Submission No 311

INQUIRY INTO HEALTH AND WELLBEING OF KANGAROOS AND OTHER MACROPODS IN NEW SOUTH WALES

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Independent Submission	
Name	
Role	Biostatistician
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This submission addresses two points from the terms of reference: (b) and (di).	

Profile: I am a full-time biostatistician and PhD candidate within the field of Medical Statistics. I have been working in medical statistics for the last 8 years and specialise in the analysis of complex time based data examining trends. I have provided my expertise into this report as an independent biostatistician and have drawn on over 25 years of experience in analysing data including military, biological, education and medical data.

Brief overview of the submission: This submission involved extensive literature research and the use of data from the Department of Planning, Industry & Environment New South Wales Commercial Kangaroo Harvest Management Plan Quota reports as well as data from a report to the New South Wales Office of Environment and Heritage on the consultancy "Design and analysis of helicopter surveys of the kangaroo populations of the Northern Tablelands kangaroo management zones, 2016." Analysis was undertaken using Microsoft Excel and the Statistical Package for Social Sciences (SPSS) (IBM Corp. Released 2020. IBM SPSS, Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp).

Summary of findings:

1. The current method for population estimates for all macropods should be revised and thereafter follow international recommendations.
2. All sample locations for estimates should be mathematically derived and include all predicting covariates in the models (For Example: The SPEI, The Standardised Precipitation-Evapo-transpiration Index)
3. Trends over time show significant decline in populations and any estimates taken from these trends should use the most appropriate mathematical model of fit for trend lines and take into consideration the change in survey methods and human interventions into topography (i.e. cluster fencing) over time.
4. All mathematical and statistical methodology of the reports should be investigated by an independent statistician(s).

Independent investigation into all population trends over time and subsequent quotas need to be urgently undertaken to ensure the survival of the species and avoid extinction.

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SECTION 1

TERMS OF REFERENCE

b) The accuracy with which kangaroo, and other macropod, numbers are calculated when determining population size, and the means by which the health and wellbeing of populations is assessed.

Counting methodology

A. Correction Factor

The correction factor of 1.85 which has been applied by the Kangaroo Harvest Management assumes that for every individual kangaroo spotted a further 0.85 of a kangaroo was not spotted. Literature has demonstrated that serious bias can occur when applying a single correction factor [(1)] especially when this is done across all covariates such as density and different species. Aerial surveys regularly do not attempt to accurately estimate these biases, namely (a) sighting probability bias where there is low probability of spotting single or small groups of animals and less conspicuous animals and (b) visibility bias where the population is concealed by obstructions such as vegetation and therefore not visible [(2)]. These variable detection probabilities caused by the above mentioned range of factors, can compromise the validity of the population estimates especially comparing over space and time [(1)]. The use of aerial surveying methods violates a critical assumption to obtaining reliable estimates, being that the probability of detecting an animal on and near the transect is usually less than one [(2)] and therefore any estimate obtained in this method would be unreliable. Also, of serious concern is that the current correction factor does not take into account any additional factors such as drought [(3)].

Inaccuracies from the use of correction factors may be large which is of serious concern as these estimates are used to determine management procedures [(2)]. Jachman et al. found that when repeat observations were undertaken on the same species there were a number of factors affecting visibility which differed between counts [(2)] demonstrating that the bias was never constant and therefore applying a constant correction factor would not correct for the bias.

In 1997 a study was done by Clancy et al. comparing aerial surveys with land surveys at only 5 sites for kangaroos and wallaroos with 4 of those conducted during winter and summer and one conducted during autumn. This study found no significant difference on population estimates between the two methods in summer and winter for either kangaroos or wallaroos. The one and only site which investigated population estimates during autumn found that aerial surveys during this one and only season were approximately 50% lower than the ground estimates. Of serious concern is that the most

recent Northern Tablelands survey (2019) of wallaroos was conducted during spring and therefore statistically there is insufficient evidence to apply the correction factor. Only one other study in 1998 has tried to verify this correction factor research and was not peer-reviewed or published.

CONCERN: The Clancy et al published peer-reviewed article which Cairns references is the only paper upon which the 1.85 correction factor is based. The Department of Primary Industries (DPI) should not statistically be applying a static correction factor of 1.85 on the Wallaroo population estimates at all times of the year. The use of a 1.85 correction factor virtually doubles the wallaroo count and this methodology has limited scientific backing being based on one report which was published nearly 25 years ago, could not be replicated in peer reviewed literature and is not applicable at any more than five sites and only during three seasons of the year.

CONCERN: The revised Department of Planning, Industry and Environment 2021 Quota report issued a correction back-dating the use of the correction factor to 2008 claiming it had not been applied. The inconsistent application of a seriously concerning mathematical method raises even more issues on population estimates and corresponding quotas.

B. Alternative methods for obtaining population estimates

The current correction factor method clearly provides concerns over the reliability of population estimates. Literature has demonstrated that use of imagery, either by way of airborne videos, remotely sensed or satellite photography, [4] provides many benefits over the human-counted aerial helicopter method and subsequent correction factor currently used

The use of mathematical algorithms instead of a set correction factor has been clearly demonstrated in the literature. Tracey et al. demonstrated the use of algorithms instead of correction factors which take into account a range of factors such as group size, vegetation and observer. Eikelboom et al demonstrated that the use of an animal detection algorithm outperformed humans in detecting from the air when used in conjunction with imagery.

The literature search clearly demonstrated that the use of imagery (either airborne, remote sensed or satellite imagery) along with mathematical algorithms (that take into consideration drought / rainfall, topography, available water) would provide many benefits:

a. Permanent unchanging record of animal locations and abundance in time and space
b. Reduction in time required by personnel
c. Aid in tracking patterns of animals across natural systems

d. Would take into consideration drought, rainfall, topography, available water etc
e. Improved estimates of population size
f. Decrease in costs [5]
g. Observations of unlimited land space rather than relying on individual transects (the selection of which may be subject to bias)
h. Decrease in costs [5]

CONCERN: Countries globally (USA, South Africa and Kenya) are using imagery and mathematical modelling to provide for more accurate population estimates which are a permanent record. This should be applied in New South Wales.

C. Transect location selection

For a sample to be considered reflective of the population it needs to be chosen so that the area of the sample can be extrapolated to the entire population. Therefore, the choice of location for the transects to be undertaken is of utmost importance to ensure that the sample is reflective of the actual population. The DPI have stated that only 4.8% of a zone may be surveyed – statistically this is extremely small and justification is needed as to how 4.8% of the zone would be reflective of the entire zones heterogeneity.

CONCERN: How each location for each transect (detection zone) is chosen should be mathematically determined and **should** take into consideration the following (as a minimum):

i. The type of macropod being estimated:
   a. Involving its movement
   b. Feeding availability
   c. Water availability
   d. Vegetation / coverage

ii. The climatic influences:
   a. Drought
   b. Floods
   c. Fires, etc

iii. Impact of helicopter noise on the animal's movement

iv. Samples of the proportion of land covered by the specific transect and how the specific transect can be then applied to the total land area which **matches** it.

All these variables need to be considered to determine where and when to undertake the survey and be publicly available.

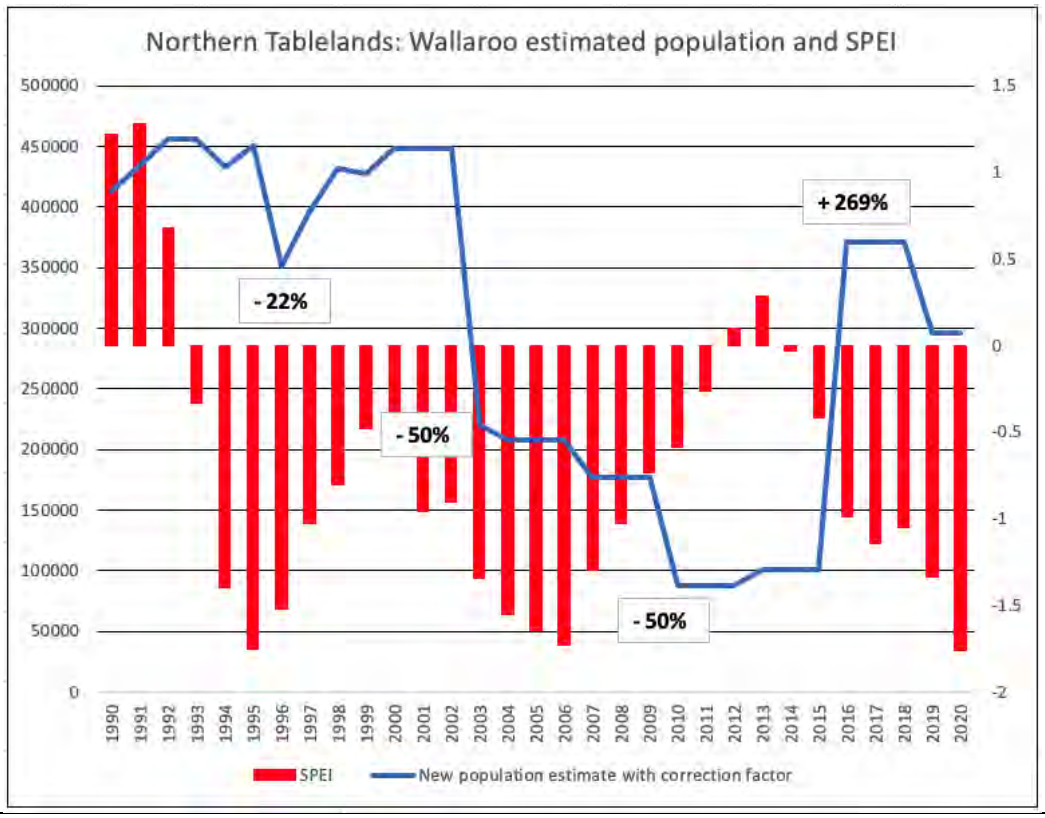
D. Consideration of climatic factors in the mathematical / statistical modelling.

