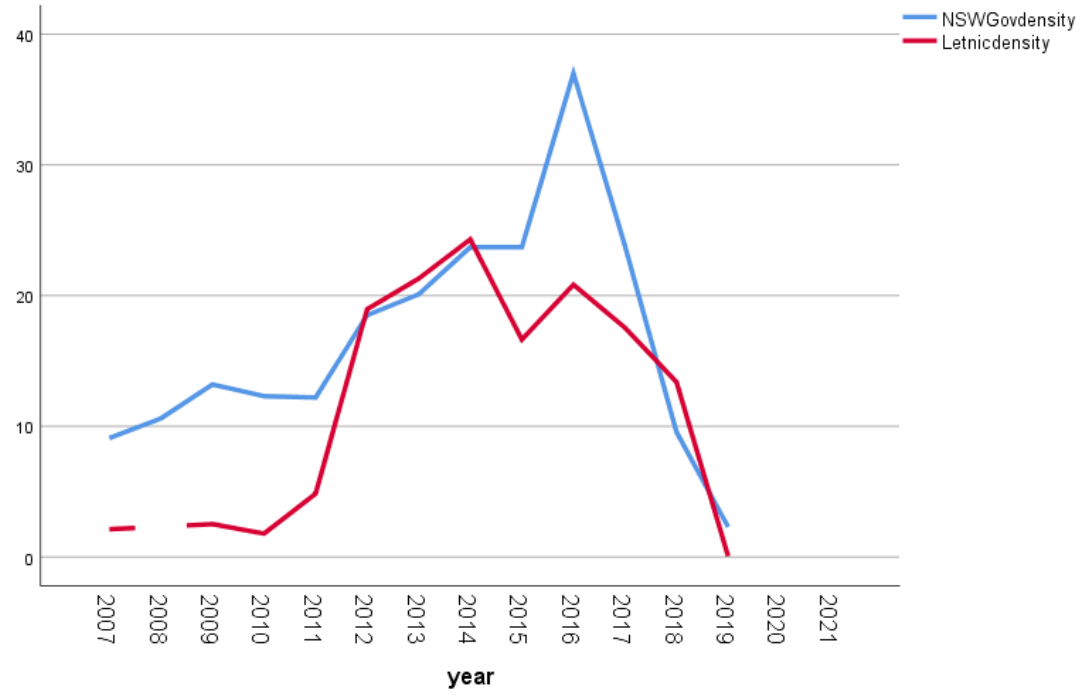
Response to additional questions: Professor Mike Letnic, University of New South Wales

1. Have you examined the raw data from surveys, or are you relying on the reported population estimates, which do in fact show increases in reported numbers that correspond to changes in survey methodologies?

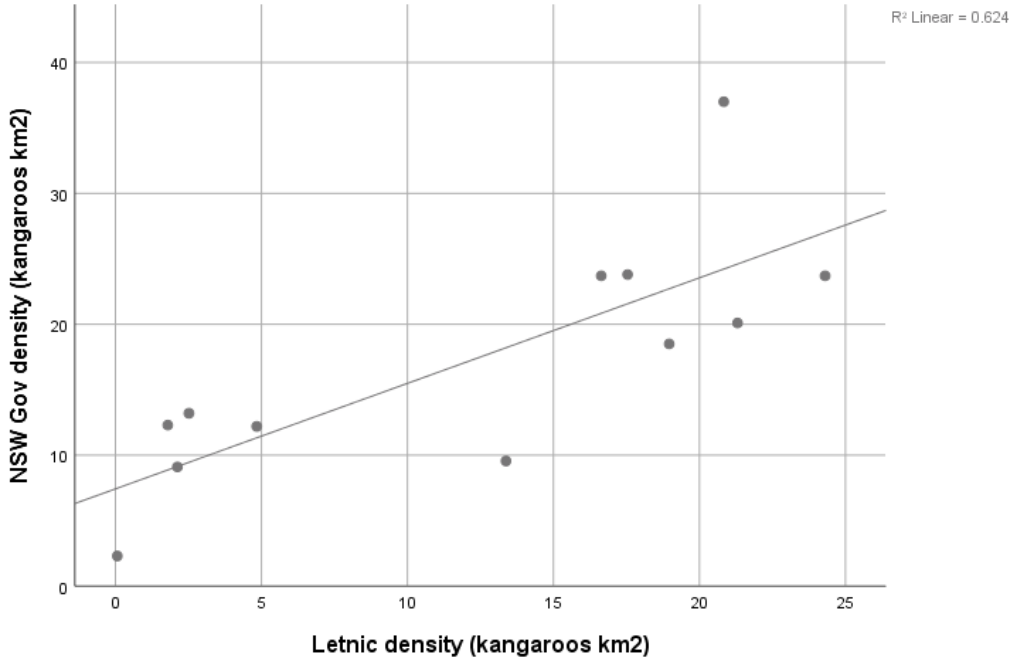
My answers were based on my understanding of trends in numbers reported in the harvesting reports and the trends evident in the field data I have collected on kangaroos at my study sites in the Tibooburra region. The fluctuations in kangaroo numbers for the Tibooburra region are generally consistent with data on kangaroo numbers that I have collected (Fig. 1). The NSW Kangaroo Management program changed their methodology between 2015 and 2016. This change in methodology coincided with an increase in kangaroo numbers in 2016 that it is not evident in my team's data in the period 2015-2016. However, both datasets show a dramatic decline in kangaroo numbers in 2017-2019 (Fig. 1). With regards to the increase in numbers in 2015-2016 it is possible that this jump was due to change in methodology but it is important to note that my surveys are from two small areas in the far-west of that region and so may have had different dynamics to the region as a whole.

