



WINTON WETLANDS

KANGAROO MONITORING PROGRAM RESULTS 2023

Prepared by Dr Lisa Farnsworth, Restoration Manager

Field data collected by: Sarah Way, Gil Cunneen and Matt Long

February 2024

Winton Wetlands Kangaroo Monitoring Results 2022

Table of Contents

Executive Summary	3
1 Introduction and background	4
1.1. Ecological, social, and economic impacts of overabundant macropods	4
1.2. Current Victorian kangaroo control/pet meat legislation	4
1.3. Previous kangaroo surveys at Winton Wetlands	5
2 Kangaroo population density estimates, September 2023	5
2.1 Ground Survey Methods	5
3 Survey Results	9
3.1 DISTANCE density and abundance estimate	9
4 Discussion of results	10
4.1 Comparison with previous ground survey results	10
4.2 Factors affecting Eastern Grey Kangaroo population/density	11
4.3 Comparison with previous kangaroo surveys elsewhere in Victoria/Australia	12
5 Macropod management actions at Winton Wetlands	12
5.1 Managing for kangaroos or managing for conservation/restoration outcomes?	12
5.2 Quantifying kangaroo related problems	13
5.2.1 Impacts on revegetation and regeneration of flora	13
5.2.2 Increased road collisions	13
5.3 Ongoing macropod population monitoring and management at Winton Wetlands	13
Appendix I: Raw data collection sheet pro forma (from Hamilton 2013)	15
References	16

Executive Summary

- 2023 was the fifth consecutive year of spring Eastern Grey Kangaroo (EGK) surveys in the Winton Wetlands Natural Features Reserve (WWNFR).
- A sound, site appropriate and repeatable survey methodology called 'distance sampling' continues to be utilised, with density estimates generated from this survey methodology.
- Average EGK densities were estimated at 1.32 kangaroos/Ha with a population estimate of 6,600 kangaroos. This density estimate is comparable to those recorded for 2021 (1.38) and 2022 (1.18).
- While EGK densities increased approximately threefold from 2020 (0.45) to 2021 (1.38) in response to rainfall events and favourable breeding conditions, EGK densities have stabilised since 2021.
- Kangaroo populations are known to fluctuate owing to a complex relationship between rainfall, resource availability, fecundity, and mortality. The increase in seasonal rainfall since 2020 and hence increase in food resource availability (and resulting increase in successful breeding), combined with the marked decrease in available terrestrial habitat during inundation events is a likely driving factor of density increases in EGK at Winton Wetlands since 2020.
- Long term annual monitoring throughout various climatic conditions is required to understand the local kangaroo population dynamics.

Winton Wetlands Committee of Management supports various initiatives to address and respond to interactions between EGKs, people, restoration efforts and agriculture including:

- 1) Ongoing annual surveys to continue to track EKG density fluctuations in response to climatic conditions at WWNFR.
- 2) Advocating for a National Kangaroo Strategy and participating in any initiatives to form a regional kangaroo management group for larger scale management in our region.
- 3) Consideration of the data generated from the Victorian Government's statewide kangaroo survey events (next planned for spring 2024).
- 4) Investigate a speed limit reduction along Lake Mokoan Road.

1 Introduction and background

1.1. Ecological, social, and economic impacts of overabundant macropods

The active management of kangaroo populations is controversial and often polarising because kangaroos are viewed both as a national wildlife icon, valuable to tourism and the national identity, an important grazer in the ecosystem, and yet also as a potential pest species for those involved in primary industries (Pople and Grigg, 1999).

High-density populations of Eastern Grey Kangaroos (EGKs) have been associated with perceived, but rarely quantified, losses to primary industries through competition for food resources or reductions in crop yield (Coulson, 2007; Descovich et al., 2016). Kangaroos are known to graze selectively and, at times, heavily enough to have a negative impact on fauna and flora through depletion of habitat (Neave and Tanton, 1989; Meers and Adams, 2003; Barton et al., 2011; Dorrough et al., 2012; Manning et al., 2013; Howland et al., 2014; McIntyre et al., 2014; Howland et al., 2016; Snape et al., 2018). Increasing crossover between spaces used by humans and kangaroos, kangaroos are also known to create a heightened risk to human safety through increased risk of road traffic accidents (Abu-Zidan et al., 2002; Coulson, 2007; Descovich et al., 2016; Brunton et al., 2018).

1.2. Current Victorian kangaroo control/pet meat legislation

Within Victoria, there are two means with which landholders can gain authority to control EGK populations by lethal means. Landholders can apply through Department of Energy, Environment and Climate Action (DEECA) for an Authority to Control Wildlife (ATCW). An ATCW permits the control of wildlife that is damaging property, farmland, or habitat, or posing a risk to the safety of people. An ATCW is required to scare, trap, move or destroy wildlife and comes with a range of conditions that must be adhered to under the *Wildlife Act 1975*. Historically, the number of ATCW's issued for EGKs in Victoria has steadily increased from 1,250 permits in 2012 (maximum number of animals destroyed 44,469) to 2,849 permits in 2018, where over 150,000 kangaroos were permitted to be destroyed (DELWP, 2019). In 2021 however, the ATCW permits issued dropped to 1514 (maximum number of animals destroyed 51,769, DELWP, 2022) and has remained at similar levels during 2022 and 2023 (2022= 1423 licences, 54,254 EGK permitted to be destroyed, 2023= 1486 licences, 68,104 permitted to be destroyed, DEECA, 2024).

Additionally, landholders can arrange for the commercial harvesting of their local kangaroo populations through the Kangaroo Pet Food Trial (KPFT) that has been implemented under the Victorian Kangaroo Harvest Management Plan. A key purpose of establishing Victoria's kangaroo harvesting program is to provide landholders with an alternative to undertaking their own legal kangaroo control. This program links landholders to registered 'harvesters' who are operating in their zone. The total sustainable kangaroo harvesting rate in Victoria is currently a maximum of 10% of the estimated population. Estimated populations of kangaroos are determined using statewide aerial surveys of non-forested systems (Moloney et al., 2018, 2021, 2023).

Similarly, the total sustainable harvesting rate in New South Wales is also calculated as a percentage of the total estimated population size, whilst in the ACT, their culling program sets specific density targets of 1 kangaroo per hectare in grasslands, 0.9/ha for open woodlands and 0.5/ha for woodlands.