The Standardised Precipitation-Evapo-transpiration Index (SPEI)[6] is globally recognised as an indicator for drought and takes into consideration many variables to determine the index. Details from the Northern Tablelands report (2019 – page 20) named only three covariates which were taken into consideration "namely observer, habitat cover at point-of-detection and cloud cover". This does not consider climate impacts such as drought or floods, which is of serious concern. Additionally, the surveys are only done every three years and therefore the Quota estimates for 2021 do not take into consideration the severe bushfires which devastated NSW in the summer of 2019-2020.

Conflicting statements in the DPI reports raise serious statistical concerns from a modelling perspective and contradict the population estimates provided.

1. "If drought persists for more than six months, wallaroos **stop breeding** until the drought breaks"
2. "Dry climatic conditions can greatly reduce numbers".

However, the graph below shows clearly that a 269% population increase (~90% per annum) in wallaroos was recorded during drought conditions. Wallaroos breed at approximately 8-10% per year in normal conditions[7]. Along with this, the DPI clearly stating that they **stop breeding** during times of drought means that the population estimates in the Northern Tablelands for wallaroos are not statistically or biologically possible.



** Red column graphs above the zero line indicate non-drought periods, whereas columns below zero indicate drought conditions.*
CONCERN: All mathematical models should include the covariates which are predictive of the outcome. The lack of "drought" index included in the model, as the department stated it did not include, is of serious mathematical / statistical concern.

E. Multiple survey methods

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. Long term averages are therefore not reliable given the change in methods of surveying.

CONCERN: The population trends and quotas are based on 40 years of data which have been collected using different methods and therefore cannot be "averaged" over time. Different methods of counting result in statistical concerns which need to be addressed using various modelling and this is essential for any time trends to be reliable.

Mathematical errors / queries / research concerns.

Data for the following was taken from the Department of Planning, Industry & Environment 2021 Quota Report New South Wales Commercial Kangaroo Harvest Management Plan 2017-2021 versions numbered 190709 and the updated (error corrected) 200485.

A. Population estimates of Red kangaroos

Using the above-mentioned data and working through the tables containing calculations in the report, mathematical errors and statistical anomalies were investigated which show serious concern in the population estimates.

a. Please refer to the diagram below (Table A3a Red Kangaroo temporal variation Lower Darling) from page 24 of the original report (190709) and see the population estimate for 2019. This is clearly a statistical outlier, in that is it lies more than 3 standard deviations away from the mean. It also requires a population increase of 265% in one year.

b. However, now please refer to the third diagram below (Table 20 Red Kangaroo temporal variation) from page 24of the revised report (200485) where the estimate has been revised down to 691119, which is a reduction of 39%.

Table A3a Red kangaroo temporal variation – Lower Darling

Average density (kangaroos/km²)	**5.77**				
Area in km²	**56,460**				
Standard deviation	**2.51**				
Year	**Population**	**Density**	**% Change**	**Quota**	**% Population**
1991	377,600	6.7	8.1	49,700	14.2
1992	399,200	7.1	5.7	86,800	23.0
1993	268,066	4.7	-32.8	95,808	24.0
1994	555,979	9.8	107.4	42,890	16.0
1995	402,592	7.1	-27.6	75,768	13.6
1996	385,844	6.8	-4.2	55,900	13.9
1997	493,302	8.7	27.9	73,117	18.9
1998	315,945	5.6	-36.0	75,000	15.2
1999	364,651	6.5	15.4	39,910	12.6
2000	221,468	3.9	-39.3	54,300	14.9
2001	279,185	4.9	26.1	36,820	16.6
2002	468,072	8.3	67.7	40,900	14.6
2003	197,864	3.5	-57.7	69,200	14.8
2004	166,340	2.9	-15.9	33,637	17.0
2005	124,665	2.2	-25.1	28,278	17.0
2006	113,119	2.0	-9.3	21,193	17.0
2007	188,018	3.3	66.2	19,230	17.0
2008	251,731	4.5	33.9	31,963	17.0
2009	185,450	3.3	-26.3	42,794	17.0
2010	193,931	3.4	4.6	31,527	17.0
2011	186,473	3.3	-3.8	32,968	17.0
2012	295,180	5.2	58.3	31,700	17.0
2013	423,518	7.5	43.5	50,181	17.0
2014	289,106	5.1	-31.7	71,998	17.0
2015	387,272	6.9	34.0	49,148	17.0
2016	619,113	11.0	59.9	65,836	17.0
2017	289,385	5.1	-53.3	105,249	17.0
2018	307,619	5.4	6.3	49,195	17.0
2019	1,124,115	12.2	124.7	52,295	17.0
2020				117,490	17.0

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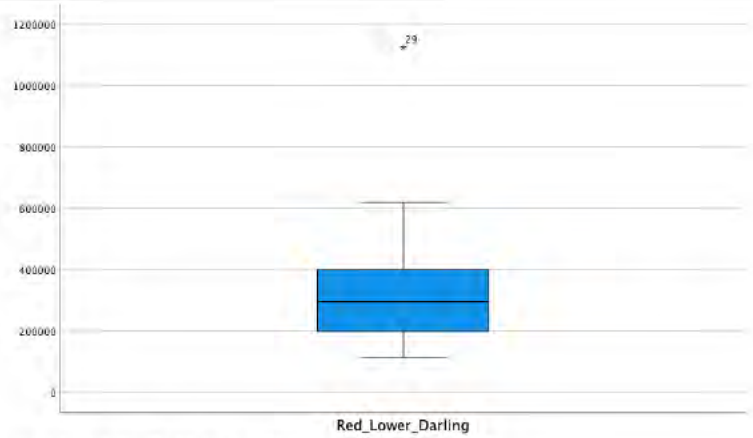

Statistical demonstration of the outlier value for 2019.

Table 20 Red kangaroo temporal variation – Lower Darling

Average density (kangaroos/km²)		6.0	Standard deviation		2.64
Area in km²		56,599			
Year	Population	Density	% Change	Quota	% Population
1991	377,600	6.7	8.1	49,700	14.2
1992	399,200	7.1	5.7	86,800	23.0
1993	268,066	4.7	-32.8	95,808	24.0
1994	555,979	9.8	107.4	42,890	16.0
1995	402,592	7.1	-27.6	75,768	13.6
1996	385,844	6.8	-4.2	55,900	13.9
1997	493,302	8.7	27.9	73,117	18.9
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2001	279,185	4.9	26.1	36,820	16.6
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2003	197,864	3.5	-57.7	69,200	14.8
2004	166,340	2.9	-15.9	33,637	17.0
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2007	188,018	3.3	66.2	19,230	17.0
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2011	186,473	3.3	-3.8	32,968	17.0
2012	295,180	5.2	58.3	31,700	17.0
2013	423,518	7.5	43.5	50,181	17.0
2014	289,106	5.1	-31.7	71,998	17.0
2015	387,272	6.9	34.0	49,148	17.0
2016	619,113	11.0	59.9	65,836	17.0
2017	289,385	5.1	-53.3	105,249	17.0
2018	307,619	5.4	6.3	49,195	17.0
2019	691,119	12.2	124.7	52,295	17.0
2020	583,802	10.3	-16	117,490	17.0
2021				**99,246**	**17.0**

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CONCERN: This is just one change that was made without mathematical justification.

B. Definition of strata

For all statistical / mathematical reports a definition of how calculations are performed should be included with justification. The Central Tablelands report section below mentions three strata: low, medium and high, however the classifications for these were based on only one survey and it does not appear to have been updated since. Instead it has been applied over and over again in the following 4 surveys.

Central Tablelands

The initial helicopter survey of the Central Tablelands management zone was completed in 2008. It was designed to provide separate population estimates for the Hunter–Mudgee– Merriwa and Central Tablelands areas, allowing the Central Tablelands zone to be managed as either one or two zones. Since its commencement on 1 June 2009, the area has been managed as two zones (Central Tablelands North and Central Tablelands South).

These two zones were surveyed again in September 2011, 2014, 2017 and 2020. The survey design incorporated the information gained from the initial survey in the delineation of low, medium, and high population density strata, allowing for improved precision in the population estimates. The population estimates and densities derived from 2020 helicopter survey are shown in Table 7.

CONCERN: Validation of the mathematical and statistical modelling in the report cannot be undertaken if definitions of how calculations were performed were not included with justification. Along with this, statistical methods applied to multiple surveys across time should be validated each time to ensure they are statistically appropriate each and every time.

C. SC Cairns study and comment on research

In 2011 a study was conducted by SC Cairns where 922 female red kangaroos with joey were shot at locations all across Australia as an experiment to see the extent to which reproductive success increases with age. However, prior to 2011 there was extensive literature [8] clearly demonstrating that reproductive success increases with age. In the 2011 publication Cairns did not take into statistical consideration time variables such as drought or access to food and also did not consider statistically the population estimate of the kangaroos in that location and concluded that "research is not the best insurance policy against overharvest and unwanted side-effects" going on to say that research is never-ending. The design of the study is evident of SC Cairns' lack of knowledge into research as taking a sample of 922 from across the entire country cannot in any way produce statistically or biologically plausible answers.

CONCERN: Prior to undertaking any research the first step is to determine if there is any literature in the space already or if there is a gap in available knowledge which needs filling. Prior to this study there was already evidence about reproductive success and therefore the study was not essential. All research needs to be undertaken with mathematical and statistical rigour, which was not the case with this study. The sample was extremely small and not reflective of the entire population and therefore could not be generalised. Finally, the analysis did not include any predictor variables, this along with the other points raises concerns about the quality of the research undertaken by SC Cairns.

D. Error in percentage calculations from revised quota report

When working through the calculations in the revised report it was noted that the calculations for the Central Tablelands North and Central Tablelands South appear to be incorrect.