Figure 1. (A) Density of kangaroos recorded obtained from the mean of spotlight counts conducted on Winnathee station and Sturt National park recorded by Letnic plotted with the sum of red kangaroo and grey kangaroo density obtained from the NSW Government Quota report. (B) Relationship of kangaroo densities recorded by Letnic and aerial surveys recorded by NSW Government between 2007-2019. There is a correlation in the trends in numbers between the two data sources.

(A)



(B)



2) Are you aware that the Kangaroo Management Advisory Panel minutes #27 reported at the time (November 2016) "The big population increase in the Western Plain surveys are due to the change in methods plus the favourable climate conditions", and the 2021 Quota report states "variation [increase] between population size estimates in 2015 and 2016 are due to a combination of the new method, climatic conditions and movement of kangaroos between zones".

At the time of the panel meeting I was not aware of the change in the methodology of the NSW Government surveys. There is an increase in kangaroo numbers in the aerial survey data between 2015 and 2016 that does not occur in my datasets (Fig. 1A) but I note that overall, the trends (ups and downs) in the densities generated by the NSW Government aerial surveys in the Tibooburra region are consistent with trends evident in the smaller scale night-time ground-based surveys conducted by my research team within the Tibooburra region as outlined in answer 1 (Fig. 1B).

3. In your evidence you stated on p25 of the 11th June Hearing transcript that "(when) We get big rains, kangaroo numbers increase and they do really well and they breed." Can you tell us what the reproductive rates of the different species of kangaroos are? At what age do they

reproduce, what are juvenile mortality rates, how many young do females rear in their lifetimes?

I am not familiar with the reproductive strategies of all species of kangaroos. Juvenile survival and the rate of population increase will depend on both the availability of forage and the intensity of predation (ie by dingoes, eagles, foxes and humans). In situations where predation is rare, such as western NSW where there are few dingoes and harvesting is targeted primarily towards larger males, the primary factor limiting juvenile survival is the availability of food. Where dingoes are present, there may be high predation of juveniles. A common feature of the reproductive system of kangaroos is embryonic diapause whereby females have an embryo in a state of "suspended animation" while older young occupying the pouch are suckling.

Red kangaroos have continuous breeding, oestrus occurs soon after birth of young with the new embryo going into diapause. If the pouch young is lost the embryo's development is reactivated. Birth to weaning takes approximately a year. Males reach sexual maturity after 2 years of age. Females may reach maturity after 20 months, and is dependent on environmental conditions. Once a juvenile reaches an age where it leaves the pouch but is still lactating, embryonic diapause will cease and the mother will give birth to another young. This means that a mother can effectively be raising two young at a time and thus potentially reproduce at a fractional rate exceeding 1 per year. Such a rate may be achievable if pasture conditions are favourable for juvenile survival and there is little predation of juveniles.

4. In your evidence on p25 of the 11th June Hearing transcript you spoke about 'ecological carrying capacity." To clarify, are you talking about areas of native vegetation or where kangaroos graze on modified pasture. What studies have examined ecological carrying capacity for both native habitat and modified agricultural land?

When discussing carrying capacity I was referring to the rangeland ecosystems in the western region of the state. In this region, livestock and kangaroos graze on native vegetation that has not been improved by sowing pasture plants or fertilizing. Carrying capacity is a widely used term in ecology to describe the maximum number of individuals of a species that an ecosystem can support. There have been numerous studies conducted on kangaroos showing that their numbers in western NSW and the rangelands of South Australia fluctuate in response to climatic fluctuations. The interpretation of these trends is that the carrying capacity of the landscape fluctuates due to the availability of forage which is in turn regulated by the availability of moisture for plant growth. The long record provided by the NSW Government aerial survey program and numerous other studies show that kangaroo populations crash during droughts and then recover when forage availability increases following rainfall events. The accepted explanation for these crashes is that during droughts, the kangaroo population is too large for the food-base available to support it and consequently there is mass mortality due to starvation. My research has primarily been conducted in the arid rangeland regions and I am not familiar with studies of kangaroos in areas with improved pastures.

