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 Mrs Claire Galea

> **1. Could you please outline your concerns from a statistical perspective regarding how the current thresholds and quota estimates are established, particularly with regard to Tibooburra?**

The quotas set for the management are of statistical concern.

1. In Tibooburra if the quota of 2020 was reached then there would have only been 77 individual kangaroos left. This species is clearly facing regional extinction due to mismanagement (Population estimate 2020 = 6859, quota was 6782).
    a. How could the 2020 quota could have even been set?
    b. Was anybody checking the numbers to determine if the quota was close to the estimated population?

Year	Population estimate	Percentage change	Quota	Difference between quota and population estimate (if quota was reached how many would be left)
1990	83400		7400	76000
1991	55500	-33%	11000	44500
1992	45900	-17%	8900	37000
1993	136489	197%	7803	128686
1994	162375	19%	34122	128253
1995	150510	-7%	8653	141857
1996	151515	1%	10460	141055
1997	274399	81%	7185	267214
1998	356751	30%	12410	344341
1999	212896	-40%	36300	176596
2000	209231	-2%	16350	192881
2001	242312	16%	18100	224212
2002	184093	-24%	41700	142393
2003	73098	-60%	31000	42098
2004	72890	0%	10965	61925
2005	52605	-28%	10933	41672
2006	59034	12%	7891	51143
2007	64222	9%	8855	55367
2008	93058	45%	9633	83425

2009	92905	0%	13959		78946
2010	37781	-59%	951		36830
2011	51214	36%	0		51214
2012	73882	44%	7153		66729
2013	163392	121%	11082		152310
2014	44669	-73%	24509		20160
2015	234927	426%	4467		230460
2016	451594	92%	35239		416355
2017	176058	-61%	67739		108319
2018	184002	5%	26409		157593
2019	48502	-74%	27600		20902
2020	6859	-86%	6782		**77**

2. Below I have referenced the statements from the department regarding how the quotas are set, however for illustrative purposes I have used the Eastern and Western grey Kangaroos in the Western Plains as this graph is included in the report.

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DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

2021 Quota Report
New South Wales Commercial Kangaroo Harvest Management Plan 2017–2021

Mathematical: Thresholds for management of commercial quotas are based on using the standard deviation from the mean. Quote from the report: "To manage commercial quotas, the thresholds are based on densities of kangaroos, calculated as the number of kangaroos per square kilometre at the time of the aerial survey. There are two thresholds, representing increasingly significant population declines. Threshold 1 is set at 1.5 standard deviations below the average density. Threshold 2 is set at 2.0 standard deviations below the average density".

Thresholds are set based on standard deviations relative to the long-term average population (c.f. Appendix B – Table 52).