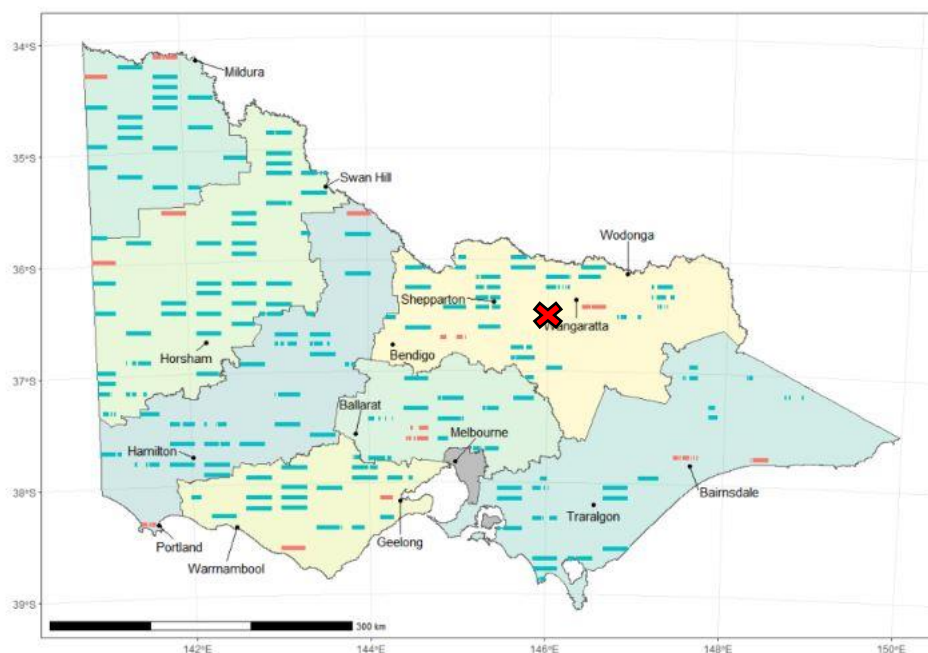


Figure 1. Kangaroo harvest zone map of Victoria, indicating (blue lines) the priority aerial survey transects sampled during aerial kangaroo surveys in spring 2022– diagram from Moloney et al., 2023). The approximate location of Winton Wetlands is indicated by the red cross.

Winton Wetlands Natural Features Reserve (WWNFR) lies within the North-East harvest zone defined by the annual kangaroo harvest estimates (Figure 1; Moloney et al., 2023).

Estimated EGK populations were calculated via state-wide aerial surveys conducted in 2017, 2018, 2020 and 2022, with the most recent 2022 aerial survey indicating the estimated abundance of EGK in the north-east harvest zone was 356,000 EGK compared with 221,100 in 2021 (Moloney et al., 2021, 2023).

1.3. Previous kangaroo surveys at Winton Wetlands

Formal EGK surveys have been conducted at Winton Wetlands by Steve Hamilton from Hamilton Environmental Services and by Winton Wetlands staff in September 2013 and then repeated over the past 4 years during spring 2019, 2020, 2021 and 2022. These surveys utilised line transect (distance sampling) methodology to determine that Winton Wetlands had approximately 0.13 kangaroos per hectare in 2013 and 0.33 kangaroos per hectare in 2019, 0.45 kangaroos per hectare in 2020, 1.38 kangaroos per hectare in 2021 and 1.18 kangaroos per hectare in 2022. No active kangaroo management was carried out after any of the previous surveys.

2 Kangaroo population density estimates, September 2023

2.1 Ground Survey Methods

We employed line transect methodology for surveying macropod density. This is a well-established and precise (Glass et al., 2015) methodology, successfully utilised by several ecologists to survey macropods throughout the 1980s and 1990s (e.g. Coulson 1979; Morgan 1979; Coulson and Raines 1985; Clancy et al. 1997; Morgan 1979; Southwell 1994). Based on the decision matrix presented in Coulson et al. (2021) distance sampling with density estimates is the most appropriate survey technique for EGKs as WWNFR as the reserve is a large and open grassland/woodland system and we are measuring a population of gregarious, grazing large-bodied macropods. Attempting to establish a population size is not possible at WWNFR due to its lack of distinct boundary (e.g. perimeter fencing) (Coulson et al., 2021).

Line transect surveys were carried out between 7.00 am and 10.00 am by Winton Wetlands employees on three separate occasions during September 2023 (6th, 13th and 20th of September 2023). All transects (See Table 1 and Figure 2 for details) were surveyed concurrently to reduce the incidence of double-counting kangaroos on the reserve. In the interests of comparison, we also utilized Hamilton's 'regional' approach to macropod population estimation, where the reserve was divided into four geographic regions- Northern, Southern, Eastern and South-Western (Figure 3). Transect number 20 was not sampled due to lack of vehicle access (water) (Table 1).

Surveys were carried out by an observer driving slowly (20-25km/h) in a vehicle along a marked out transect line and recording any kangaroos sighted along this transect. For each kangaroo sighting, the number of individuals in the 'mob' was recorded. The distance of this mob from the observer was then calculated using a laser rangefinder and the angle (from the transect line) recorded using a standard compass (Figure 4).

All raw data for the current (and previous) surveys is recorded and stored on the Winton Wetlands Sharepoint Drive.

Table 1. The details of the nineteen transects surveyed in September 2023. * denotes transects unable to be sampled

Region	Transect	Description	Length (km)	Direction (°)	Start		End	
					easting	northing	easting	northing
SW	1	Dam wall	7.068	300	412241	5965002	415307	5959493
SW	2	North Road	2.636	150	412281	5964103	413219	5961897
SW	3	Flynn's Track	1.248	60	413219	5961897	414356	5962466
SW	4	SW link track	1.373	150	414356	5962466	415107	5961303
SW	5	SW link track	1.706	160	415107	5961303	415531	5959559
SW	6	Flynn's Bike Path	2.89	340	415809	5963192	417103	5960629
S	8	Winton North Road	3.884	30	418411	5960100	421793	5965451
S	9	Firebreak (Hernans Tk)	4.712	30	419045	5961065	422321	5963601
S	10	Lunette Track	2.676	360	419772	5962320	419152	5965108
S	11	Ashmeads Swamp Rd	1.602	120	421331	5964764	422414	5963667
E	12	Humphries Lane	4.879	30	421793	5965451	425294	5967081
E	13	Boggy Bridge Road	3.554	330	421873	5965609	420459	5968661
E	14	NE Track	2.464	70	421700	5969441	423893	5970590
E	15	Firebreak alignment	1.228	160	424079	5970630	424660	5969599
E	16	Tom's track	5.037	290	424197	5966508	422691	5969956
E	17	Firebreak alignment	3.535	180	424660	5969599	424343	5966547
N	18	Pipeline track	10.204	45	412268	5964473	420485	5968529
SW	19	Flynn's Track	1.588	60	414356	5962466	415809	5963192
SW	20*	Boardwalk alignment	2.70	10	415758	5963223	415126	5965545

