.F. and Herreman, J.K., 2021. Comments on integrating distance sampling and minimum count data (Schmidt et al. 2019). The Journal of Wildlife Management **85**, 407–410.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L., 2001. Introduction to distance sampling: estimating abundance of biological populations.

Schmidt, J.H., Wilson, T.L., Thompson, W.L. and Reynolds, J.H., 2017. Improving inference for aerial surveys of bears: The importance of assumptions and the cost of unnecessary complexity. Ecology and evolution **7**, 4812–4821.

Thompson, W.L., Peirce, K. and Mangipane, B.A., 2010. Protocol for monitoring brown bears─ Version 1.0: Southwest Alaska Inventory and Monitoring Network. Natural Resource Report NPS/SWAN/NRR—2010/275. National Park Service, Fort Collins, CO: https://irma.nps.gov/DataStore/DownloadFile/421231.

Walsh, P., Reynolds, J., Collins, G., Russell, B., Winfree, M. and Denton, J., 2010. Application of a double-observer aerial line-transect method to estimate brown bear population density in southwestern Alaska. Journal of Fish and Wildlife Management **1**, 47–58.

51. Could the department please justify why the Quota reports do not need to go through a peer-reviewed process?

    (a) 3 reports have been published since 2007, how did no one notice the error of the correction factor not being applied in each of these 3 reports backdating to 2008?

    (b) Because these reports continually reference non peer-reviewed work from the key researcher S C Cairns[v], could the department please justify why a range of researchers / scientists / statisticians are not involved?

(c) An interim population survey with reduced precisions (20% compared with the normal 40%) was completed in 2020 to assess the effects of 2019-2020 bushfires on kangaroo populations (Page 6 and 7 of the 2021 Quota report). Could the department please statistically justify how the precision was reduced, what methods were applied, and how did this meet the modelling assumptions?

ANSWER:

51. The reports are reviewed by the Department. Peer review would increase the cost but is a worthwhile consideration.

(a) When the error in the reports was discovered it was corrected and an explanation published on the Department's website.

(b) The design and analysis of the tablelands surveys is contracted to Dr Cairns. As stated in response 51, adding peer review would add further cost but is a worthwhile consideration.

(c) The survey was an interim, lower-cost survey conducted to get a population assessment for 2020–2021. Fewer transects were flown than would normally be flown for a regular triennial survey and this reduced the precision of the population estimate. The interim survey was designed to achieve 40 per cent precision.

A full survey of the South East Tableland management zone is scheduled for September 2021. This survey will be designed to achieve a standard level of precision of 20 per cent for eastern grey kangaroos. 20 per cent is the target level of precision for eastern grey kangaroos for all the tablelands surveys.

52. Given we received testimony from the KMT and the Western Pastoralist Association that kangaroos contribute significantly to total grazing pressure, yet the NSW Commercial Kangaroo Harvest Management Plan 2012-2016 states this *"the relative contribution of kangaroo populations to overall grazing pressure is smaller than previously thought… reducing kangaroo populations will have less impact on grazing systems than control of feral herbivores and management of domestic livestock"*, can you please make a comment on what your Department's view is on the contribution of kangaroos to overall grazing pressure?

ANSWER:

52. The Department recognises a low level of consensus on the definition of 'total grazing pressure'. This is evident in the question itself, which refers to both 'total grazing pressure' and 'overall grazing pressure'.

There are several dimensions to the kangaroo grazing pressure debate. At times there appears to be little competition between kangaroos and domestic livestock, at other times there is significant competition. There are therefore both temporal and spatial dimensions to the relationship.

The quote in the question comes from a literature review published prior to 2012 and does not necessarily reflect the Department's views. The Department's current view is that more research is needed to understand 'the contribution of kangaroos to overall grazing pressure'.

53. Can you please outline what research your dept. has commissioned in the last 45 years on either the impact of the commercial kangaroo industry or non-commercial kangaroo industry on kangaroo sustainability, viability and health and wellbeing of kangaroos?

ANSWER:

53. The Department commissioned the University of Queensland to model the effect of harvesting on kangaroo populations during drought in 2003 (see Pople 2003 on the Department's website).