Using a standardised measurement rather than estimated population size figures allows spatio-temporal variation between species and climatic zones to be considered when setting a quota. Red kangaroo populations in the Far West, for example, change more rapidly and deviate more from the average than do Eastern Grey kangaroo populations in the Northern Tablelands. This variation is reflected in the standard deviation, and in the population change allowable before harvest reductions or suspensions are implemented.
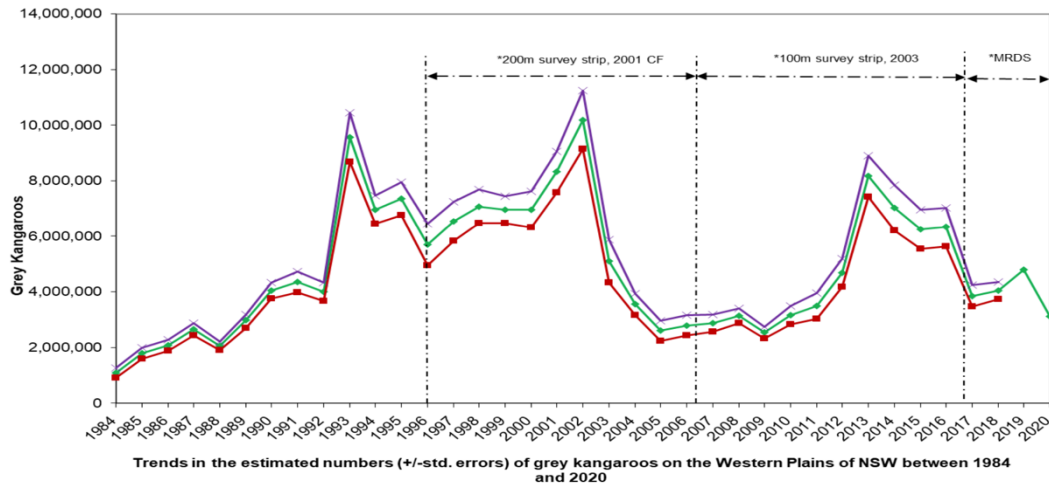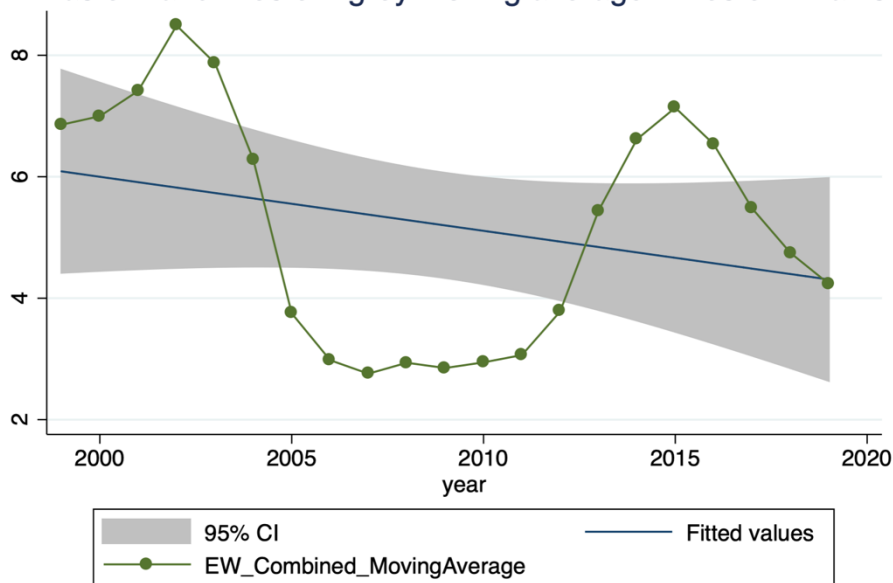
14,000,000

Figure 2   Population trends in grey kangaroos on the Western Plains of NSW. The purple and brown lines indicate the standard error of the population estimate.

Trends in the estimated numbers (+/-std. errors) of grey kangaroos on the Western Plains of NSW between 1984 and 2020

In order to use the standard deviation, it requires fitting a linear trend line to the data (which I have done throughout my submission) and assuming a constant average over the entire time period. When we fit lines to data we look at the how well the line (model) fits the data based on a percentage type value, the higher the value the better. If the fit of the model is too low it should not be applied, for example in the Grey's in Tibooburra the line fit which they base the thresholds on is 0.3% this is appalling and clearly the wrong option. For example, a good fit for a line would be at about 30 to 40%. The data does not follow straight trend lines and if thresholds are based on this – then mathematically this is wrong. This is not complicated statistics this would be included in first year University level – of which I have lectured.

Looking at the data from Tibooburra:

Table 17: Grey kangaroo temporal variation - Tibooburra

$$y = -608.79x + 146710$$
$$R^2 = 0.003$$
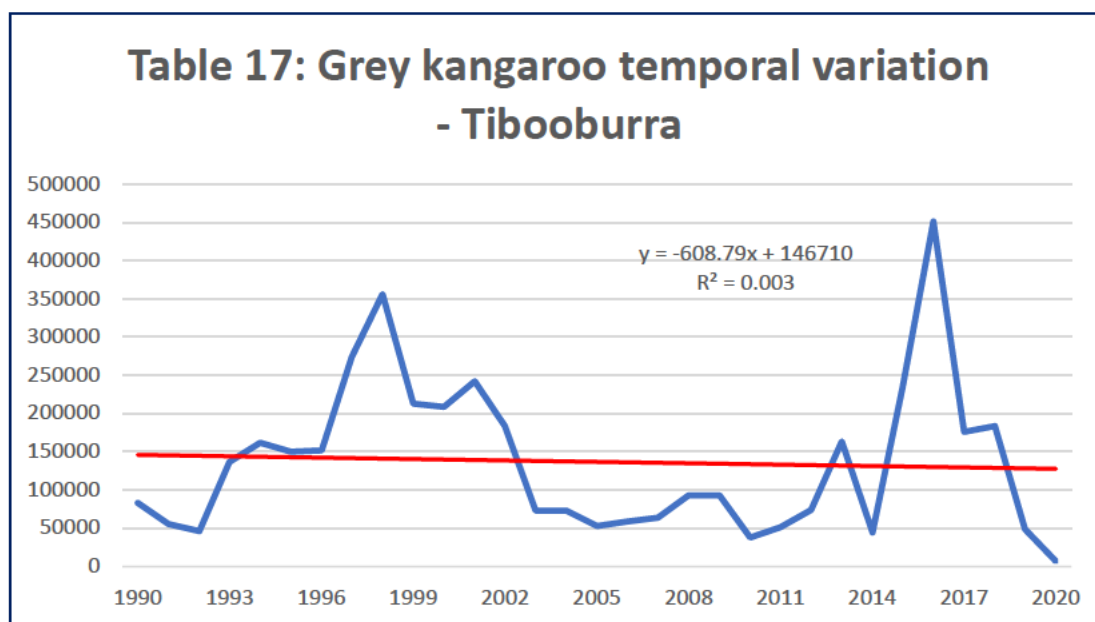
Applying the moving average – which takes the average over the first three years 1990, 1991, 1992 then the average over 1991, 1992, 1993 then the average over 1992, 1993, 1994 etc. Although the moving average is a better option than just taking the standard average across the whole time period, it still doesn't factor in drought or any other significant factors which would influence the population, nor does it take into consideration the change in survey methods used over time.

	Grey Tibooburra
Average population over time from the moving average	143146
1 Standard deviation below the mean	78079
1.5 Standard deviations below the mean THRESHOLD 1	117118
2 Standard deviations below the mean THRESHOLD 2	156157

If the average population over time was 143146 then 1.5 standard deviations below the mean would be 143146 – 117118 = 26028, meaning that the population would have to have dropped to 26028 to have reached THRESHOLD 1. However, if we then look at 2 standard deviations below the mean that would be 143146 – 156175 = -13011, that is a negative population and extinction. These THRESHOLDS are not statistically possible.

EASTERN AND WESTERN GREYS
WESTERN PLAINS
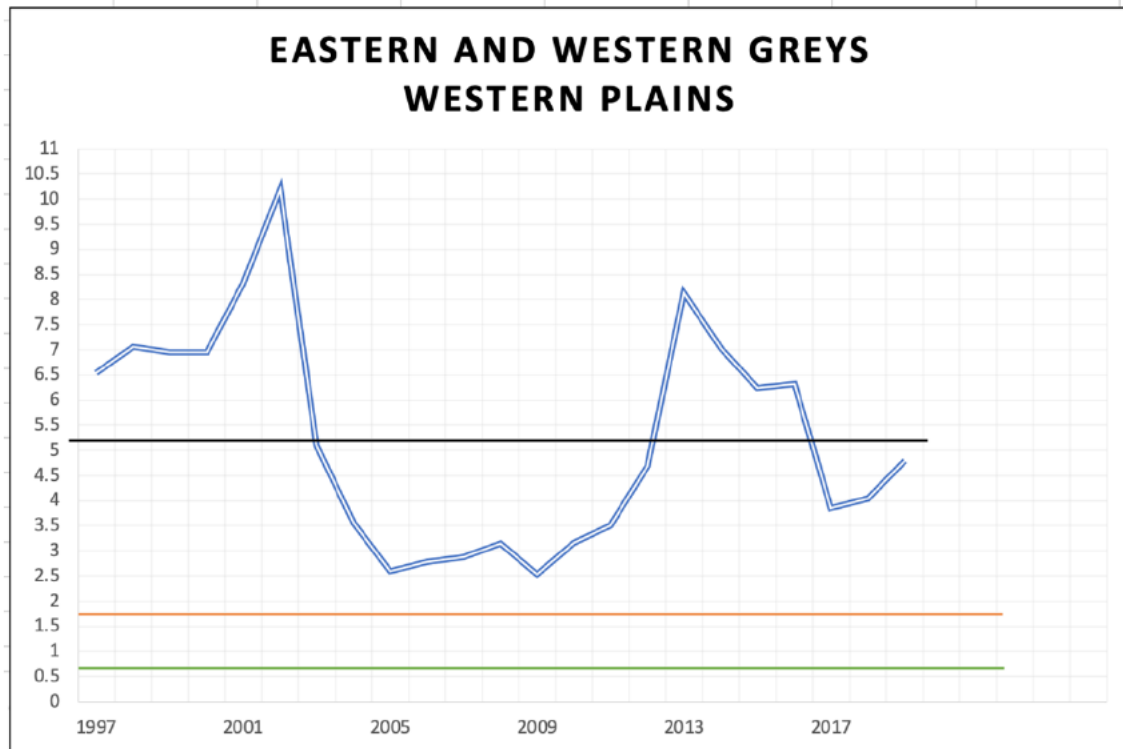
Long term average = 5.4, 2 SD below = 0.6. That means that it would need a 480% drop in the population to reach this threshold.