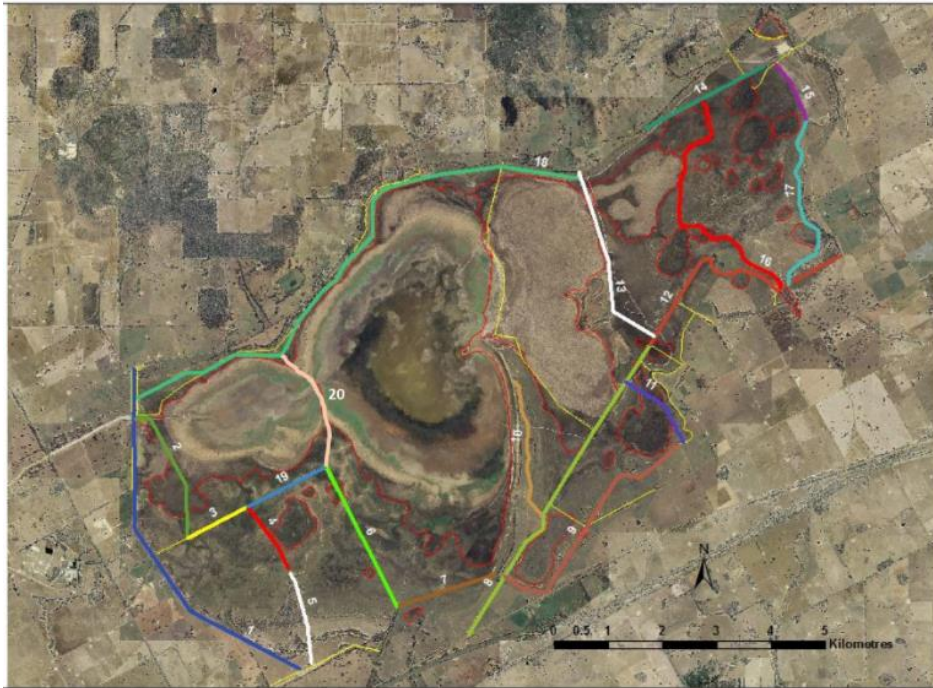


Figure 2. Aerial map of the twenty transects surveyed at Winton Wetlands Reserve in 2023 (map from Hamilton (2013), with additional transect 20 added)

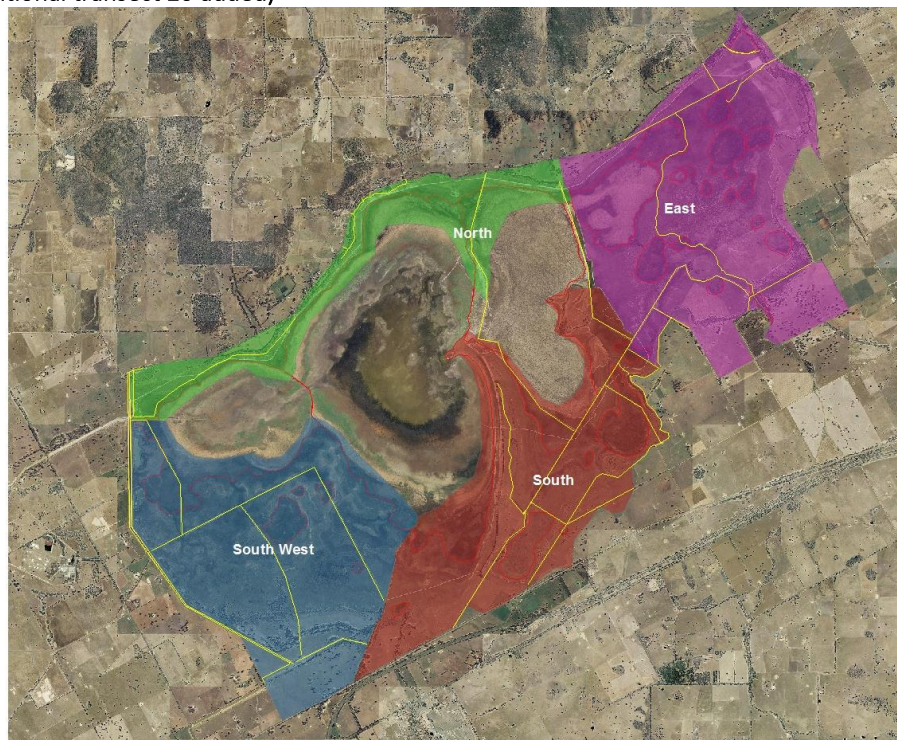


Figure 3. Map of defined 'regions' from Hamilton (2013), also used within our ongoing survey work (2019-2023)

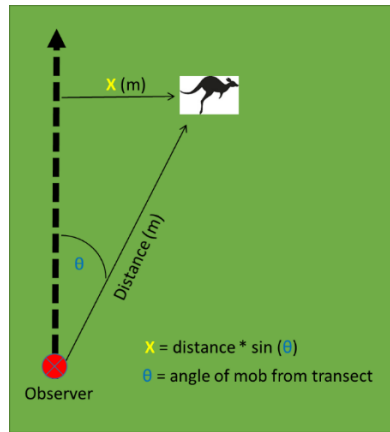


Figure 4. Illustration of survey method in the field. Observer travelling along transect in car measures distance to kangaroo mob using laser rangefinder and angle to mob from the direction of heading on the transect where 0 degrees is straight ahead using standard compass. A simple trigonometric formula allows calculation of X (m).

3 Survey Results

Raw data (distances, angles, and mob sizes) from the surveys were entered into a Microsoft excel spreadsheet. Distance 'x' (otherwise known as the perpendicular distance (m)) was calculated for each group of macropods observed using the formula $x = \text{distance (m)} * \sin(\theta)$.

