WINTON WETLANDS

KANGAROO MONITORING PROGRAM RESULTS

2021

Table of Contents

Report prepared by:

Dr Lisa Farnsworth, Winton Wetlands Committee of Management

Field data collected by: Luke Legudi, Gil Cuneen, Louis Boyle-Bryant and Lisa Farnsworth

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, and yet also as a potential pest species for those involved in primary industries[1].

High-density populations of Eastern Grey Kangaroos (EGKs) have been associated with perceived (yet not often quantified) losses to primary industries through competition for food resources or reductions in crop yield[2]. Kangaroos are known to graze selectively and, at times, heavily enough to have a negative impact on fauna and flora through depletion of habitat[3]. With 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[4].

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 Environment, Land, Water & Planning (DELWP) 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*. The number of ATCW's issued for EGKs 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.[5]

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 10% of the estimated population. Estimated populations were calculated via state-wide aerial surveys conducted in 2017, 2018 and 2020.

The total sustainable harvesting rate in New South Wales is also calculated as a percentage of the total estimated population size[6], whilst in the ACT, their culling program sets density targets of 1 kangaroo per hectare in grasslands, 0.9/ha for open woodlands and 0.5/ha for woodlands.[7]

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 in spring 2019 and 2020. 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 and 0.45 kangaroos per hectare in 2020. No active kangaroo management was carried out after any of the previous surveys.

---

[1] Pople and Grigg 1999
[2] Coulson, 2007; Descovich et al., 2016
[3] 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
[4] Abu-Zidan et al, 2002; Coulson, 2007; Descovich et al., 2016; Brunton et al., 2018
5 DELWP, 2019
6 Office of Environment and Heritage NSW, 2011
7 ACT Government, 2017

2 Kangaroo population estimation, September 2021

2.1 Ground Survey Methods

We employed line transect methodology for surveying macropod density. This is a well-established and precise[8] methodology, successfully utilised by several ecologists to survey macropods throughout the 1980s and 1990s[9]. This was also the method employed by Hamilton (2013) in his initial macropod survey at the reserve, so for the benefit of direct comparison, we attempted to replicate Hamilton's study methods as closely as possible.

Line transect surveys were carried out between 7.00 am and 9.30 am by Winton Wetlands employees on three separate occasions during September (Table 1). All transects (See Table 2 and Figure 1 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 2). Transect number 9 and transect number 16 were not sampled due to lack of vehicular access (water) (Table 2).

We could then generate macropod density estimates for regions, as well as overall estimates for the entire reserve. 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 3).

All raw data for the current (and previous) surveys is recorded and stored on the Winton Wetlands OneDrive data cloud.[10]

Table 1. The timing and weather conditions during the three kangaroo surveys undertaken on September 8th, 15th and 29th, 2021 (data from Benalla Airport BOM weather station). Note survey on the 8th September took longer as we waited for fog to lift to get better visibility.

Date	Time start	Time end	Temp Range (°C)	Rainfall (24hr)	Wind speed (km/h)	Cloud cover
08/09/2021	0700	1030	1.2-15.8	0.1mm	calm	nil
15/09/2021	0700	0930	1.2-16.3	0	2	Light cloud (1)
29/09/2021	0700	0930	12.9-17.1	7.5mm	7	Cloudy (8)

Table 2. The details of the seventeen transects surveyed in September 2021. *Note: transect 7 from Hamilton's surveys was not sampled. Instead, we sampled a new transect number 20. * 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

[8] Glass *et al.*, 2015
[9] (e.g. Coulson 1979; Morgan 1979; Coulson and Raines 1985; Clancy *et* al. 1997; Morgan 1979; Southwell 1994)
[10] L>Restoration Science>Terrestrial Ecology>Fauna>Native Species>Kangaroo Management>2019 Survey