Table 3 **Commercial harvest for 2020 up to 16 November 2020**

Management zone	No.	Eastern grey kangaroo				Red kangaroo				Western grey kangaroo				Wallaroo			
		2020 Quota	Harvest	%q	%p	2020 Quota	Harvest	%q	%p	2020 Quota	Harvest	%q	%p	2020 Quota	Harvest	%q	%p
Tibooburra	1	5,796	0		0%	0	0		0%	986	0		0%				
Broken Hill	2	20,435	1,218	5%	1%	191,100	34,574	16%	3%	28,562	5,264	17%	2%				
Lower Darling	4	17,780	10,573	54%	8%	117,490	18,738	14%	2%	39,027	5,239	11%	2%				
Cobar	6	0	0		0%	0	0		0%	0	0		0%				
Bourke	7	0	0		0%	84,504	8,931	9%	2%	0	0		0%				
Narrabri	8	114,009	22,637	18%	3%	58,897	5,970	9%	2%								
Armidale	9	63,285	27,001	36%	5%									17,594	1,480	8%	1%
Coonabarabran	10	213,288	34,252	15%	2%	85,023	7,236	7%	1%	17,156	62	0%	0%				
Glen Innes	13	81,780	16,199	17%	3%									20,230	1,096	5%	1%
Upper Hunter	14	24,975	17,068	62%	9%									6,660	2,282	34%	5%
South East NSW	16	258,210	46,960	16%	2%												
Griffith North	17	128,000	24,080	18%	3%	27,123	14,528	47%	8%	26,380	3,687	12%	2%				
Griffith South	18	82,091	22,419	23%	3%	0	0		0%	16,919	90	0%	0%				
Central Tablelands North	48	259,230	28,810	11%	2%												
Central Tablelands South	49	140,085	19,904	13%	2%												
Total		**1,408,964**	**271,121**	**17%**	**3%**	**564,137**	**89,977**	**14%**	**2%**	**129,030**	**14,342**	**10%**	**1%**	**44,484**	**4,858**	**11%**	**2%**

11% of 259,230 = 28,515 **NOT** 28,810
13% of 140,085 = 18,211 **NOT** 19,904

CONCERN: The errors within the report are of mathematical concern– a full review of all reports is warranted to ensure all calculations are correct – especially the quota calculations.

E. Methodology of: A report to the New South Wales Office of Environment and Heritage on the consultancy: "Design and analysis of helicopter surveys of the kangaroo populations of the Northern Tablelands kangaroo management zones, 2016." S. C. Cairns, D. Bearup & G. W. Lollback.

As a mathematician / biostatistician this report raises serious concerns:

1. Mathematical modelling: When determining population estimates through modelling the report states that there were only three covariates "namely observer, habitat cover at point-of-detection and cloud cover". However, in Glen Inness and the Upper Hunter only the covariate "observer" was included yet in Armidale **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.

2. Below is Table 3 from the report, which states that only 11 and 13 Red-necked wallabies were visibly seen in Armidale. The reports states that this was considered "high enough" to do population estimates on. Applying statistical models to data requires various assumptions, with such a small count (n) for the model the model fit would be of significant concern.

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

3. The 2019 report references the 2016 report of the same study and states that the coefficient of variation (CV) in the 2016 report was as high as 49% (2016). This is of serious mathematical concern as it clearly demonstrates that the heterogeneity of the samples is flawed and therefore the work cannot draw any valid statistical conclusions. The population estimates and quotas set from the 2016 report onwards are not statistically valid.

4. In the report the discussion around the variation found acknowledges the "variation in the general sightability" of macropods in relation to the differing

broad landscapes which make up the survey area. As well as acknowledging that it also reflects the influence of general weather conditions and light.

Statistically these covariates are "related" to the outcome of population estimate and therefore **should** be considered in any modelling.

5. The reference stated as (Clancy *et al.* 1997; S. C. Cairns, A. R. Pople & J. Gilroy, *unpubl. data*) was not included in the reference list and is essential.

6. The land capabilities of the Geographic Information System (GIS) shapes were obtained in 2004 and do not appear to have been updated until 2011 and not since then. This should be done every time a survey is undertaken to ensure consistency between the data collection. Without this done population estimates over time cannot be undertaken.

7. Densities within the strata range from 26% to 68% - this should be considered in the mathematical modelling.

F. Triennial survey concerns

The table below shows the population decrease from 2017 to 2020 of 950850 Eastern Grey Kangaroos. Assuming the triennial survey and assuming this is the equivalent of 55% over the three years.

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

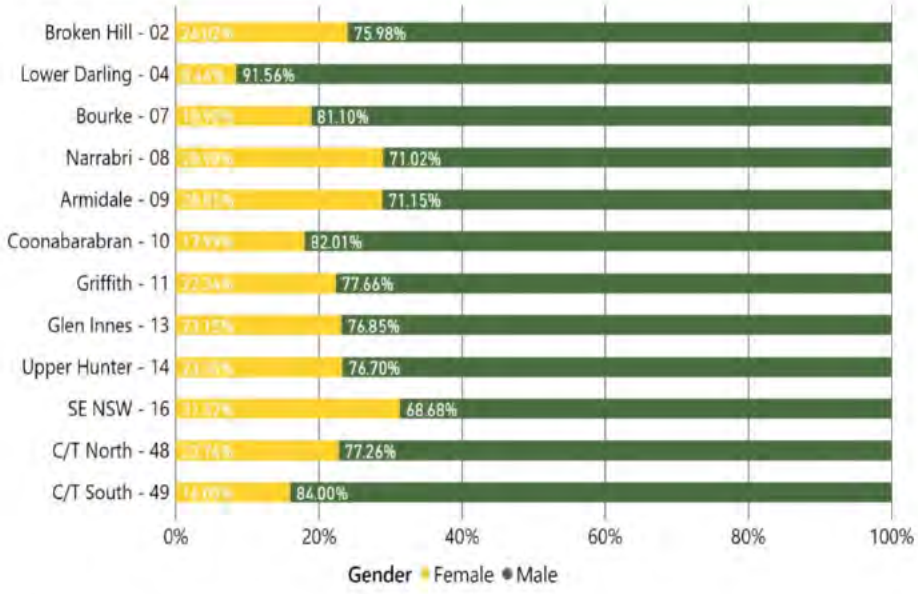
CONCERN: Conducting the surveys every three years and setting quotas for the next three years based on these figures (when there is a very large decline in numbers) will lead to significantly higher quotas and decreasing trends in population – ultimately leading to day 0. The Northern Tablelands report in the above section (E) states that triennial surveys are "considered safe" however this assumes no major events take place

which is statistically flawed given the 2019-2020 bushfires and subsequent 2021 flooding.

G. Zones for Wallaroos

Working through the DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT NSW Commercial Kangaroo Harvest Management Plan: 2019 Annual Report New South Wales Commercial Kangaroo Harvest Management Plan 2017-21 investigating mathematical / statistical concerns it was noted that although the wallaroos had quotas set for the Northern Tablelands there is also data on wallaroos for all zones.

Figure 2 **Wallaroo sex bias in the commercial harvest, 2019**



CONCERN: From the above table wallaroos appear to be in all commercial zones however no mathematical or statistical quotas appear in the reports other than for the Northern Tablelands.

H. Double population estimate in one year

In the kangaroo management annual population estimates for red and grey kangaroos the population more than doubled from 2000 to 2001 from 7689100 to 13915500. As has been stated earlier in this document, kangaroos breed at a rate of 8-10% (Reds ~

14%)[9] therefore assuming no culling, no drought, 100% successful breeding conditions and 100% successful breeding the population should have only increased 8458010.

CONCERN: The DPI has admitted this was an error, but it dates back even further than the wallaroo errors (they dated back to 2008). Therefore, all trend quota estimates are incorrect.

RED AND GREY KANGAROO ANNUAL POPULATION ESTIMATES - ANNUAL QUOTAS - ANNUAL CULL FIGURES AND RELATIVE PERCENTAGES

YEAR	POPULATION	QUOTA	% POPULATION	COMMERCIAL TAKE	% POPULATION	% QUOTA
1973	no estim.	213,000	0	132,000	0	61.97%
1974	no estim.	216,000	0	95,000	0	43.98%
1975	3,365,300	212,000	0	123,000	0	58.02%
1976	no estim.	319,400	9.49%	96,000	2.85%	30.06%
1977	4,699,000	321,000	0	167,200	0	52.09%
1978	4,383,000	345,000	7.34%	220,000	4.68%	63.77%
1979	4,288,000	645,000	14.72%	520,000	11.86%	80.62%
1980	6,174,000	645,000	15.04%	619,023	14.44%	95.97%
1981	7,046,000	694,500	11.25%	488,647	7.91%	70.36%
1982	9,400,000	843,000	11.96%	664,342	9.43%	78.81%
1983	5,500,000	843,000	8.97%	400,477	4.26%	47.51%
1984	2,738,000	500,000	9.09%	229,484	4.17%	45.90%
1985	4,155,000	300,000	10.96%	326,028	11.91%	108.68%
1986	4,662,100	577,000	13.89%	444,509	10.70%	77.04%
1987	5,425,000	577,000	12.38%	473,454	10.16%	82.05%
1988	5,498,000	730,000	13.46%	421,200	7.76%	57.70%
1989	7,593,500	804,000	14.62%	500,355	9.10%	62.23%
1990	9,150,000	1,172,000	15.43%	633,000	8.34%	62.23%
1991	9,734,000	1,520,000	16.61%	856,406	9.36%	56.34%
1992	7,981,900	2,074,000	21.31%	796,007	8.18%	38.38%
1993	7,112,000	1,663,600	20.84%	775,220	9.71%	46.60%
1994	5,962,800	1,409,100	19.81%	971,694	13.66%	68.96%
1995	6,202,200	1,146,626	19.23%	977,459	16.39%	85.25%
1996	5,170,000	1,206,000	19.44%	1,149,917	18.54%	95.35%
1997	6,549,800	976,000	18.88%	897,937	17.37%	92.00%
1998	8,362,800	1,175,140	17.94%	940,789	14.36%	80.06%
1999	7,653,725	1,532,916	18.33%	937,642	11.21%	61.17%
2000	7,689,100	1,389,700	18.16%	883,478	11.54%	63.57%
2001	13,915,500	1,390,722	18.09%			
2002		1,920,100	13.80%			