The research showed that undertaking an additional survey in February during drought was approximately equivalent to setting quotas in the first instance at around 8–10 per cent of the winter survey population estimate with no adjustment.

The Department also commissioned the University of Queensland to research genetic population structure of kangaroos in NSW (Hale 2004; available on the Department's website). This research showed that commercial harvesting is unlikely to produce genetic changes in the population.

54. Given you stated there were no kangaroo experts from DPIE on the inquiry panel on the day of the hearing but that you have them in your team, can you please provide details of these experts including names, roles within DPIE, and their relevant qualifications?

ANSWER:

54. The Department sources expertise broadly when required. This includes, but is not limited to:

- leading kangaroo population ecologists that have an extensive peer reviewed publication history in the field
- members of the Kangaroo Management Advisory Panel (KMAP). KMAP includes members with expertise in animal welfare, kangaroo population dynamics and survey, and land management
- expert input and assistance with aerial survey design to ensure surveys are conducted efficiently and effectively to achieve the survey program objectives
- compliance and legal experts
- experts in information technology and data management
- ecology and zoology expertise across Environment, Energy and Science as required.

In addition, we have other essential expertise in the team such as program management, commercial kangaroo management program licensing, and community engagement. These functions are all essential to the effective operation of the commercial kangaroo management program. If the committee would like to meet with the expert kangaroo population ecologists who advise the Department, the Department can arrange a meeting.

55. Given you stated "we have got 45 years' worth of data" yet you have changed methods on multiple occasions, and added zones drastically increasing the area of survey space, could you please mathematically justify how you can calculate long term averages when the sampling methods have changed and along with this mathematically demonstrate how the population estimates were modelled to account for the changing area / zone space?

ANSWER:

55. Kangaroo density is calculated from the surveys. This density is then multiplied by the area of the zone in that year. This accounts for changes in zone area from time to time.

All quotas are set at a zone and species level. Thus, calculations are done for each zone and each species occurring in the zone. This accounts for the addition of zones from time to time.

56. Given that when asked about why correction factors have changed over time you responded that they haven't and you referenced that the wallaroo count was the only count that has a correction factor applied, can you please confirm correction factors were indeed used in kangaroo counts up until 2016 as referenced in the 2012-2016 report?

ANSWER:

56. Yes, correction factors were used with the strip transect surveys of the western plains up until 2016.

57. Given that you stated "the way the quota setting works is that we look at the long-term mean and then we look at the variation away from the mean … If it is a large variation away from the mean, then the quota is set at zero … In statistical terms it is two standard deviations…. If it is between 1.5 and two standard deviations from the mean, the proportional quota is reduced to 10 per cent of the population", could the department please provide the "long term" mean and subsequent 1.5 and 2 standard deviations for the thresholds for all zones, for Red, Eastern and Western Greys and wallaroos?

ANSWER:

57. The following tables present the long term mean, 1.5 standard deviations below the mean and two standard deviations below the mean for each zone and each species for the 2021 quota calculations.

Table 1. Red Kangaroo population threshold summary

KMZ	Population Mean (PM)	PM - 1.5 SD	PM - 2 SD
Bourke	323,648	136,082	101,948
Broken Hill	1,069,999	635,714	534,427
Cobar	159,353	58,944	42,313
Coonabarabran	283,531	139,582	110,214
Griffith	378,128	191,467	152,609
Lower Darling	285,551	128,482	98,453
Narrabri	331,132	136,877	101,963
Tibooburra	623,418	211,749	147,741

Table 2. Eastern Grey Kangaroo population threshold summary

KMZ	Population Mean (PM)	PM - 1.5 SD	PM - 2 SD
Bourke	147,322	39,547	25,511
Broken Hill	150,548	72,706	57,043
Cobar	106,342	19,776	11,288
Coonabarabran	1,134,423	547,185	429,128
Griffith	730,181	371,186	296,241
Lower Darling	89,392	44,716	35,497
Narrabri	802,273	361,140	276,774
Tibooburra	68,794	17,694	11,252
Armidale	233,917	119,579	95,614
C. Tbl. North	842,852	372,090	283,322
C. Tbl. South	585,765	321,945	263,715
Glen Innes	306,456	144,880	112,864
South East NSW	729,939	266,987	190,937
Upper Hunter	127,350	64,270	51,170