These data were used in conjunction with the *Distance* (Buckland *et al.*, 2003) software package to model how detectability decreases with increasing distance from the transect. This allows estimation of total population density of macropods in the surveyed area (Table 2). These density estimates could then be extrapolated to the total area of available habitat on the reserve.

3.1 DISTANCE density and abundance estimate

Table 2. Eastern Grey Kangaroo density and abundance estimates calculated during each of three surveys (September 2023) using the conventional distance sampling software DISTANCE (Buckland *et al.* 2003). *note that the survey data from 20/09/2023 was excluded from the final analyses as it was likely biased by helicopter disturbance during a SES and VicPol search and rescue operation.

Survey date	Effort ^a (km)	N ^b	Model ^c	P ^d	Density ^e (no./ha)	Density ^f CI	CV ^g (%)	ESW ^h (m)
06/09/2023	62.3	194 (3329)	HN Cos	0.31	1.33	0.88-2.01	21	157
13/09/2023	62.3	224 (3647)	-X Cos	0.23	1.31	0.82-2.1	23	119
20/09/2023	62.3	204 (2525)	HR Cos	0.41	0.81	0.55-1.81	19	163

^aThe distance of line transects surveyed within each of the regions, "All" is all data pooled together from that survey event

^bThe number of kangaroo 'mobs' or clusters, with the total number of Eastern Grey Kangaroos observed during each survey in parentheses

^cThe most suitable detection function model and adjustments used to calculate Eastern Grey Kangaroo density and abundance (Buckland *et al.* 2003). -X = negative exponential, HR= Hazard-rate, HN= Half normal, Uni= Uniform, Cos= cosine adjustments, Poly= Polynomial adjustments, Herm= Hermite Polynomial adjustments

^dThe unconditional probability of detecting a kangaroo within the surveyed area (Buckland *et al.* 2003)

^eThe estimated density of Eastern Grey Kangaroo

^fThe 95% confidence interval for the density estimate

^gThe coefficient of variation (percentage) of the density estimate

^hThe Effective Strip Width (ESW) in metres where there is an unconditional probability of detecting an Eastern Grey Kangaroo in the surveyed area (Buckland *et al.* 2003)

There were too few (n= 18 total over 3 survey days) Black tailed Swamp Wallabies (BTWs) sighted to conduct any meaningful analyses.

During this survey 3329, 3647 and 2525 EGK were counted by observers across the approximately 62kms of transect surveyed. These EGK were in 194, 224 and 204 clusters, respectively. EGKs were observed in larger mobs up to 150 individuals, however the average cluster size observed was 15 EGK.

EGK density estimates for the whole reserve ranged from 0.81-1.33 EGK/ha. The precision of these density estimates is acceptable, given the modest values for the coefficient of variation (19-23%). Pooled data averaged across the three surveys was used to generate an overall mean EGK density for the reserve of 1.15 EGK/ha and there is a 95% chance that EGK density across the whole reserve was 0.75-1.97 EGK/ha. Based on the density of 1.15 EGK/ha and the availability of approximately 5000 ha of land (most of the Red gum swamp areas are now underwater or too wet to inhabit) on the reserve, we believe that the reserve currently carries approximately 5750 EGK.

We would highlight that the kangaroo survey, conducted on 20th September 2023, was likely to have been biased by the presence and disturbance of regular helicopter search activity that scattered the kangaroo mobs in the 3-5 days leading up to that survey event. To be more confident in the accuracy of our results it is prudent to exclude the density estimate and EGK counted for this third survey event (0.81 EGK/ha) and use the average density and EGK counted over the first two undisturbed survey events (1.32 ± 0.01 EGK/ha, 3488 ± 129 EGK counted). That being said, we estimate that the reserve currently carries 6600 EGK.

4 Discussion of results

4.1 Comparison with previous ground survey results

As we replicated the methods (and where possible the observers) for the on-ground survey we can directly compare the results of earlier surveys with 2023 density results. In 2020, we estimated a density of 0.45 EGK/ha (approximately 4000 EGK) on the reserve, slightly higher than the previous year (Figure 5). In 2021 we estimated a density that was approximately three times higher than that of 2020 (Figure 5), whilst in the most recent surveys, density estimates (excluding the third survey event) have continued to stabilise, (1.38 EGK/ha in 2021, 1.18 EGK/ha in 2022, 1.32 EGK/ha in 2023). Impressively, the error margins are so small on the 2023 surveys that the error bars are barely visible.

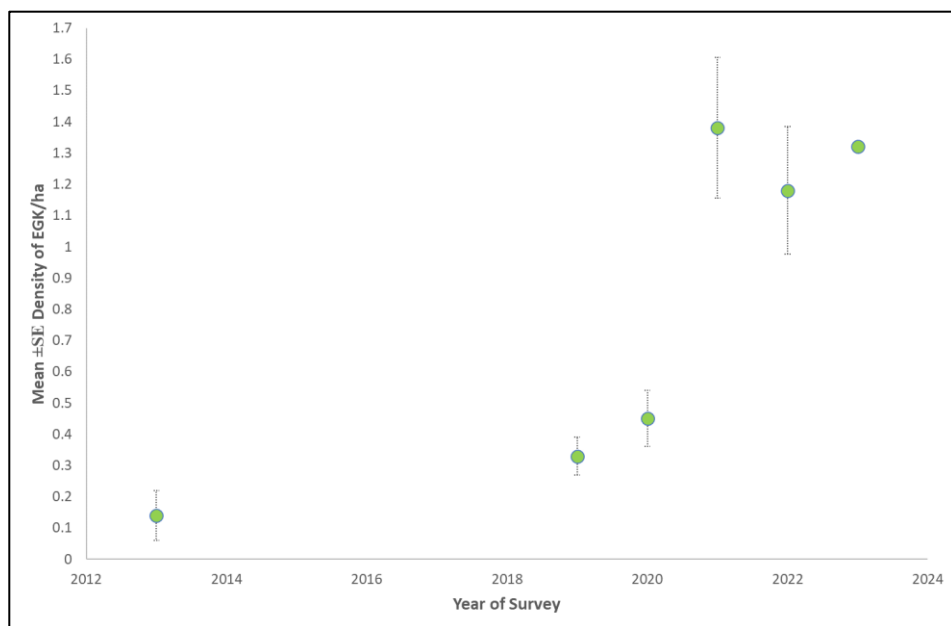


Figure 5. The average density (\pm S.E., EGK/ha) of Eastern Grey Kangaroos at Winton Wetlands Reserve, surveyed in Spring 2013 and 2019-2023. * note only survey 1 and 2 data were included in the analyses of 2023 information.