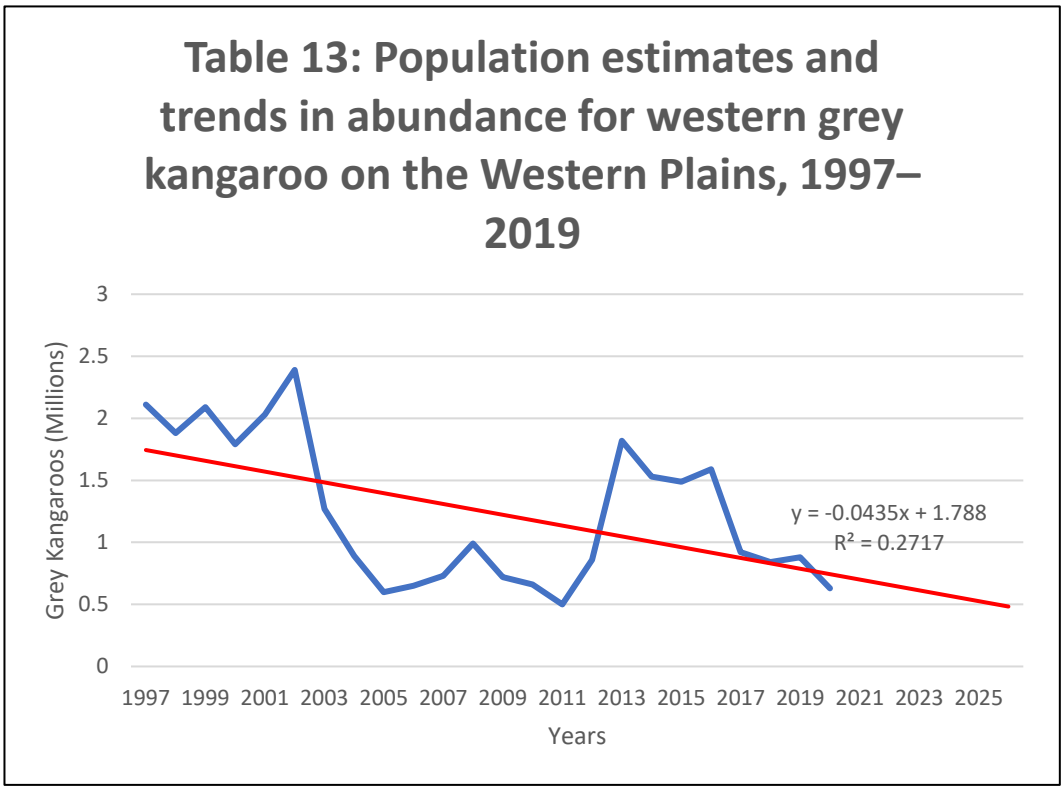
Population estimates and trajectories

Data for the following graphs was taken from the Department of Planning, Industry & Environment 2021 Quota Report New South Wales Commercial Kangaroo Harvest Management Plan 2017-2021.

This data was then entered into excel, double checked for entry errors and graphed demonstrating the departments choice of linear regression for both population estimates and quotas (where possible) to demonstrate the following:

a) Trajectories of population estimates

1. Linear regression equation used to calculate extinction dates where possible
2. R^2 to show the fit of the trend line (how well the data represents the trend of the data over time – the closer to 1 the better).
3. Percentage changes over time for statistical outliers, statistical and biological implausibility.
4. How and when the two trend lines (population estimates and quotas) intersect or come very close.



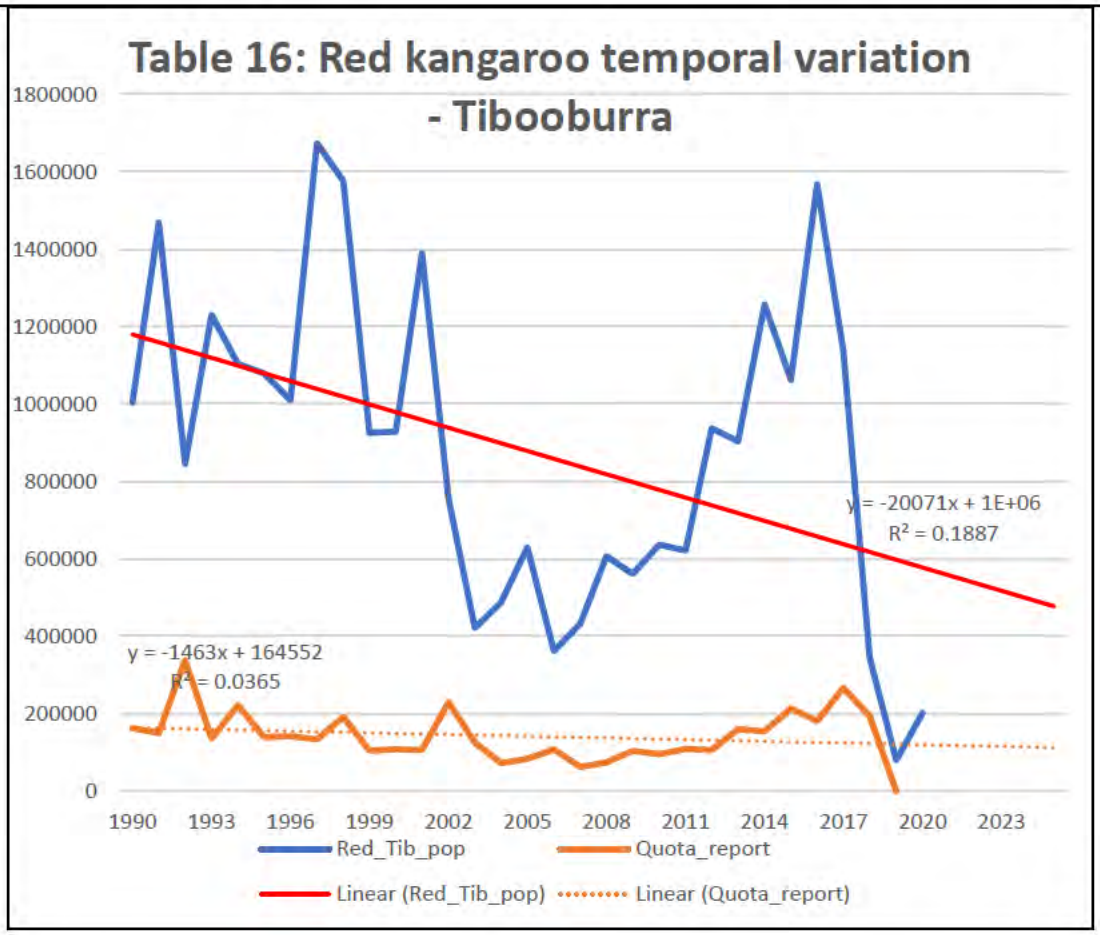


Table 16: Red kangaroo temporal variation - Tibooburra
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
y = -20071x + 1E+06
R² = 0.1887
y = -1463x + 164552
R² = 0.0365
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020
2023
Red_Tib_pop
Quota_report
Linear (Red_Tib_pop)
Linear (Quota_report)

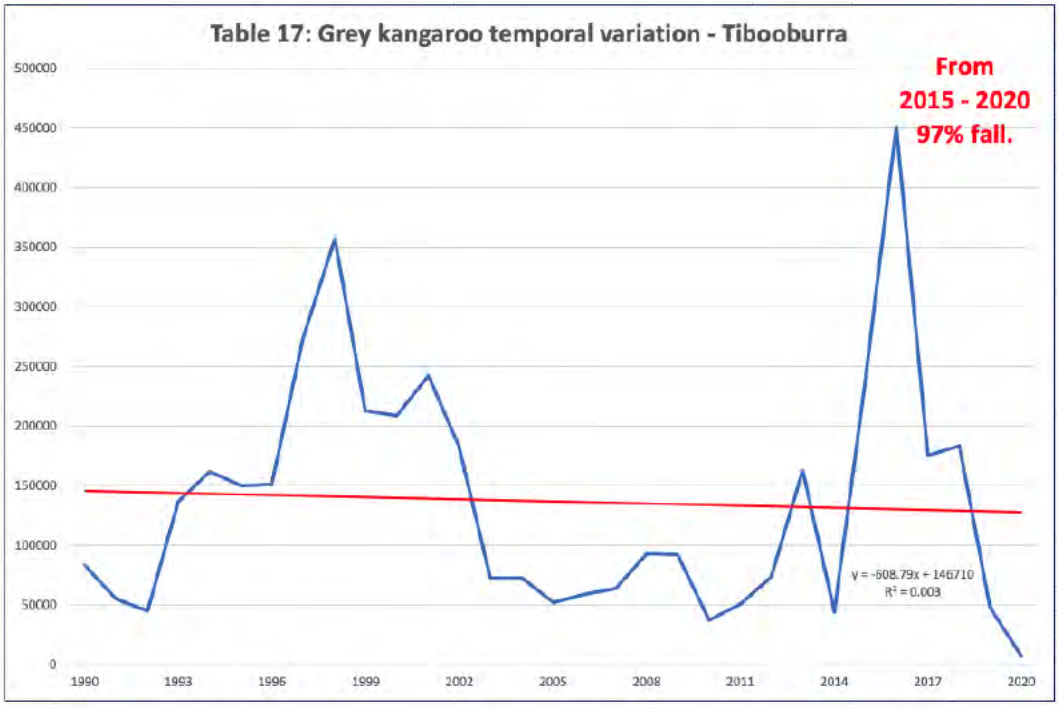


Table 17: Grey kangaroo temporal variation - Tibooburra
From 2015 - 2020 97% fall.
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
y = -608.79x + 146710
R² = 0.003
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020