IMMEDIATE INVESTIGATION INTO THE THRESHOLDS AND QUOTAS SHOULD BE UNDERTAKEN

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2. How much time have you spent looking at the data for Tibooburra?

Thank you for this question, in terms of looking at just the Tibooburra data that is hard to quantify however with respect to looking at all the data and investigating the mathematical and statistical plausibility's of the work included in the report named below I have spent approximately 100 hours.

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2021 Quota Report
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The time needed to investigate the reports going right back through the 45 years' worth of data would be approximately 3 months for one statistician – however a team investigating this work could do this in a much shorter time frame.

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

3. Are there any other zones or areas where you have statistical concerns about declining numbers of kangaroos?

Thank you for the question, yes there definitely are other zones and species which I have statistical concerns regarding declining numbers.

1. From this table below it can be clearly seen that the number of Red kangaroos culled in 2018 (although the quota was determined from the previous year), came extremely close to causing extinction of this species in Cobar (44733 − 39014 = 5719). These kangaroos saw a population decline of 81% between 2017-2018 and exclusion fencing has now been erected in this zone.

Year	Red: Cobar	Quota
1990	264300	38300
1991	238600	48500
1992	170700	45300
1993	127658	27312
1994	201113	12766
1995	161314	28116
1996	170917	31441
1997	163624	19780
1998	312413	25580
1999	228367	41640
2000	231400	29375
2001	196029	29700
2002	258662	29200
2003	121756	38600
2004	146292	20699
2005	117137	24870
2006	107825	19913
2007	85913	18330
2008	156639	14605
2009	97823	26629
2010	148177	16630
2011	210921	25190
2012	252750	35857
2013	193738	42968
2014	298459	32935
2015	357287	50738
2016	437129	60739
2017	229495	74312

	2018	44733	39014
	2019	36058	0
	2020	102480	0

Other concerns:

2. The Grey kangaroos in Cobar saw a 99% fall in population between 2014-2019.
3. The Grey kangaroos in Bourke saw a 91% population fall between 2016-2020.
4. The Common wallaroo in the Upper Hunter saw a population fall of 67% between 2018-2019.
5. The Grey kangaroo in Coonabarabran saw a population fall of 42% between 2019-2020.
6. Red kangaroos in Tibooburra declined from 1 567 598 in 2016 to 344 619 in 2018 which is a huge 355%, however the quota was sustained at 17%.
7. Eastern Grey kangaroos saw a 55% decline in population from 2017-2020 in the Central Tablelands North and a 458% decline in the Central Tablelands South.

Table 12   Population estimates and trends in abundance for eastern grey kangaroos on the Central Tablelands North and South, 2008–2020

Zone	Population estimate (millions)		Density (km⁻²)		Trend in abundance (% change from previous survey)		Total population
	CT North	CT South	CT North	CT South	CT North	CT South	
2020	777,350	488,270	33.5	25.8	-55.0	-47.7	1,265,620
2017	1,728,200	933,900	74.5	49.4	44.8	15	2,662,100
2014	1,193,600	811,800	47.1	35.9	94.9	133.4	2,005,400
2011	612,590	347,830	20.9	15.1	41.5	-35.1	960,420
2008	433,030	535,600	14.7	23.2	0	0	968,630

CT, Central Tablelands

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

4. Do you agree with the DPIE's assertion that their use of MRDS is the best possible method, and if not why not?

The mark recapture method is used for population estimates, however it requires large sample sizes as evident in the literature and has been demonstrated to be a questionable method which produced biased results when surveying Eastern Grey kangaroos in Australia in 2008. Given the factors affecting detectability of macropods, such as tree coverage and the incredibly low numbers of Wallaroos sighted, for example, this method would produce biased and statistically unreliable results.