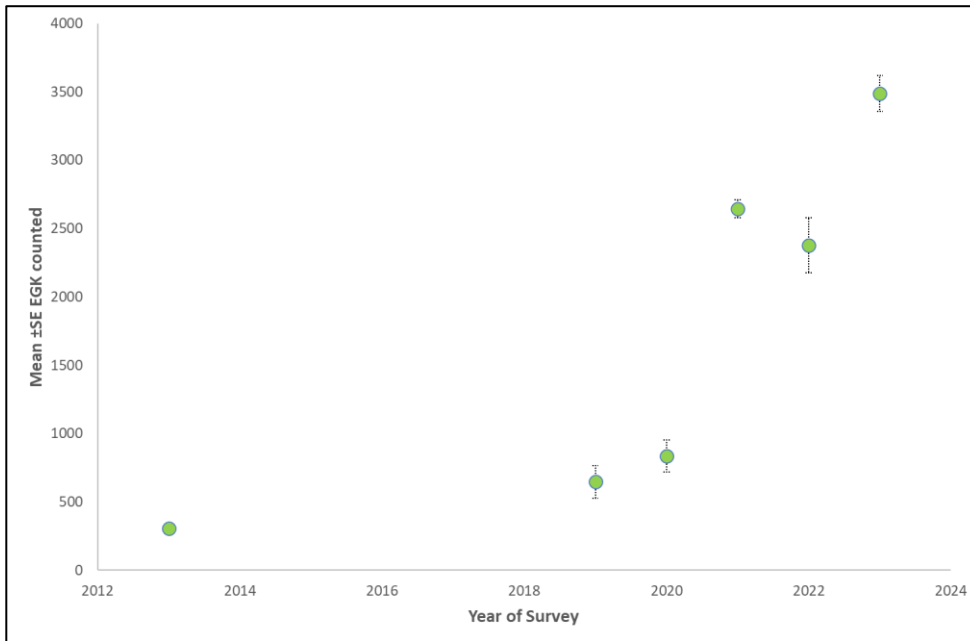


Figure 6. The average number (\pm S.E.) of Eastern Grey Kangaroos counted during spring surveys at Winton Wetlands Reserve (surveyed in Spring 2013 and 2019-2023). * note only survey 1 and 2 were included in this analyses for 2023.

4.2 Factors affecting Eastern Grey Kangaroo population/density

Kangaroo populations are known to expand and contract owing to a complex relationship between rainfall, resource availability, fecundity, and mortality (Caughley et al., 1984; Caughley et al., 1987; Davis et al., 2003; Fletcher, 2006, McLeod et al., 2021). It is highly likely that the increase in food resource availability (possibly as a result of greater rainfall; Figure 7) at Winton Wetlands could be one factor driving the increase in EGK densities measured in the 2021 surveys (compared with the 2020 surveys) and why the density has remained at around the same level in 2022 and 2023.

In an extensive ephemeral wetland system such as WWNFR, consecutive seasons of higher rainfall not only influences EGK resource availability (i.e. increases vegetative growth and therefore forage), but also diminishes the available area of dryland (terrestrial) habitat. This is an important consideration when interpreting the data and reviewing EGK population estimates over time (see Section 5.3 for more information).

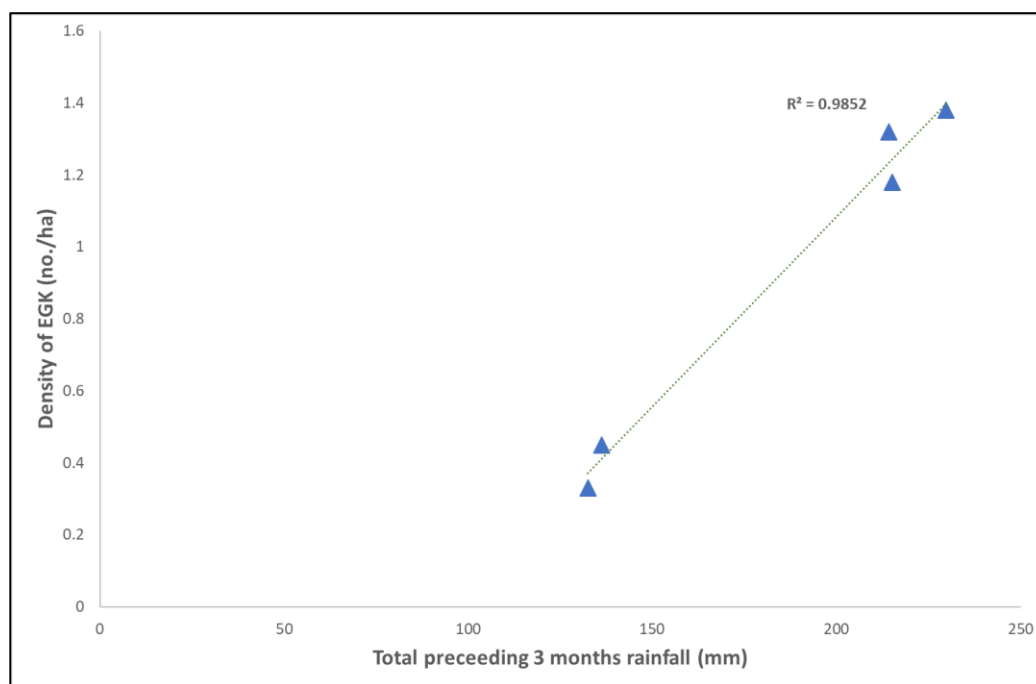


Figure 7. The average density of Eastern Grey Kangaroos counted during 5 spring surveys (2019-2023) at Winton Wetlands Reserve in relation to preceding winter rainfall (rainfall total recorded at Benalla Airport June, July, August).