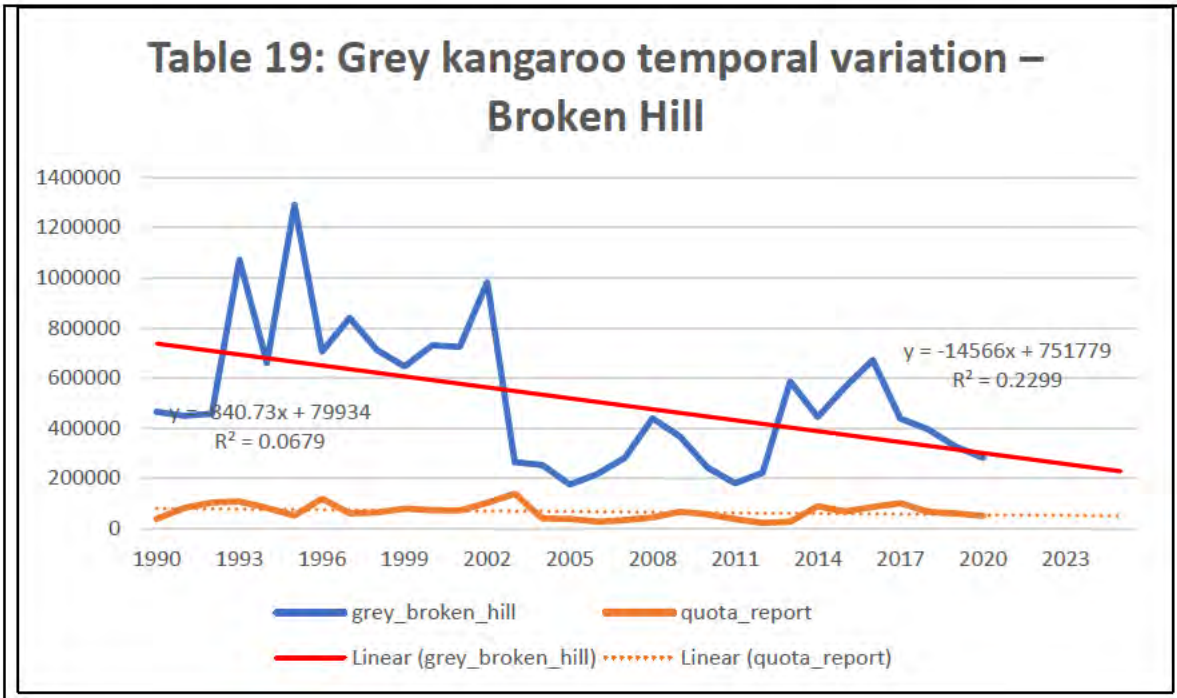
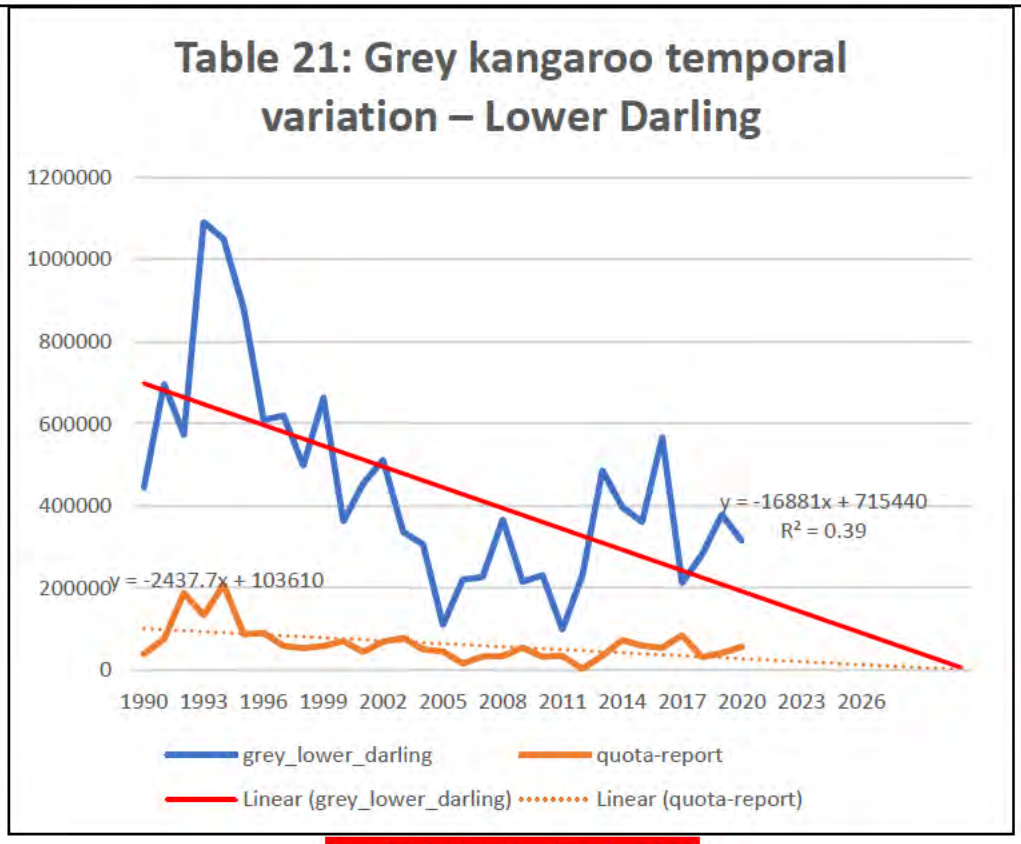
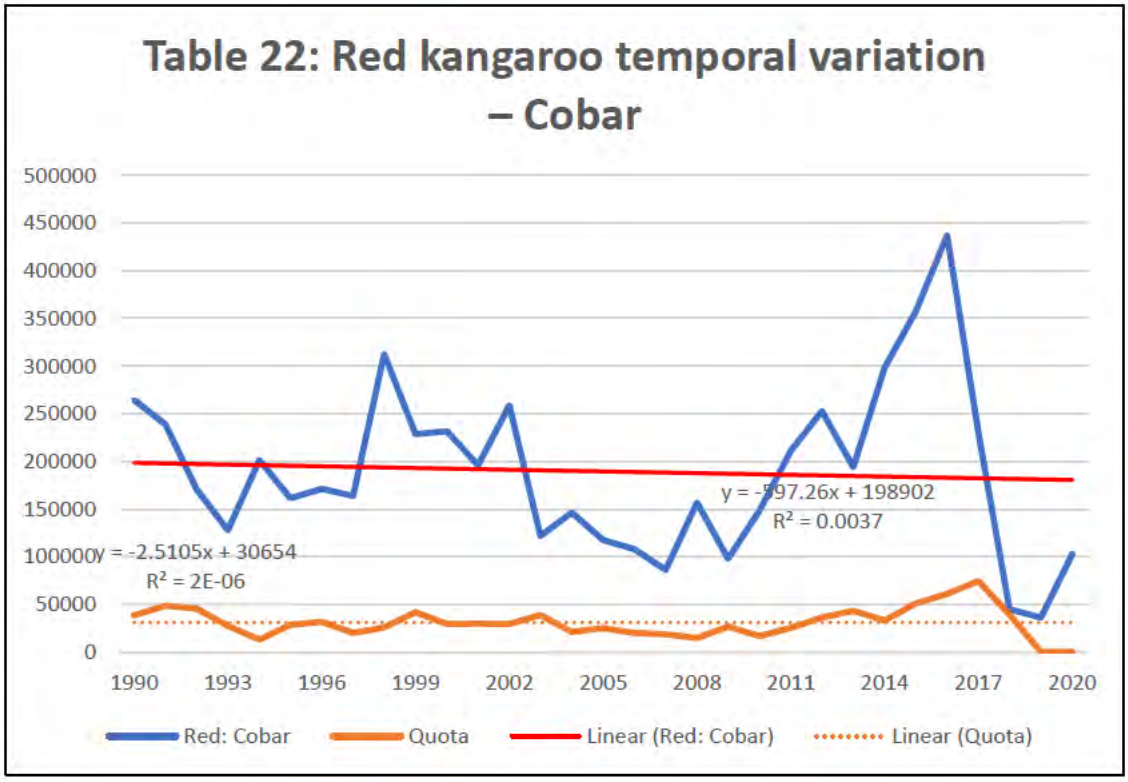


Table 19: Grey kangaroo temporal variation – Broken Hill
1400000
1200000
1000000
800000
600000
400000
200000
0
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020
2023
y = -14566x + 751779
R² = 0.2299
y = 840.73x + 79934
R² = 0.0679
grey_broken_hill
quota_report
Linear (grey_broken_hill)
Linear (quota_report)