Table 3. Number of transects flown, total survey effort (km) and raw counts of macropods for each of the two survey strata within the three kangaroo management zones.

Kangaroo management zone	Number of transects	Survey effort (km)	Raw counts			
			Eastern grey kangaroos	Common wallaroos	Red-necked wallabies	Swamp wallabies
Glen Innes						
High	30	225.0	910	107	84	46
Medium	34	255.0	951	101	53	30
Armidale						
High	37	277.5	1,030	54	11	19
Medium	22	165.0	667	118	13	.123
Upper Hunter						
High	35	175.0	534	58	16	30
Medium	37	277.5	506	70	21	13

There was also no validation of this method in comparison to previous methods, this is mathematically essential to ensure that the new method is equivalent or better at producing results that the previous method.

Without images taken for the sightings of macropods this data cannot be verified or validated. To apply a statistical method without validation is of serious concern and should not be undertaken.

As stated in my submission and at the inquiry, the use of drones and satellite imagery (as per my tabled peer reviewed documents) is far more accurate and provides a lasting record for accurate population estimates.

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

5. **Do you agree with the DPIE's assertion that surveying less than 1% of the entire Western zone represents sufficient size to make an extrapolation for the entire zone, and if not why not?**

In the inquiry the department stated that they survey less than 1% of the entire Western Zone. I would like a statistical justification from the department as to how this can be a sufficient sample space to then extrapolate to an entire zone. Throughout my entire career as a statistician, I have never been involved in a survey which took less than 1% of a population. Even large data-linked studies involving Medicare will use a minimum of 5% to undertake any form of inference.

The graph below clearly shows the population is in serious decline and is clearly facing day 0 where the population will be 0. Note: This doesn't take into consideration the harvest which will decrease the population faster.

How can a survey of less than 1% accurately extrapolate to an entire zone – given the serious extinction facing these kangaroos a comprehensive survey using cameras in planes and drones and satellite imagery will provide accurate population estimates.

Table 13: Population estimates and trends in abundance for western grey kangaroo on the Western Plains, 1997–2019
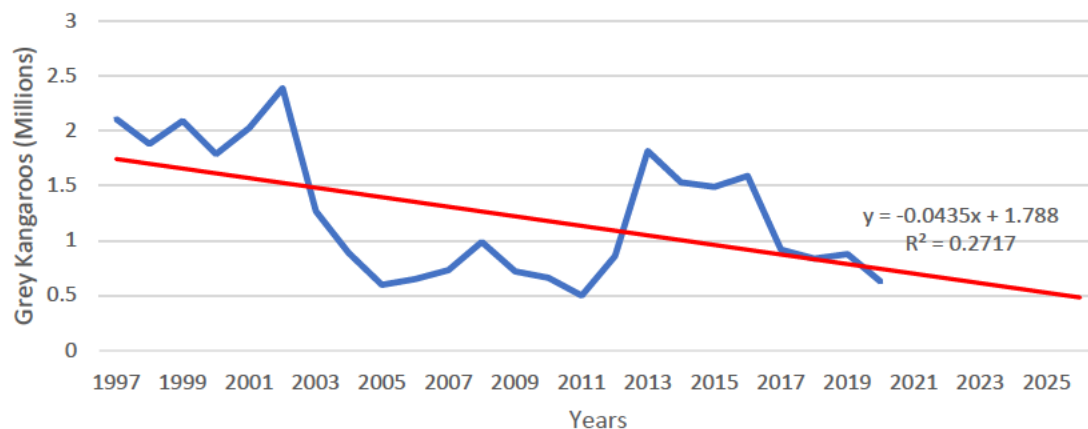
$y = -0.0435x + 1.788$
$R^2 = 0.2717$

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

6. **Regarding wallaroos sighted in the Northern Tablelands, how can you statistically explain the numbers going from 508 to 299,190?**

Following rigorous statistical mathematically accurate methodology I cannot statistically explain how a number of 508 can be extrapolated to 299190 – however please remember that this number of 508 comes from a summed total below in the column of Common Wallaroos. If a total 54 Wallaroos were seen across 37 transects that is an average of 0.69 wallaroos per transect, that is less than 1 wallaroo per transect. I cannot statistically explain or justify the extrapolation of 299190.