4.3 Comparison with previous kangaroo surveys elsewhere in Victoria/Australia

Estimated EGK densities from aerial surveys of non-forested areas of the north east harvest region have decreased from 0.12 EGK/ha in 2018 (Moloney et al., 2018) to 0.10 EGK/ha in 2020 (Ramsay and Scroggie, 2020; Moloney et al., 2021) and has increased to 0.144 EGK/ha in 2022. EGK abundance estimates have reduced from 288,000 for the north-east region in 2018 to 239,850 in 2020 and 221,100 in 2021 (Ramsay and Scroggie, 2020; Moloney et al., 2021; Ramsay and Scroggie, 2021). However, an analyses of aerial survey results in 2022 reported that estimated EGK abundance increased to 356,000 in the north-east harvest zone (Moloney et al., 2023). The next statewide aerial survey for EGK is due in spring 2024.

Whilst the EGK densities reported in this survey (1.32 EGK/ha) are far higher than those in the north-east harvest region, they are relatively low compared to areas where active kangaroo management activities are the norm (ACT Government, 2017).

5 Macropod management actions at Winton Wetlands

5.1 Managing for kangaroos or managing for conservation/restoration outcomes?

Our data collected during 2023 indicates that estimated kangaroo densities at Winton Wetlands (1.32 EGK/ha) have remained stable for the past 3 years.

It is very easy to simply label kangaroos as the ‘problem’, where in reality the true definition of the problem (from all stakeholder’s perspectives) is not ‘overabundant kangaroos’ (Coulson, 2007). Instead, the problems are more accurately defined as things like decreased neighbouring crop yield, failure of regeneration or revegetation efforts or increased road accidents etc. It is important to clearly define these potential problems, explore whether kangaroos are indeed the *cause* of these through research and if so, plan to manage the kangaroo population to reduce the ‘problem’ (not to just reduce the kangaroo population). Recent publications advocate for a commitment to management focussed on achieving pasture outcomes rather than reduction in kangaroo population density per se (Snape et al., 2021).

5.2 Quantifying kangaroo related problems

5.2.1 Impacts on revegetation and regeneration of flora

Whilst acknowledging the presence of a variety of herbivores (hares, rabbits, wallabies, kangaroos, deer) on Winton Wetlands reserve, we have little *quantified* understanding of the impact of herbivory on our revegetation efforts. There is certainly a need to be innovative and active when protecting young revegetation areas from the impact of browsing and grazing. We are actively using alternative guarding to deter herbivores including mesh and kangaroo guards as opposed to corflute guards and planting trees adjacent to stags for physical protection. We will also consider other means of vegetation protection as they become available.

Our current research compendium includes research topics that specifically examine the impacts of herbivores (including kangaroos, rabbits, hares and wallabies) on native and introduced plants at Winton Wetlands and test the efficacy of innovative on-ground solutions (such as fencing) to some of these negative impacts. These research opportunities were circulated widely to local universities in 2023 in an effort to engage post graduate student participation.

Most recently research has been published suggesting that ‘Olfactory Misinformation’ may be a potentially effective deterrent for macropods foraging on highly palatable eucalypt seedlings (Finnerty et al., 2024). This study explored the olfactory treatment and its impacts on Swamp Wallaby browsing behaviour, demonstrating the effectiveness of spreading the scent of an ‘unpalatable’ neighbour on protecting new eucalypt seeds from browsing. The study highlights it has enormous potential for use on other macropod species at other sites.

Our updated revegetation plan (to be prepared for the new land managers) will include longer term goals for pasture and revegetation outcomes and suggest how, through measuring pasture and revegetation outcomes, we can make a more informed decision with regards to the necessity of local kangaroo culls.

5.2.2 Increased road collisions

There have been ongoing concerns from local residents with regards to the increase in the incidence of cars colliding with kangaroos along Lake Mokoan Road. Whether or not this is due to increases in kangaroo densities, or simply an increase in road traffic using the thoroughfare has yet to be determined. One simple way to potentially reduce the incidence of kangaroo collisions would be to reduce the speed limit along Lake Mokoan Road. Winton Wetlands will support a proposal to reduce the speed limit along the length of Lake Mokoan Road to 80km/h, should the neighbouring landholders support this option. In studies of kangaroo collisions in the ACT, most kangaroo collisions occurred in areas with speed limits above 60 km/h (Dunne and Doran, 2021). It follows that a reduction in the speed limit will actively reduce the likelihood of kangaroo collisions and increase the response time of the drivers to on-road hazards. This will also have a flow-on benefit to reduce collisions with other wildlife, including threatened turtle species.

5.3 Ongoing macropod population monitoring and management at Winton Wetlands

Due to the fact that kangaroos are highly mobile species, any active management (such as culls) should be applied at a large scale. Whilst Winton Wetlands provides kangaroos with highly suitable habitat in which to shelter and feed, the reserve is not fenced, hence the local macropods represent an ‘open population’ that allows for both emigration and immigration of animals. This movement of animals into and out of the reserve represents an issue when considering any culling activity. Our ongoing broadscale efforts at fox control are largely being negated by the constant emigration of new foxes into the landscape from neighbouring untreated land. A similar situation would exist should we consider localised culling of kangaroos in the reserve.

A statement released in 2021 on “Improving Kangaroo Management” recognises the need to apply kangaroo management methods at larger scales (Read et al., 2021). It states the need for the

establishment of both Regional Kangaroo Management Groups (that have input from land managers, ecologists, Indigenous, welfare, industry, government and conservation stakeholders) and also advocate for the creation of a National Kangaroo Strategy. Winton Wetlands would be an active participant in any regional kangaroo management group that was to form as a result of these recommendations.

This year's kangaroo density results suggest that our kangaroo population remains stable, but that kangaroo density is still considerably higher than during drier times when the full 8750ha of the reserve was available for habitation and foraging (2019, 2020). We believe that this increase in population density represents a reduction in available foraging habitat as opposed to a perceived explosion in local kangaroo numbers- the consistency of our density estimates over the past 3 years (since inundation) lend support to this belief.

We would encourage the readers of this report to consider the *true drivers* of this density increase. Winton Wetlands is an ephemeral and stochastic wetland ecosystem. Kangaroo populations will fluctuate in response to changes affecting this ecosystem. The increase in rainfall and hence food resource availability (and resulting increase in successful breeding), combined with the marked decrease in available terrestrial habitat (at least 3750 ha of area was inundated at the time of surveys) may well be driving the density increase in EGK at Winton Wetlands. As the wetlands have inundated and the terrestrial habitat decreased, the kangaroo population has clustered and moved to the higher ground. This has highly likely resulted in us 1) counting more kangaroos in total during the surveys and 2) counting larger mobs of kangaroos. The consistency of the density results from 2021-2023 lend further support to this argument as these 3 surveys have been conducted during inundation events where terrestrial habitat availability is at its minimum.