Table 3. Western Grey Kangaroo population threshold summary

KMZ	Population Mean (PM)	PM - 1.5 SD	PM - 2 SD
Bourke	90,294	24,239	15,636
Broken Hill	207,900	100,404	78,774
Cobar	146,854	27,310	15,588
Coonabarabran	85,387	41,186	32,300
Griffith	149,555	76,026	60,676
Lower Darling	198,970	99,530	79,009
Narrabri	8,104	3,648	2,796
Tibooburra	17,198	4,423	2,813

Table 4. Wallaroo population threshold summary

KMZ	Population Mean (PM)	PM - 1.5 SD	PM - 2 SD
Armidale	61,856	26,095	19,571
Glen Innes	65,913	25,502	18,582
Upper Hunter	49,279	16,729	11,670

58. Could you please provide the “science” you referred to regarding how the 15% quota is set with full mathematical explanation including the reproduction rate?

ANSWER:

58. The original derivation of the 15 per cent quota was described in Caughley (1987), and subsequently confirmed by other researchers (e.g. Hacker et al. 2003, Hacker et al. 2004, and McLeod et al. 2004).

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59. Given that you stated that "there was no parallel surveying" undertaken when the method was changed to MRDS, how can you statistically justify the change to MRDS if no parallel investigation was undertaken?

    (a) What evidence do you have which demonstrates that MRDS is better?

    (b) If no parallel investigation was undertaken, and therefore no statistical justification to demonstrate its equivalent or better success at deriving population estimates, then mathematically could you please justify the use of long term averages without this parallel comparison and justification?

ANSWER:

59–59(b) The decision to move to mark-recapture distance-sampling (MRDS) is based on scientific evidence and broad scientific consensus that it is the most appropriate technique for the circumstances (Borchers et al., 2006; Laake et al., 2008; Burt et al., 2014).

The strip transect methods used on the western plains prior to 2016 used correction factors to account for detection bias (Caughley, 1974; NSW DECC, 2008). These were the best methods for the circumstances given the statistical tools and aircraft that were available at the time. The move to MRDS does not render the strip count data invalid. The population estimates are all valid population estimates that have been determined using the most appropriate technique at the time. Therefore, it is valid to use the estimate from each year in the long-term average calculations.

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60. Given your department seems to rely heavily on the work of S.C Cairns and his consultancy, with

Cairns listed as an author in all 5 reports referenced in the 2021 quota report and 4 of the reports referenced being consultancy reports produced for the department, do you think it is an issue that the DPIE relies so heavily on the work of one paid consultant and if not, why not?

ANSWER:

60. Long-term ecological monitoring programs face many challenges but strong research partnerships are not one of them. Strong partnerships between government agencies and researchers usually occur when researchers have a relevant skillset and research interest and history that complements the goals of an ecological monitoring program. Consequently, strong and complementary partnerships are a key factor in the success of long-term monitoring programs (Gibbons et al., 2008; Lindenmayer and Likens, 2010; Burns et al., 2014). Dr Cairns fits this criteria and has a long and relevant history of research into population dynamics.

The Department therefore does not think it is an issue that one consultant has provided expert macropod population survey design, analysis and reporting for multiple consecutive years.

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Lindenmayer, D.B. and Likens, G.E., 2010. The science and application of ecological monitoring. *Biological conservation* **143**, 1317–1328.

61. Considering that when asked about a 269% variation in the wallaroo count you responded that you checked with S.C cairns and he responded that it was 'within an acceptable variation', yet you could provide no more details and it appeared from your response that you had received this information via a phone conversation as opposed to a written response, can you confirm who in your department is responsible for checking and verifying the work of S.C Cairns Consulting and how they do so?

ANSWER:

61. The Senior Team Leader Kangaroo Management Program is responsible for the work contracted by the Kangaroo Management Program.

62. Given you spoke to Mr Cairns regarding the variation of 269% in the Wallaroos (mentioned by Cate Faehrmann, relating to drought conditions), could you please provide mathematical evidence of how Mr Cairns was able to derive that this is in fact possible, taking into consideration wallaroos are not migratory and do not breed in drought[vi], and providing the reproduction rate applied, the covariates included (i.e. tree coverage, water access etc) the long-term average and standard deviations along with the modelling?