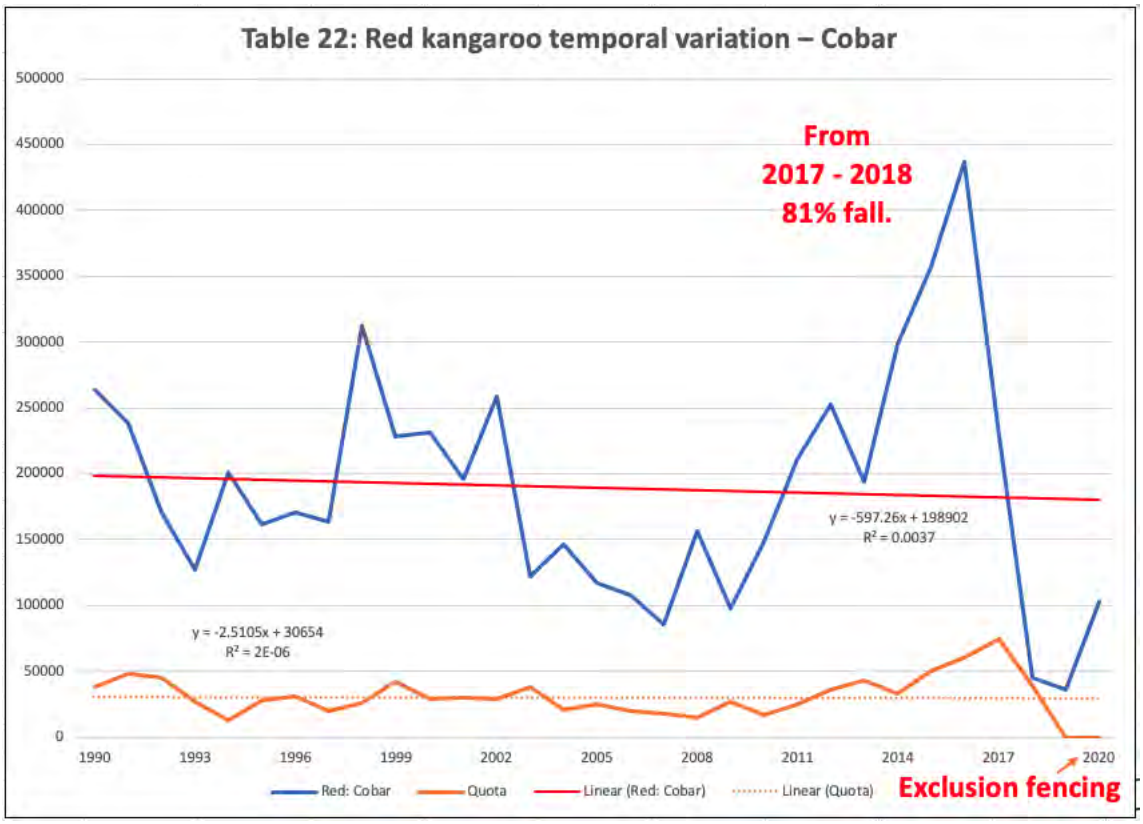
Day 0 (Extinction): July 3030

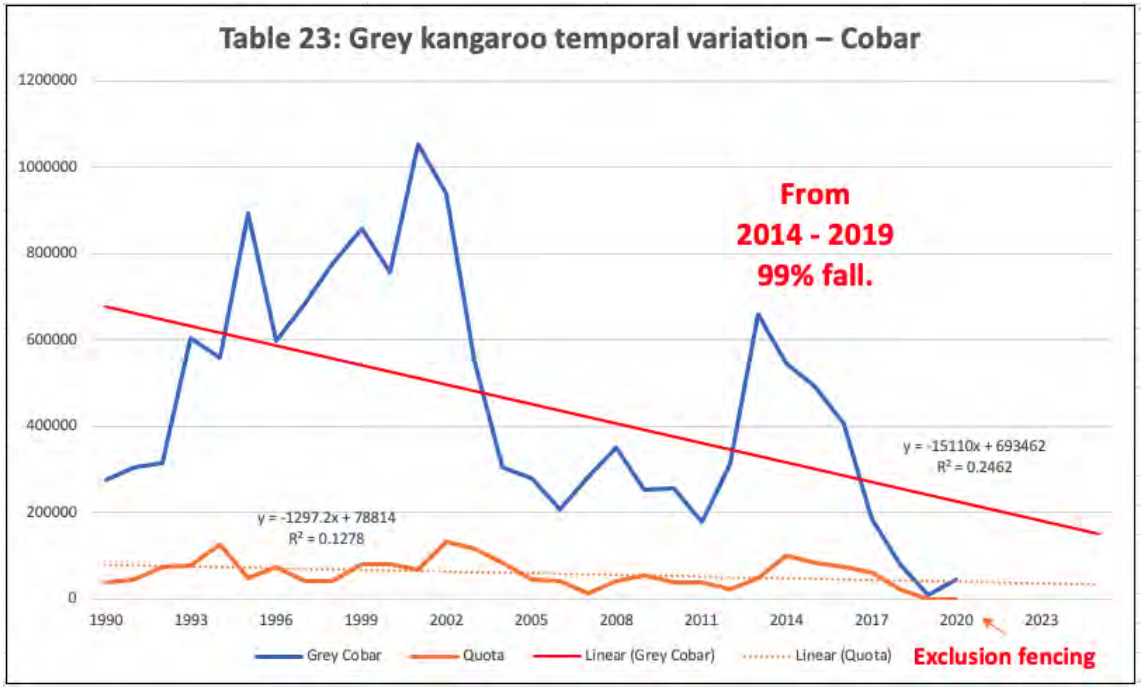


Year	Red: Cobar	Quota
1990	264300	38300
1991	238600	48500
1992	170700	45300
1993	127658	27312
1994	201113	12766
1995	161314	28116
1996	170917	31441
1997	163624	19780
1998	312413	25580
1999	228367	41640
2000	231400	29375
2001	196029	29700
2002	258662	29200
2003	121756	38600
2004	146292	20699
2005	117137	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

From this table above 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). Had this of occurred and the quota not reduced, allowing for a 10% breeding rate on 36058 is approximately 3600 kangaroos, but only 5719 would have remained. This would need to assume over 100% breeding population i.e. All females of breeding age and 100% success of breeding.

CONCERN: Within this geographic location (Gilgunnia) an exclusion fence was erected covering 500000 acres (177000 hectares) and 18 licenses were issued to harm kangaroos – the impact of these two factors need to be mathematically taken into consideration for quotas.





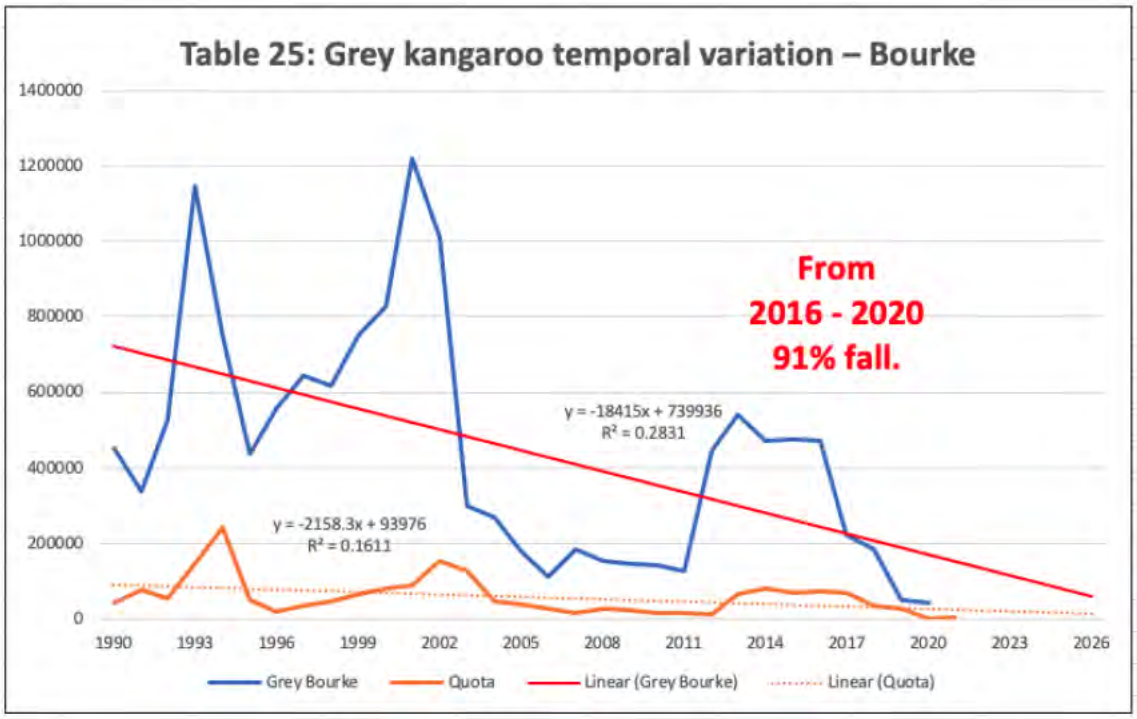
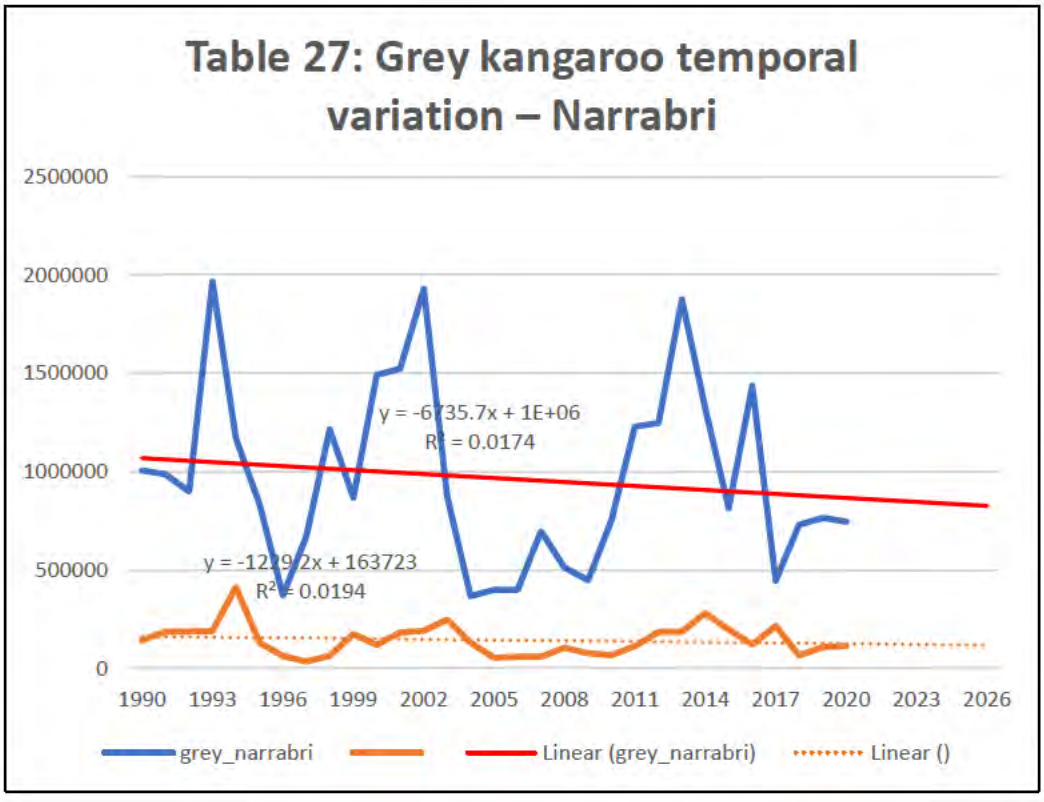


TABLE 25: Using linear regression analysis and extending the regression line 10 years ahead the intersection of the two lines will be in August 2029 – this means that Grey kangaroos in Bourke will be extinct within 8 years.