The benefit of long-term monitoring of our kangaroo population is that we can begin to track changes in density with changes in resource availability and understand the 'fluctuations in both kangaroo populations and their associated available food and habitat resources. To gain a comprehensive understanding of the nuances in local kangaroo population fluctuations, we need to continue gathering data and capture the population density changes as the drawdown (drying) events occur. As such we will not be pursuing any active kangaroo management at this stage. We believe that the consistent collection of this local kangaroo population information (along with local climate data and inundation information) will be vital to establishing any potential culling targets within the region, should the need exist to conduct those activities in the future. Indeed, even at the statewide level, Ramsey (2024) suggests that **'8 statewide survey events'** are necessary to sufficiently calibrate the predictive capacity of their EGK abundance models to determine accurate annual harvest quotas for EGKs. They have only completed half of these surveys to date.

Macropod population monitoring will continue at the wetlands on an annual basis, in early spring, following the same ground-based methods as outlined for previous surveys. This will allow us to track long term annual changes in the population density and examine any correlation between resource and habitat availability and local kangaroo density/population estimates. These data will assist us in adjusting our management activities when/where necessary. Methods used in this, and Hamilton's (2013) study are easily replicated; and staff requirements and costs are minimal. WWCOM owns 3 laser rangefinders and 3 compasses that can be used for future surveys. It took 36 staff hours total to complete the field component of the survey work (three staff for four hours per morning for 3 mornings). The three vehicles used would only use a maximum of a tank of fuel each, meaning overall ongoing annual costs of the survey are likely to be approximately \$2500 including staff pay.

Appendix I: Raw data collection sheet pro forma (from Hamilton 2013)

Transect Number	Section	Start Time	Finish Time	Species	Number	Distance (m)	Angle (°)
				K or W			
				K or W			
				K or W			
				K or W			

References

- Abu-Zidan, F., Parmar, K. and Rao, S. (2002). Kangaroo-related motor vehicle collisions. *Journal of Trauma-injury Infection and Critical Care* **53**: 360-363.
- ACT Government (2017). Eastern Grey Kangaroo: Controlled Native Species Management Plan. Environment and Planning Directorate, ACT Government, Canberra, Canberra, Australian Capital Territory
- Allcock, K.G. and Hik, D.S. (2004). Survival, growth, and escape from herbivory are determined by habitat and herbivore species for three Australian woodland plants. *Oecologia* **138**: 231-241.
- Barton, P.S., Manning, A.D., Gibb, H., Wood, J.T., Lindenmayer, D.B., Cunningham, S.A. (2011). Experimental reduction of native vertebrate grazing and addition of logs benefit beetle diversity at multiple scales. *Journal of Applied Ecology* **48**: 943-951
- Brunton, E.A., Srivastava, S.K. and Burnett, S. (2018) Spatial ecology of an urban eastern grey kangaroo (*Macropus giganteus*) population: local decline driven by kangaroo-vehicle collisions. *Wildlife Research* **45**: 685-695.
- Bryant-Boyle, L. (2020) Winton Wetlands Herbivory Impact Assessment. Report prepared for the University of Melbourne, Parkville, Victoria.
- Buckland ST, Anderson DR, Burnham KP, and Laake JL (2003). *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, London. 446 pp.
- Cairns, S.C., Bearup, D. and Lollback, G. (2019). Design and analysis of helicopter surveys of kangaroo populations in the South East NSW kangaroo management zone, 2018. A report to the New South Wales Office of Environment and Heritage.
- Clancy T, Pople A, and Gibson L (1997). Comparison of helicopter line transects with walked line transects for estimating densities of kangaroos. *Wildlife Research* **24**: 397-409.
- Caughley, J., Bayliss, P. and Giles, J. (1984). Trends in kangaroo numbers in western New South Wales and their relation to rainfall. *Australian Wildlife Research* **11**: 415-422.
- Coulson, G. M., and Raines, J. A. (1985). Methods for small-scale surveys of grey kangaroos. *Australian Wildlife Research* **12**, 119–125.
- Coulson, G.M. (2007). Exploding kangaroos: assessing problems and setting targets in Pest or Guest: the zoology of overabundance, Pp 174 – 181, edited by Daniel Lunney, Peggy Eby, Pat Hutchings, and Shelley Burgin. 2007. Royal Zoological Society of New South Wales, Australia.
- Descovich, K., Tribe, A., McDonald, I.J. and Phillips, C.J.C. (2016) The eastern grey kangaroo: current management and future directions. *Wildlife Research* **43**:576-589.
- Coulson, G.M., Snape, M., and Cripps, J.K. (2021) How many macropods? A manager's guide to small scale population surveys of kangaroos or wallabies. *Environmental Management and Restoration* **22 (S1)**: 75-89
- Davis, S. A., Pech, R. P. and Catchpole, E. A. (2003). Populations in variable environments: the effect of variability in a species' primary resource. In 'Wildlife Population Growth Rates.' Eds. R. M. Sibly, J. Hone, and T. H. Clutton-Brock pp 180-197. (Cambridge University Press: Cambridge.)
- Department of Environment, Land, Water and Planning (2019). Authorities to control wildlife (ATCW) data. Victorian Government Publication, Melbourne, Victoria.
- Department of Energy, Environment and Climate Action (2024). Authorities to control wildlife (ATCW) data. Victorian Government Publication, Melbourne, Victoria.
- Department of Environment, Land, Water and Planning (2019). Victorian Kangaroo Harvest Management Plan 2019. Victorian Government Publication, Melbourne, Victoria.
- Department of Environment, Land, Water and Planning (2022). Victorian Kangaroo Harvest Quota Determination 2022. Victorian Government Publication, Melbourne, Victoria.
- Dunne, B. and Doran, B. (2021) Spatio-temporal analysis of kangaroo-vehicle collisions in Canberra, Australia. *Ecological Management and Restoration* **22 (S1)**: 67-70.
- Dorrrough, J., McIntyre, S., Brown, G., Stol, J., Barrett, G., Brown, A. (2012). Differential responses of plants, reptiles, and birds to grazing management, fertilizer and tree clearing. *Austral Ecology* **37**: 569-582.
- Farnsworth, L.M. (2017). Winton Wetlands Revegetation Review 2017. Report prepared for WWCOM.
- Finnerty, P.B., Possell, M., Banks, P.B., Orlando, C.G., Price, C.J., Shrader, A.M. and McArthur, C. (2024) Olfactory misinformation provides refuge to palatable plants from mammalian browsing. *Nature ecology and evolution* <https://doi.org/10.1038/s41559-024-02330-x>
- Fletcher, D. (2006). Population dynamics of Eastern Grey Kangaroos in Temperate Grasslands. PhD Thesis, Institute of Applied Ecology, University of Canberra.
- Glass, R., Forsyth, D.M., Coulson, G. and Festa-Bianchet, M. (2015). Precision, accuracy, and bias of walked line-transect distance sampling to estimate eastern grey kangaroo population size. *Wildlife Research* **42**: 633-641.
- Hamilton, S.D. (2013). Winton Wetlands-Macropod Survey 2013. Report prepared for WWCOM by Hamilton Environmental Services, Tatong.
- Howland, B., Stojanovic, D., Gordon, I.J., Manning, A.D., Fletcher, D., and Lindenmayer, D. B. (2014). Eaten out of house and home: impacts of grazing on ground-dwelling reptiles in Australian grasslands and grassy woodlands. *PLoSOne* **9**(12).
- Howland, B., Stojanovic, D., Gordon, I. J., Radford, J., Manning, A. D., and Lindenmayer, D. B. (2016). Birds of a feather flock together: using trait groups to understand the effect of macropod grazing on birds in grassy habitats. *Biological Conservation* **194**: 89 –99.
- Manning, A.D., Cunningham, R.B., Lindenmayer, D.B. (2013). Bringing forward the benefits of coarse woody debris in ecosystem recovery under different levels of grazing and vegetation density. *Biological Conservation* **157**: 204-214.
- McIntyre, S., Cunningham, R.B., Donnelly, C.F., Manning, A.D. (2014). Restoration of eucalypt grassy woodland: effects of experimental interventions on ground-layer vegetation. *Australian Journal of Botany* **62**: 570-579.
- McLeod, S.R., Finch, N., Wallace, G., and Pople, A.R. (2021) Assessing the spatial and temporal organization of Red Kangaroo, Western Grey Kangaroo and Eastern Grey Kangaroo populations in eastern Australia using multivariate autoregressive state-space models. *Environmental Management and Restoration* **22 (S1)**: 106-123
- Meers, T. and Adams, R. (2003). The impact of grazing by Eastern Grey Kangaroos (*Macropus giganteus*) on vegetation recovery after fire at Reef Hills Regional Park, Victoria. *Ecological management and Restoration* **4 (2)**: 126-132
- Moloney, P.D., Ramsey, D.S.L., and Scroggie, M.P. (2018). State-wide abundance of kangaroos in Victoria: results from the 2018 aerial survey. Arthur Rylah Institute for Environmental Research Technical Report Series No. 296. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P.D., Ramsey, D.S.L., and Scroggie, M.P. (2021). State-wide abundance of kangaroos in Victoria: results from the 2020 aerial survey. Arthur Rylah Institute for Environmental Research Technical Report Series No. 324. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P.D., Ramsey, D.S.L., and Scroggie, M.P. (2023). State-wide abundance of kangaroos in Victoria: results from the 2022 aerial survey. Arthur Rylah Institute for Environmental Research Technical Report Series No. 356. Department of Energy, Environment and Climate Action, Heidelberg, Victoria.