When applying mathematical modelling there are rules which need to be followed, for example if we want to include in the model a covariate such as "number of observers in the plane" there should really be a minimum of 30 subjects to undertake the modelling and another 20 for every covariate we want to add to the model. In the High zone of Armidale the department stated that **no** covariates were included in the modelling. All modelling should take into consideration any covariates which may predict / interact with the outcome. This modelling is of serious concern given globally methods of allowing for covariates such as the SPEI index are considered essential, however the sighting numbers of wallaroos is too small to apply any reliable modelling to.

Covariates include (but are not limited to) breeding rate, tree coverage, access to water, SPEI etc however in order to do this there would need to be a sighting of a minim of 110 per transect!

Table 3. Number of transects flown, total survey effort (km) and raw counts of macropods for each of the two survey strata within the three kangaroo management zones.

Kangaroo management zone	Number of transects	Survey effort (km)	Raw counts			
			Eastern grey kangaroos	Common wallaroos	Red-necked wallabies	Swamp wallabies
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Given the incredibly low numbers actually sighted and that there is no evidence of these numbers, (i.e. images) no modelling should be undertaken on this population of Wallaroos.

NOTE: The correction factor is applied to these Wallaroos, which was never proven to be accurate in the zone of the Upper Hunter (it was actually derived in Queensland).

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

7. **Do you think the DPIE are correct in saying that they have 45 years of data from all zones across the state, and if not why not?**
8. **Do you have any concerns with the DPIE using their 45 years' worth of data for long term trends and if so what are those concerns and why?**

The above two questions relate to the reliability of the data over the last 45 years. As my testimony and submission to the inquiry outlined the data is very concerning and cannot draw reliable statistical conclusions for three key reasons:

1. Multiple survey methods have been used over the years to produce the estimates. This is concerning for extrapolation with the DPI clearly stating that three different methods have been used between 2003-2016 with a total of four methods used throughout the 45 years of data collection. Long term averages are therefore not reliable given the change in methods of surveying.

2. When the latest change was made in 2018 to MRDS there was no "parallel surveying": as stated by Mr Brill in the inquiry undertaken. That means that the department did not validate the new method and did not compare it to the previous method to demonstrate that it is more effective. Therefore, statistical trends over time should not be used.

3. There have been significant changes to the definitions of the zones and the land area they cover with three key changes made in 1991, 2004 and 2008. This means that trends over time are being set over land areas that are changing - this is incorrect statistical methodology.

IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

9. **Given what was presented in the inquiry about the behaviour and reproduction of wallaroos and your knowledge as a statistician do you think a 269% increase in a wallaroo population could be described as an 'acceptable variation' as Cairns reportedly does?**

Given I am a biostatistician and not a biologist I still found it implausible that a population could increase at 90% per annum over three years. The further investigation I did into the department's documents stated the following:

"Wallaroos are opportunistic breeders. Under normal conditions females can breed continuously, giving birth to a single young every eight to nine months (Sadlier 1965, Ealey 1963, Kirkpatrick 1968, Poole and Merchant 1987). If drought persists for more than six months, wallaroos stop breeding until the drought breaks (Tyndale-Biscoe 2005)". Reference: NSW Commercial Kangaroo Harvest Management Plan 2017 – 2021.

| Threats	Comments	Selected References*
Drought	Rainfall affects plant productivity and water availability. It is the single most important factor affecting kangaroo populations. Dry climatic conditions can greatly reduce kangaroo numbers. Kangaroos, however, are well adapted to a dynamic environment and populations have recovered after drought-driven population declines. Therefore drought is not considered a threat to the conservation status of kangaroos amidst commercial harvesting with conservative quotas.	Caughley et al. 1985; Robertson 1986; Bayliss 1987; Cairns & Grigg 1993;; McCarthy 1996; Cairns et al. 2000; Pople 2003; Dawson et al. 2007; Underhill et al. 2007; Fensham & Fairfax 2008; Pople et al. 2010;

Looking at the graph below which uses the Standardised Precipitation-Evapo-transpiration Index (SPEI)[6] which is globally recognised as an indicator for drought and takes into consideration many variables to determine the index, in addition to the above statements, I cannot conclude that the 269% increase is an acceptable variation.