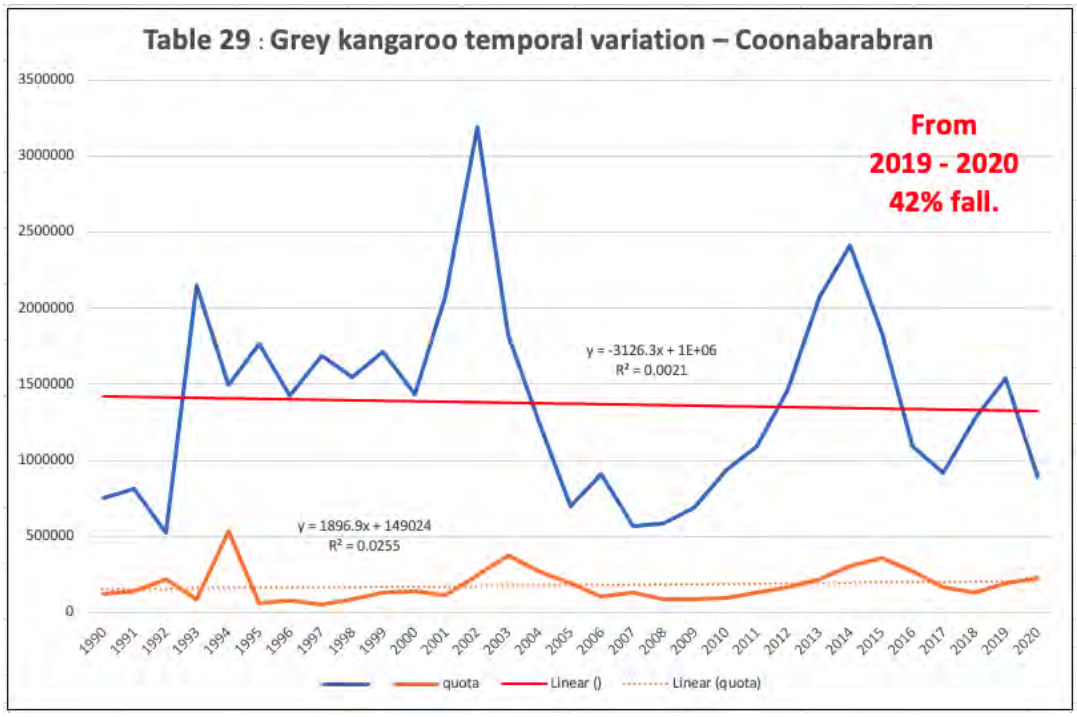


Table 29 : Grey kangaroo temporal variation – Coonabarabran
From
2019 - 2020
42% fall.
y = -3126.3x + 1E+06
R² = 0.0021
y = 1896.9x + 149024
R² = 0.0255
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
quota
Linear ()
Linear (quota)

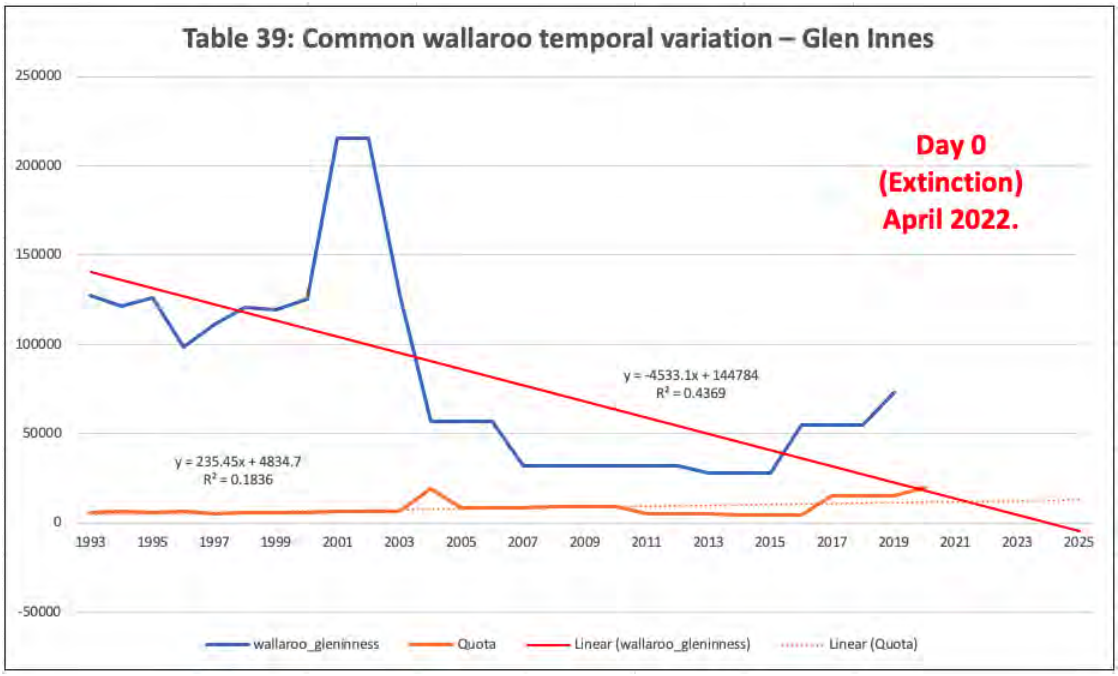
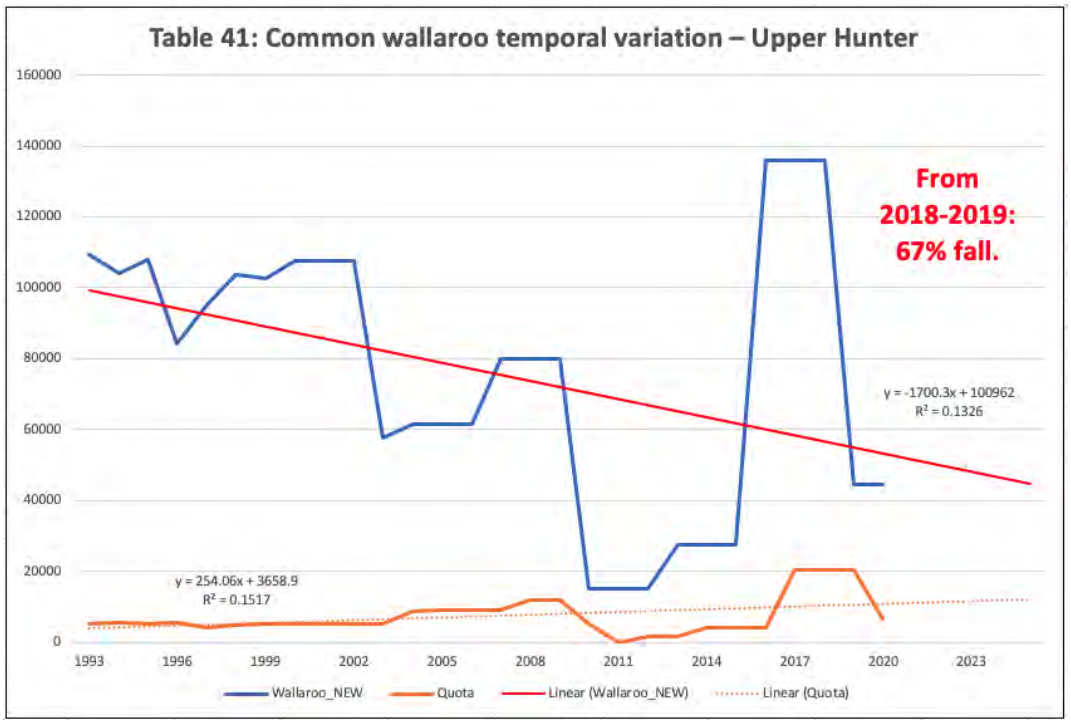


Table 39: Common wallaroo temporal variation – Glen Innes
Day 0
(Extinction)
April 2022.
y = -4533.1x + 144784
R² = 0.4369
y = 235.45x + 4834.7
R² = 0.1836
250000
200000
150000
100000
50000
0
-50000
1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025
wallaroo_gleninness
Quota
Linear (wallaroo_gleninness)
Linear (Quota)



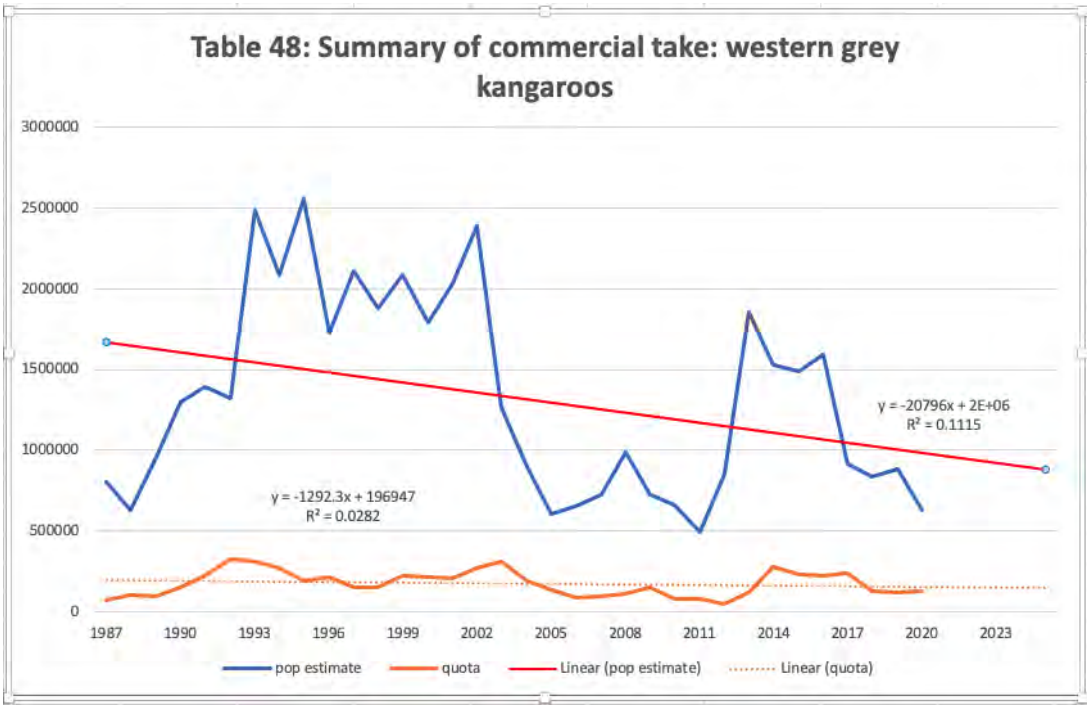


Table 48: If kangaroos breed at 8-10% per annum which is agreed upon by conservation biologists, how is it biologically plausible that the population increased in 2012 by 72% and then in 2013 by a further 116%, even if drought conditions had ceased this breeding rate is not plausible?