- Morgan DG (1979). Density changes in black-faced kangaroo (*Macropus fuliginosus*) populations at Wyperfeld National Park, 1972-78. *Bulletin of the Australian Mammalogy Society* **6**: 51-2.
- Neave, H.M., Tanton, M.T. (1989). The effects of grazing by kangaroos and rabbits on the vegetation and the habitat of other fauna in the Tidbinbilla Nature Reserve, Australian Capital Territory. *Australian Wildlife Research* **16**:337-351.
- Office of Environment and Heritage (NSW) (2011). New South Wales Commercial Kangaroo Harvest Management Plan 2012–2016, Office of Environment and Heritage, Department of Premier and Cabinet (NSW), Sydney.
- Pople, A. R., and Grigg, G. (1999). 'Commercial Harvesting of Kangaroo in Australia.' (Environment Australia: Canberra.)
- Read, J.L., Wilson, G.R., Coulson, G., Cooney, R., Paton, D.C., Moseby, K.E., Snape, M.A., Edwards, M.J. (2021) Improving Kangaroo Management: A Joint Statement. *Environmental Management and Restoration* **22 (S1)**: 186-192.
- Ramsey, D.S.L. and Scroggie, M.P. (2020). Kangaroo harvest quotas for Victoria, 2021. Arthur Rylah Institute for Environmental Research Technical Report Series No. 323. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Ramsey, D.S.L. and Scroggie, M.P. (2021). Kangaroo harvest quotas for Victoria, 2022. Arthur Rylah Institute for Environmental Research Technical Report Series No. 334. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Ramsey, D.S.L. (2022) Kangaroo Harvest Quotas for Victoria 2023. Arthur Rylah Institute for Environmental Research Technical Report Series No. 349, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Ramsey, D.S.L. (2024) Kangaroo Harvest Quotas for Victoria 2024. Arthur Rylah Institute for Environmental Research Technical Report Series No. 371, Department of Energy, Environment and Climate Action, Heidelberg, Victoria.
- Snape M., Caley P., Baines G., and Fletcher D (2018). Kangaroos and Conservation: Assessing the effects of kangaroo grazing in lowland grassy ecosystems. Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra.
- Snape, M., Fletcher, D., and Caley, P. (2021) Species composition, herbage mass and grass productivity influence pasture responses to kangaroo grazing in a temperate environment. *Environmental Management and Restoration* **22 (S1)**: 16-23.
- Southwell, C. (1987). Activity pattern of the eastern grey kangaroo, *Macropus giganteus*. *Mammalia* **51**: 211–223.
- Southwell, C. (1994). Evaluation of walked transect counts for estimating macropod density. *The Journal of Wildlife Management* **58**: 348–356.
- Wilson, M. and Coulson, G. (2021) Early warning signs of population irruptions in Eastern Grey Kangaroo (*Macropus giganteus*) **22 (S1)**: 157-166.