Northern Tablelands: Wallaroo estimated population and SPEI
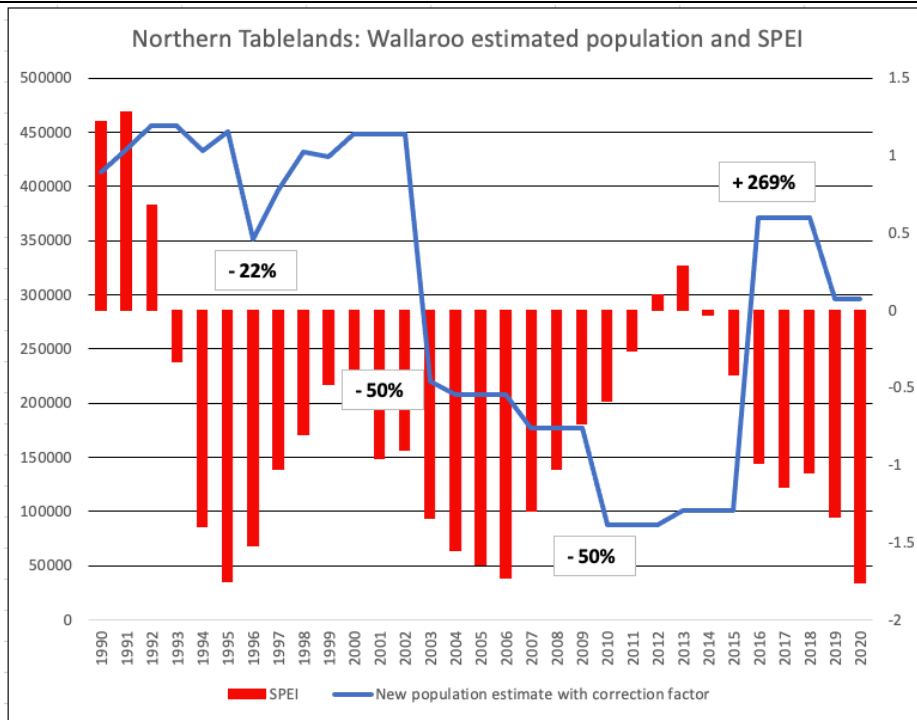
Using statistical software, we can clearly see that the value of 269% (identified as the star in the graph below as 26) is an **extreme outlier** and does not reflect the pattern of data over time. This is a statistical conclusion and has no biological evidence – this data point (269%) is statistically unreliable.
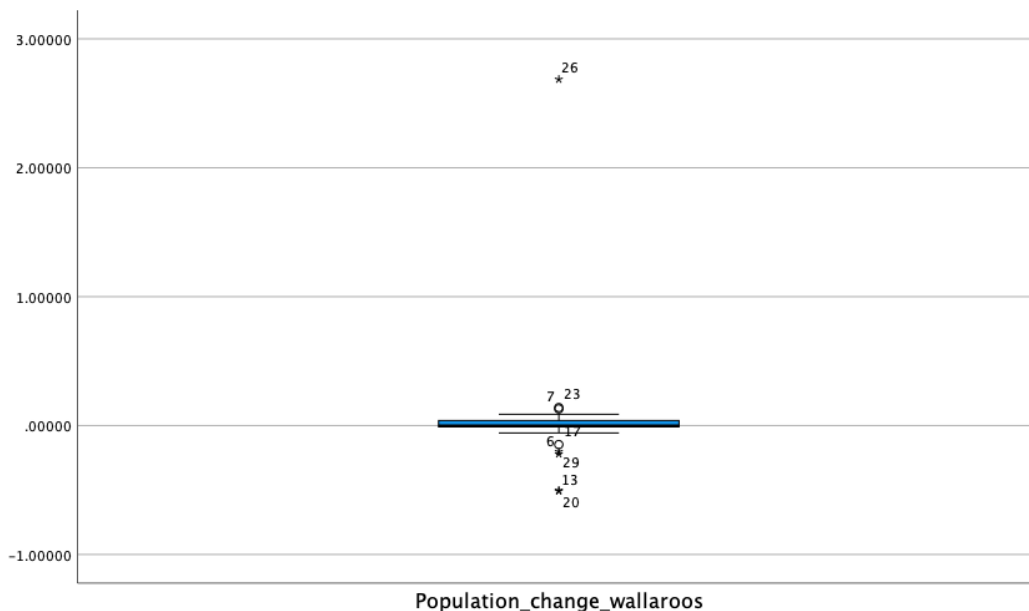
For the committee's reference a normal box plot showing data that is reliable should look like the graph below:
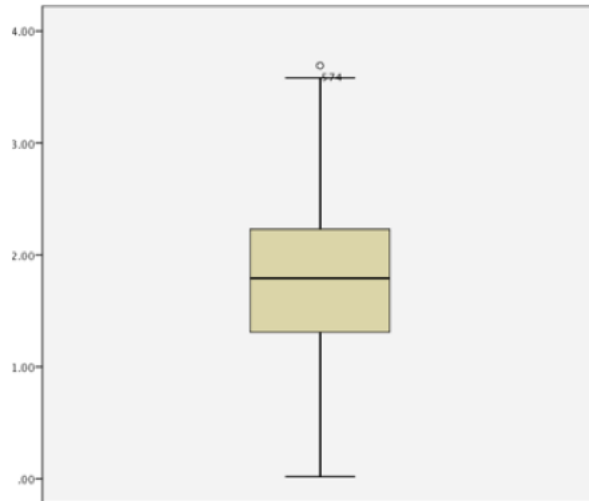
The graph below demonstrates that the population and quota will meet in 2032, which is only 11 years away and means extinction for the species – however this doesn't take into consideration the above statements either and therefore, the extinction date is likely to be much sooner.
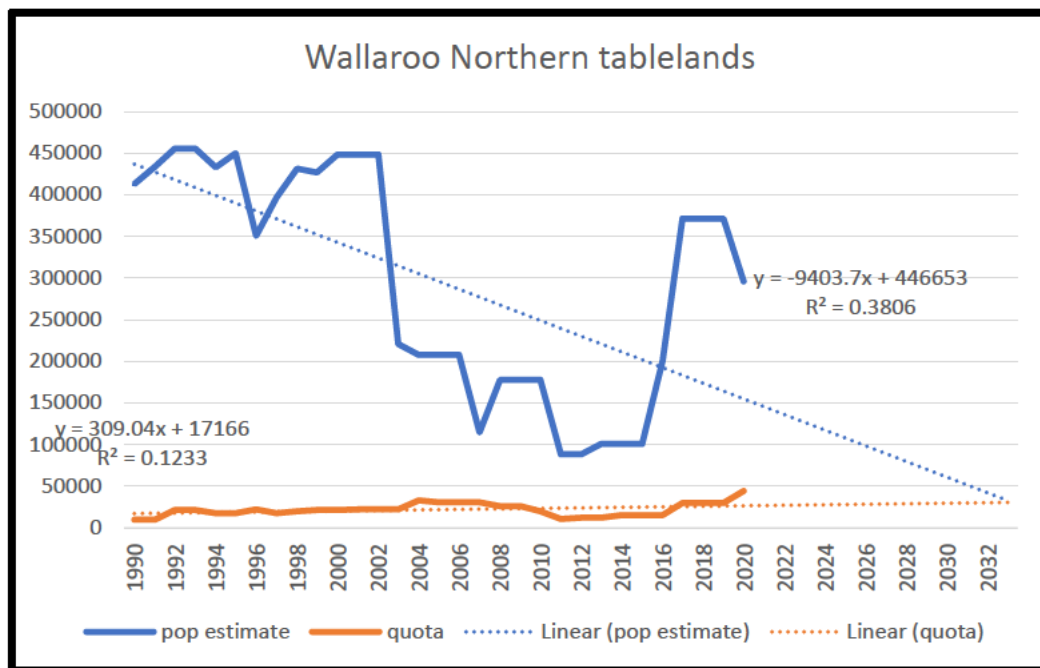
IMMEDIATE INVESTIGATION OF THE MATHEMATICAL AND STATISTICAL METHODS IN THE REPORTS IS URGENTLY NEEDED TO ENSURE SURVIVAL OF THE SPECIES

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