ANSWER:

62. The population increase of 269 per cent referred to is the increase in wallaroo numbers across the three Northern Tablelands zones from the spring 2013 survey to the spring 2016 survey. Officially, the

most recent drought in the Northern Tablelands was in 2017–2018 and the drought was not as severe in the Northern Tablelands as it was further south and west.

The 269 per cent increase in wallaroo numbers for the period 2013–2016 represents three consecutive years over which numbers increased by 39 per cent each year. This is not unfeasible, given that this period was a non-drought period. Between 2016 and 2019, during which the 2017–2018 drought occurred, wallaroo numbers essentially remained steady.

Note the precision of the wallaroo estimates is not as high as it is for the eastern grey kangaroo estimates because the surveys are specifically designed for surveying the much more abundant eastern grey kangaroos.

The 2016 and 2019 Northern Tablelands Survey reports provide some discussion of the changes in wallaroo numbers over the period 2013–2019.

63. Why is there a need to import Bennett's wallabies into NSW and how does this reflect on the number of kangaroos in NSW?

ANSWER:

63. The decision to import carcasses from other jurisdictions is a commercial decision made by individual businesses. The Department is not aware of any direct relationship between the import of Bennett's wallaby carcasses and the number of kangaroos in NSW.

64. Given Mr Brill acknowledged that he was the one responsible for amending the licences earlier this year so that Bennett's wallabies could be imported in NSW and be processed by the Staughton Group, did Staughton, who are the owners of Wild Game Resources Australia approach Mr Brill and/or the DPIE and request a licencing change to allow wallabies to be imported from Tasmania and processed in NSW?

    (a) If not did someone else approach the DPIE or what was the impetus for the licencing change?

ANSWER:

64–64(a) The Department received a number of inquiries regarding whether it is possible to import macropod carcasses from different jurisdictions.

The impetus for the licence changes was to allow NSW based operators to process wallaby carcasses legally harvested in another state.

Appendix

[i] *Jared H. Oyster, Ilai N. Keren, Sara J.K. Hansen & Richard B. Harris.* Hierarchical Mark-Recapture Distance Sample to Estimate Moose Abundance. (2018) The Journal of Wildlife Management.

ii

Wallaroos raw numbers and population estimates Northern Tablelands 2019

Common wallaroo	Actual Wallaroos seen Table 3	Pop estimate Table 10
Glen Innes	208	136,820
Armidale	172	117,290
Upper Hunter	128	45,080
Northern Tablelands total	508	299,190

*data from 'A report to the Biodiversity and Conservation Division, New South Wales Department of Planning, Industry and Environment on the consultancy: "Design and analysis of helicopter surveys of the kangaroo populations of the Northern Tablelands kangaroo management zones, 2019.

[iii] "The mark–recapture method relies on an assumption that all factors affecting detectability can be identified, and that their influence on detectability can be correctly modelled. If there is unmodelled heterogeneity in detection probabilities, density estimates will be biased." This work was conducted in Australia back in 2008 on Eastern grey kangaroos, demonstrating clearly that MRDS is a questionable method and produces biased results.

Rachel M. Fewster[A,C] *and Anthony R. Pople*[B] A comparison of mark–recapture distance-sampling methods applied to aerial surveys of eastern grey kangaroos. (2008) CSIRO publishing.

[iv] Joshua H. Schmidt, Tammy L. Wilson, William L. Thompson & Joel H. Reynolds. Improving inference for aerial surveys of bears: The importance of assumptions and the cost of unnecessary complexity. (2016) Ecology and Evolution.

[v] *NSW Kangaroo Management Program 2021 Quota Report page 17*

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[vi] *Wallaroos have small home ranges - they are not migratory - It is relatively sedentary, occupying small home ranges that overlap broadly with those of other individuals (Ealey 1967, Croft 1981, Jarman and Taylor 1983). Home ranges remain stable from year to year. NSW Commercial Kangaroo Harvest Management Plan 2017 – 2021 page 7*

Wallaroos do not breed in drought - If drought persists for more than six months, wallaroos stop breeding until the drought breaks (Tyndale-Biscoe 2005) NSW Commercial Kangaroo Harvest Management Plan 2017 – 2021 p 6.

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