Caughley, Graeme, Neil Shepherd, Jeff Short, S. K. Eltringham, J. Harwood, D. Pimentel, A. R. E. Sinclair, and M. P. Sissenwine, eds. *Kangaroos: their ecology and management in the sheep rangelands of Australia*. Cambridge University Press, 1987.

Caughley, J., Peter Bayliss, and J. Giles. "Trends in kangaroo numbers in western New South Wales and their relation to rainfall." *Wildlife Research* 11, no. 3 (1984): 415-422.

Jonzén, N., Pople, T., Knape, J., & Sköld, M. (2010). Stochastic demography and population dynamics in the red kangaroo Macropus rufus. *Journal of Animal Ecology*, *79*(1), 109-116.

5. On p27 of the June11 transcript, you seem to indicate that the kangaroo management plan is driven more by the kangaroo industry's commercial need for large numbers of kangaroos to kill, rather than by the NSW Government's statutory obligation under the Biodiversity Conservation Act 2016 (BC Act) to ensure ecologically viable populations of kangaroos in NSW. Does this concern you as a conservationist?

As a conservationist my focus is on maintaining healthy functional ecosystems. My research on the effects that removing dingoes has on ecosystems has shown that that irruption of kangaroo populations is just one of many symptoms associated with the removal of dingoes that can have adverse effects on the biodiversity values of ecosystems. Where dingoes are removed, numbers of kangaroos, red foxes and feral cats increase and as a consequence there are adverse effects on plants, soils, small mammals and ground nesting birds. Hence, I am concerned that the current numbers of kangaroos are a product of modern modifications of Australian ecosystems and may be too high for effective biodiversity conservation and jeopardize the conservation of other species. Further studies are required to isolate and understand the effects that high numbers of kangaroos have on ecosystems.

With regards to harvest quotas, I am concerned that the current plans in place for kangaroo management have mixed objectives and in particular I am concerned that the numbers of herbivores in western NSW including kangaroos, feral goats and livestock are too high and may be jeopardizing biodiversity across much of the state including in conservation reserves. Following this line of logic the harvest in far-western NSW may actually be too low to effectively reduce grazing pressure by kangaroos. However, it is important to note that feral goats and livestock also make up a large proportion of the grazing pressure in the western part of the state and there is no effective regulation of grazing by sheep or goats in these regions. The ecology of the rangelands would benefit from their being lower numbers of herbivores irrespective of identity.

6. Given the large number of localized kangaroo extinctions as a result of peri-urban developments occurring all around NSW, should more be done to protect the interests of kangaroo populations before they are displaced and dispersed by planned developments such as new roads, suburbs, industrial estates and airports?

I am very sympathetic to the need to conserve kangaroo and wallaby populations in peri-urban areas in the eastern parts of the state. The key to conserving kangaroos and wallabies in these areas is preserving their habitat.

7. Do you consider kangaroos to be a keystone species playing a vital ecological role in the environment? If so, what is that role?

A keystone species is a species that has a disproportionate effect on the environment relative to its own numbers. Under this definition kangaroos are not a keystone species as their per

capita impacts tend to be low. Kangaroos play a number of roles in ecosystems, they are herbivores which shape plant communities and soils, they are competitors with other herbivores which eat the same forage plants, they disperse seeds and nutrients around ecosystems, they are prey for dingoes, foxes and wedge-tailed eagles and their carrion is a food resource for scavengers such as foxes, wedgetailed eagles, ravens, goannas and kites. The interactions that kangaroos have with other species in each of these roles has measurable effects on the species around them, sometimes these effects are construed as positive for populations or individuals of the species they interact with (ie as prey kangaroos benefit the predator that consumes them) and sometimes they are negative (as herbivores kangaroos have negative impacts on the plant individuals they consume). The challenge for managing kangaroo populations is ensuring that some of the direct and indirect effects they have on ecosystems as a whole are not too strong. For example, when kangaroo populations are very high, intense herbivory can have negative effects on the plants they eat and also indirectly impact other species that rely on the same food plants or use those food plants for shelter.

8. As a conservationist, do you have concerns about whether the interests of kangaroos are being protected given the NSW Government's support for agricultural industries, including the removal of native vegetation protections and the ease with which landholders can obtain permits for damage mitigation killing of kangaroos?

This is a difficult question because the circumstances regarding the ecology and management of kangaroos differ across the state. I am very concerned about habitat destruction anywhere in the state because of the impact this activity has on the biodiversity value of the landscape as a whole. I treat land-clearing as a separate issue to kangaroo management. I am sometimes uncomfortable with the ease with which permits and circumstances under which permits can be obtained but I am also conscious that there are probably too many kangaroos in many parts of the state, because their populations have irrupted due to the removal of dingoes. In these situations kangaroos can have negative effects on ecosystems due to their grazing impacts.