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

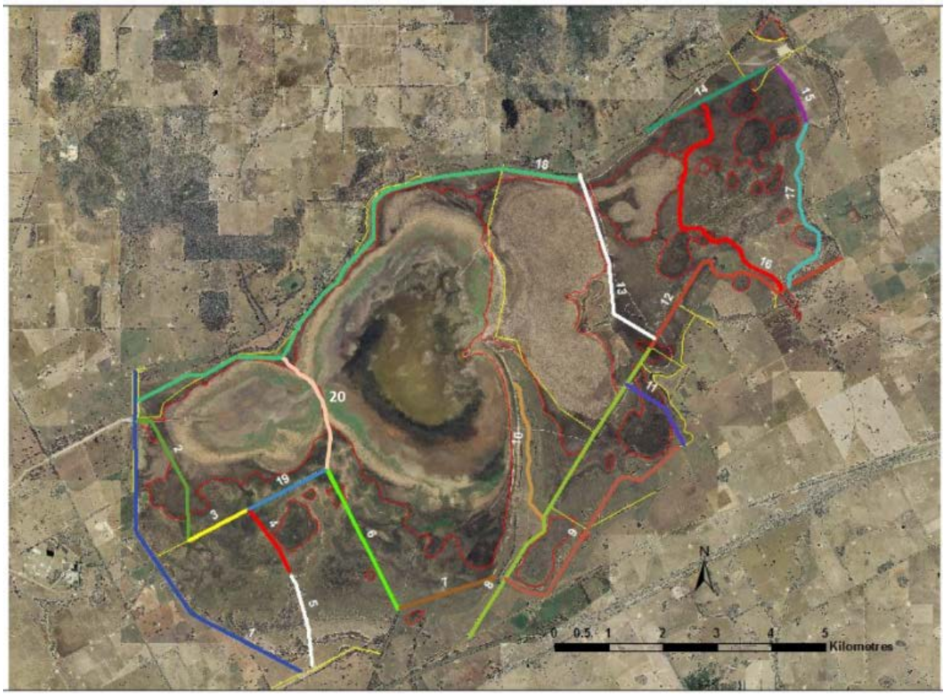

Figure 1. Aerial map of the twenty transects surveyed at Winton Wetlands Reserve in 2021 (map from Hamilton (2013), with additional transect 20 added)

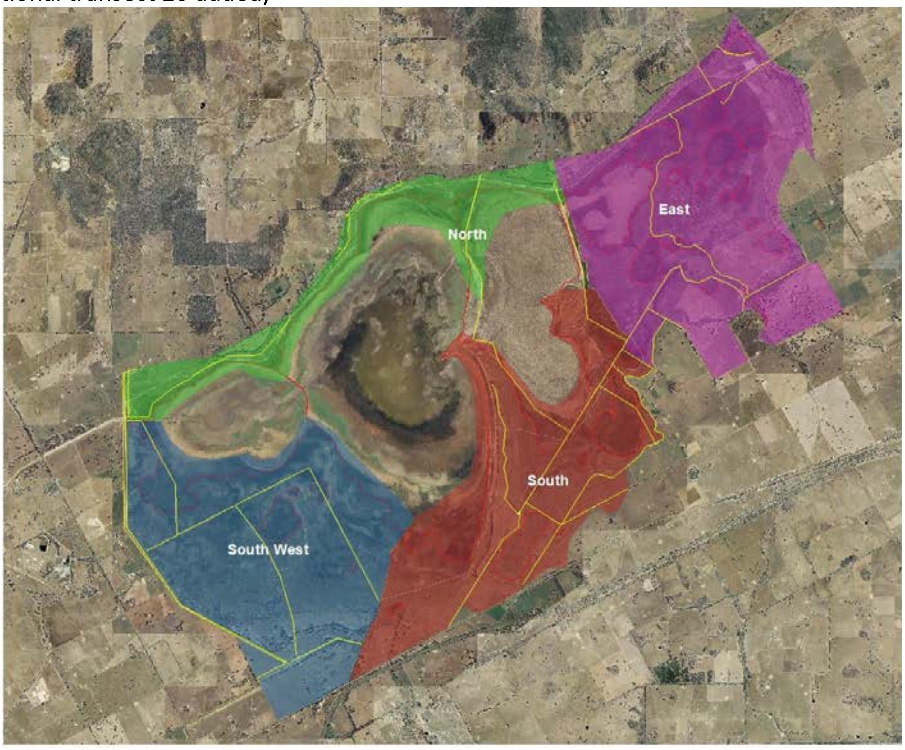

Figure 2. Map of defined 'regions' from Hamilton (2013), also used within our ongoing survey work (2019-2021)