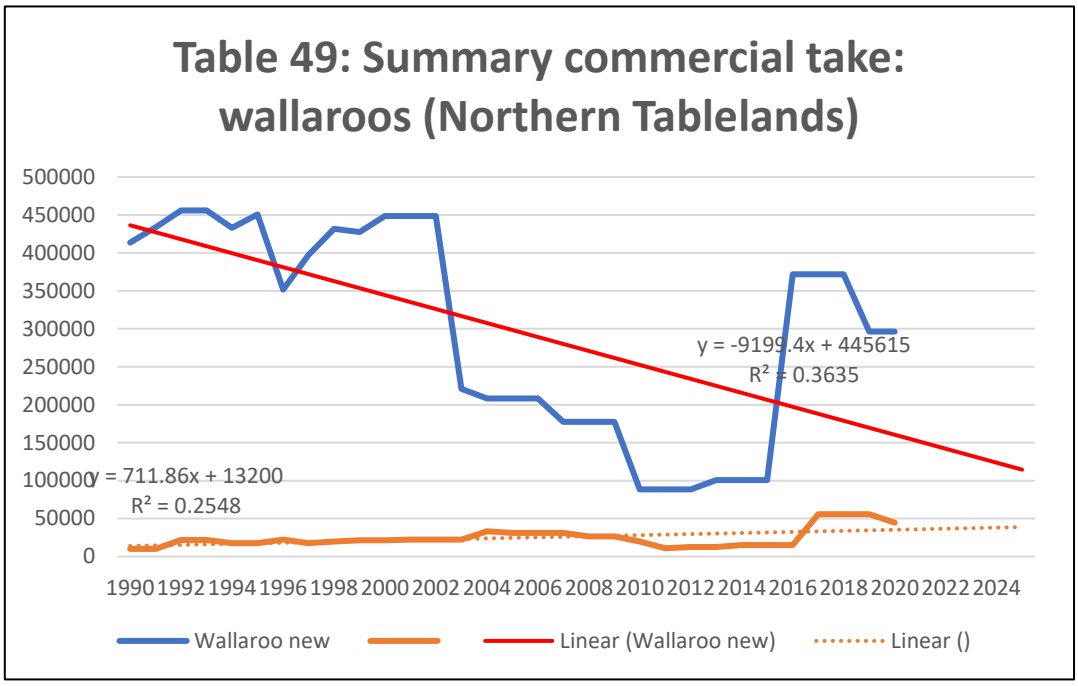


Table 49: Prior to the DPI "determining" they made an error on the population estimates, using linear regression analysis and extending the regression line 2 years ahead the intersection of the two lines will be in December 2022 – this means that the wallaroos in the Northern Tablelands will be extinct next year. Note this data was before the "correction factor" was applied retrospectively 13 years after the DPI realised they made a mistake back in 2008. After they backdated the correction factor Day 0 for the wallaroos is December 2034.

SECTION 2

TERMS OF REFERENCE

d) Current government policies and programs for kangaroo management, including:

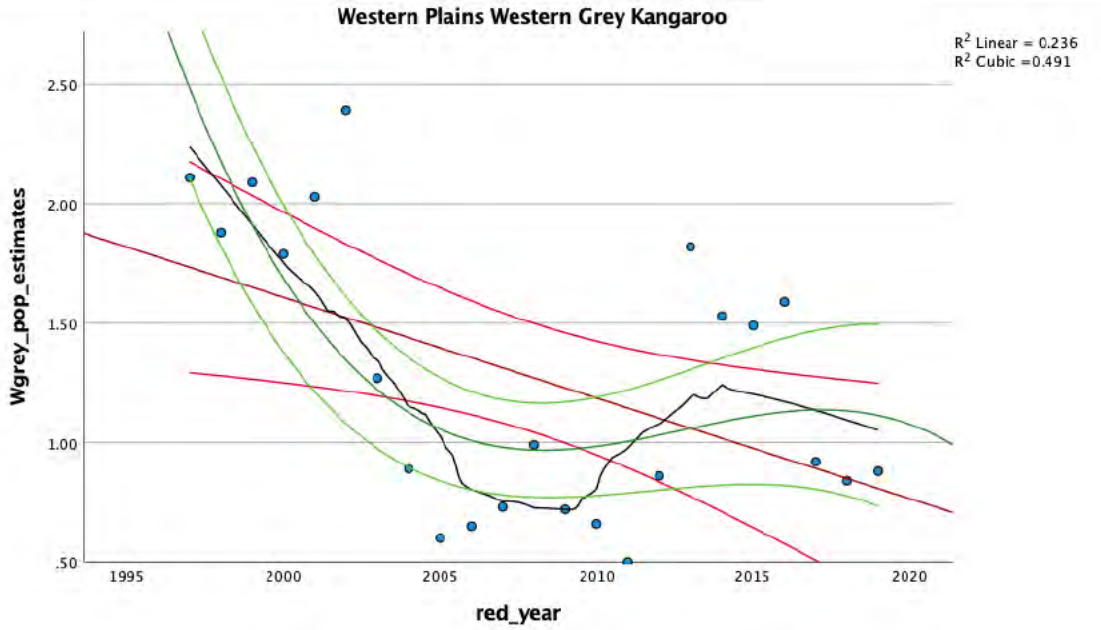
(i) the method used for setting quotas for kangaroo culling,

A. Thresholds for management and factors influencing estimates

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"*.

In order to use the standard deviation, it requires fitting a linear trend line to the data and assuming a constant average over the entire time period. Using the Western Grey kangaroo in the Western Plains as one example, the linear trend line has been fitted with 95% confidence intervals which show the spread (reliability) of the data. The fit of the trend line is measured using R^2, the higher the R^2 (closer to 1) the better the fit. As can be clearly seen the fit of the red trend line is 0.236 or 23.6%, which is very low and would not be considered a good / reliable trend line for the data. When a cubic model is fitted to the data (green) the trend of the population is better represented as the fit of the line is 49.1% - over 2 times as better fit.

For the management thresholds to be determined, the mathematically accurate trend of the population needs to be taken into consideration and that includes using the most appropriate mathematical model and the corresponding 95% confidence intervals. These confidence intervals take into consideration the sample size at each time point and therefore are more reflective of the variations caused by many factors.



Concern: The kangaroo management allows for a consistent ≈15% which is not sustainable as they are based on thresholds from unreliable information using an average over time which is clearly not the correct mathematical choice. Using the standard deviation obtained from different survey methods to determine thresholds is mathematically concerning.

B. Quota estimates from incorrect population estimates

As previously stated the DPI reports made errors throughout which are of mathematical concern.
With the red kangaroos in 2019 in the Lower Darling the revised population estimate was a 39% decrease – the quota which was set on the incorrect estimate was significantly high and raises serious concerns on the process of settings quotas when the population estimates are incorrect.

CONCERN: Any population estimates and subsequent quota estimates need to be based on reliable counting methodologies which include permanent images and mathematical modelling.

SECTION 3

All recommendations in the table below are mathematically and statistically based upon available evidence from the Department of Planning, Industry & Environment

Section	Sub-section	Heading	Recommendation
1	Counting methodology	A. Correction Factor	The correction factor should not be applied to any population estimates on wallaroos as it is not statistically validated across all seasons of the year and all locations within the zone.
		B. Alternative methods for obtaining population estimates	All population estimates should follow international recommendations of using imagery either airborne, remote sensed or satellite imagery along with mathematical modelling to determine cost effective and accurate estimates as well as providing a permanent record for research.
		C. Transect line selection	Transect location and size should be determined mathematically and must take into consideration the type of macropod, climatic influences and style of data capture.
		D. Consideration of climatic factors in the mathematical / statistical modelling	The SPEI, The Standardised Precipitation-Evapo-transpiration Index, which is applied globally for population estimates in modelling should be applied to macropods.
		E. Multiple survey methods	Trends over time of population estimates must statistically take into consideration the change in data capture methods.
	Mathematical errors / queries / research concerns	A. Population estimates	As per sub-section A for section 1 above: All population estimates should follow international recommendations of using imagery either airborne, remote sensed or satellite imagery along with mathematical modelling to determine cost effective and accurate estimates as well as providing a permanent record for research.

		B. Definition of strata	Mathematical justification of the strata and its consistent application should be justified at all times either in the report or as publicly available supplementary material to the report.
		C. SC Cairns study and research	All investigators involved should have independent experts support and verify their research with clear referencing and ethics.
		D. Error in percentage calculations from revised quota report	Errors in government published reports should not occur and should be acknowledged and corrected.
		E. Methodology of the Northern Tablelands reports 2019	The mathematical and statistical methodology of the report should be investigated by an independent statistician.
		F. Triennial survey concerns	As outlined for sub-section A above; All population estimates should follow international recommendations of using imagery either airborne, remote sensed or satellite imagery along with mathematical modelling to determine cost effective and accurate estimates as well as providing a permanent record for research. Therefore, triennial surveys would not need to be undertaken.
		G. Zones for wallaroos	All zones should clearly state all population characteristics for all macropods to ensure correct sampling sizes are chosen.
		H. Double population estimate in one year	All populations estimates should be investigated for statistical outliers / abnormalities.
	Population estimates and trajectories	A. Trends in data from the Department of Planning, Industry & Environment 2021 Quota Report New South Wales	Independent investigation into all population trends over time and subsequent quotas needs to be urgently undertaken to ensure the survival of the species and avoid extinction.

		Commercial Kangaroo Harvest Management Plan 2017-2021.	
2		C. Thresholds for management and factors influencing estimates	All thresholds need to be reviewed by an independent statistician or team of statisticians to ensure the survival of the species and avoid extinction.
		D. Quota estimates from incorrect population estimates	As for sub-section A Independent investigation into all population trends over time and subsequent quotas needs to be urgently undertaken to ensure the survival of the species and avoid extinction.

OVERALL RECOMMENDATION

Independent statistical investigations into the New South Wales Commercial Kangaroo harvest management plans should be urgently undertaken.

SECTION 4

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