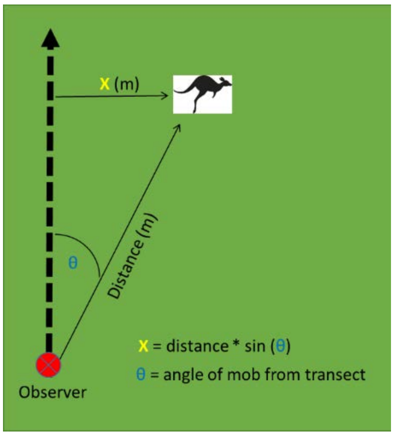

Figure 3. Illustration of survey method in the field. Observer travelling along transect in car measures distance from kangaroo mob using laser rangefinder and angle from mob using standard compass. A simple trigonometric formula allows calculation of X (m).

2.2 Aerial (thermal) survey methods

In addition to our ground-based surveys, we also undertook one night of aerial (drone) surveys (using thermal imaging technology) to address concerns from locals in relation to the accuracy of ground-based survey techniques. Specific concerns were raised about our ground survey technique missing hidden kangaroos in long grass or Cassinia, so we decided to compare our on-ground based results with density estimates from the air to validate our on-ground results.

We designed the aerial survey such that it could be repeated (i.e. transects could be replicated) if ongoing annual comparisons needed to be made. Each transect was a 'square' (1km x 1km) in shape and the drone footage taken covered a linear strip of approximately 52m x 4000m (20.8 hectares) per transect. This equates approximately 270ha of survey area in total. The location of the survey transects (Figure 4) were selected such that: 1) the area surveyed was representative of the mix and cover of each key vegetation type on the reserve (Table 3) and 2) the transects covered all main geographic regions on the reserve.

The aerial surveys were conducted by an experienced contractor, AUAV (Melbourne) on the evening of Monday 27th September 2021. A drone, equipped with a thermal imaging camera was flown around the perimeter of thirteen 1km x 1km square transects with the camera facing down. The drone was flown at an average height of 60m and speed of 20km/h. Surveys were undertaken after dark, between the hours of 2000hrs on the 27th September to 0300hrs on the 28th September in order to capture a good contrast on the thermal imaging footage. The video footage provided by AUAV was then analysed by WWCOM staff to derive density estimates of EGK/ha.

Table 3. The proportion of each vegetation type on the reserve and the relative distance of transect required to be sampled (in kms) within the 8750ha reserve.

Vegetation Type	Area (ha) on reserve	Area as proportion of whole reserve (ha)	Distance of survey transect required (nearest km)
Cassinia Scrub	578	6.6	3
Red Gum Swamp	2593	29.6	15
Riverine Swampy Woodland	2776	31.7	16
Plains Grassy Woodland	1257	14.4	8
Lunette Woodland	134	1.5	1
Grassy Woodland	140	1.6	1
Riverine Swampy Forest	11	0.1	0
Open Water/Tall Marsh Mosaic	1334	15.2	8

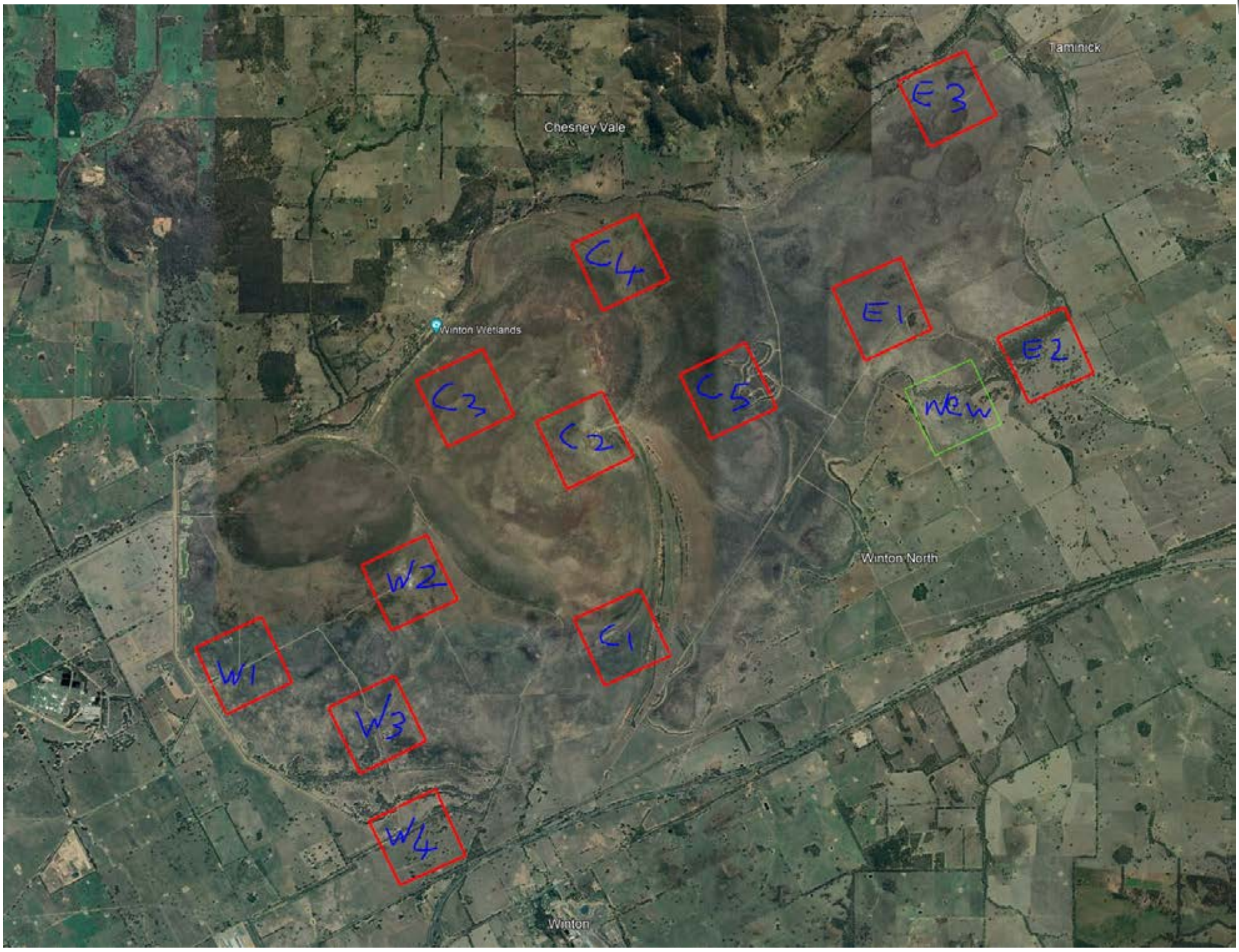

Figure 4. The locations of the thirteen aerial kangaroo survey transects (red squares) at Winton Wetlands Reserve, September 2021.*Note W4 was not sampled due to low powerlines being an issue. The "New" area in the green square was surveyed instead.

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 = distance (m) * sin (θ).

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 3). 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 4. Eastern Grey Kangaroo density and abundance estimates calculated during each of three surveys (September 2021) using the conventional distance sampling software DISTANCE (Buckland *et al.* 2003). ^ indicates insufficient data collected and therefore no analyses

Survey date	Region	Area (ha)	Effort[a] (km)	N[b]	Model[c]	P[d]	Density[e] (no./ha)	Density[f] CI	CV[g] (%)	Abundance[h]	Abundance[i] CI	ESW[j] (m)
08/09/2021	**All**	**6428**	**55.3**	**143 (2681)**	**-X/Poly**	**0.17**	**1.75**	**1.07-2.89**	**25**	**11282**	**6847-18592**	**61**
	SW	1817	18.5	22 (209)	-X/Poly	0.39	0.21	0.07-0.65	56	386	127-1176	117
	E	2016	15.7	63 (1235)	Uni/Cos	0.52	1.50	0.93-2.43	22	3026	1866-4908	184
	N	640	12.9	30 (658)	HR/Herm	0.07	5.63	2.96-10.7	37	3603	1895-6580	5
	S	1955	8.2	28 (579)	Uni/Poly	1.00	1.49	0.90-2.45	25	2912	1768-4798	238
15/09/2021	**All**	**6428**	**55.3**	**146 (2599)**	**HN/Cos**	**0.36**	**1.42**	**0.92-2.21**	**22**	**9162**	**5913-14196**	**149**
	SW	1817	18.5	38 (362)	-X/Poly	0.28	0.16	0.04-0.13	35	300	150-597	118
	E	2016	15.7	49 (911)	-X/Cos	0.47	2.23	0.95-5.24	40	4502	1917-10573	146
	N	640	12.9	30 (678)	Uni/Cos	0.54	2.30	1.28-4.15	30	1473	817-2656	220
	S	1955	8.2	29 (648)	-X/Cos	0.37	3.07	0.99-9.46	54	6001	1948-18487	94
29/09/2021	**All**	**6428**	**55.3**	**150 (2656)**	**HN/Cos**	**0.31**	**0.97**	**0.68-1.40**	**18**	**6264**	**4375-8698**	**193**
	SW	1817	18.5	45 (527)	HN/Cos	0.37	0.45	0.26-0.77	28	808	465-1403	228
	E	2016	15.7	27 (432)	-X/Cos	0.37	0.95	0.51-1.75	30	1911	1034-3534	162
	N	640	12.9	27 (805)	Uni/Cos	0.54	1.81	0.80-4.09	41	1158	512-2618	244
	S	1955	8.2	51 (892)	-X/Cos	0.27	2.08	0.80-5.40	45	4066	1564-10571	96

[a] The distance of line transects surveyed within each of the regions, "All" is all data pooled together from that survey event

[b] The number of kangaroo 'mobs' or clusters, with the total number of Eastern Grey Kangaroos observed during each survey in parentheses

[c] The 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

[d] The unconditional probability of detecting a kangaroo within the surveyed area (Buckland *et al*. 2003)

[e] The estimated density of Eastern Grey Kangaroo

[f] The 95% confidence interval for the density estimate

[g] The coefficient of variation (percentage) of the density estimate

[h] The estimated abundance of Eastern Grey Kangaroo within the surveyed area

[i] The 95% confidence interval for the abundance estimate

[j] The 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=16 total over 3 survey days) Black tailed Swamp Wallabies (BTWs) sighted to conduct any meaningful analyses.

During this survey a remarkably consistent 2681, 2599 and 2656 EGK were counted by observers across the approximately 55kms of transect surveyed. These EGK were in 143, 146 and 150 clusters, respectively. EGKs were observed in larger mobs up to over 100 individuals, however the average cluster size observed was 18 EGK.

EGK density estimates for the whole reserve ("All"= all transects included in analyses) ranged from 0.97-1.75 EGK/ha. These density estimates appear to be reasonable, given the modest values for the coefficient of variation (18-25%). Pooled data averaged across the three surveys was used to generate an overall mean EGK density for the reserve of 1.38 EGK/ha and there is a 95% chance that EGK density across the whole reserve was 1.16-1.61 EGK/ha. Based on the density of 1.38 EGK/ha and the availability of approximately 5000ha 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 6900 EGK.

From a regional perspective, the southern and northern regions on the reserve showed relatively high EGK densities (1.49-3.07 EGK/ha in the south; 1.81-5.63 EGK/ha in north) compared with other regions. The southwestern regions had consistently lower densities with 0.16-0.45 EGK/ha (Table 3).

3.2 Aerial thermal survey density estimates

The total number of kangaroos counted within each of the aerial survey transects ranged from 0 (an entirely inundated transect) to 42 EGK, with an average density of EGK across all transects being 1.24 EGK/ha (Table 5).

Table 5. Results of aerial thermal imagery surveys for Eastern Grey Kangaroos undertaken on the evening of Monday 27th September 2021. ^ denotes transects that were entirely or predominately under water (not included in analyses). Density (1.24 ± 0.18 EGK/ha) was calculated as total No. kangaroos counted in the transect divided by the total transect area (4000 m x 52 m =208000 m2 or 20.8ha).

Transect ID	Region	Kangaroos counted	Density (EGK/ha)
C1	S	42	2.02
C2^	S	1	0.05
C3^	N	0	0
C4	N	30	1.44
C5	S	34	1.63
C6	S	21	1.01
E1	E	32	1.54
E2	E	10	0.48
E3	E	22	1.06
New One	E	13	0.63
W1	SW	32	1.54
W2	SW	42	2.02
W3	SW	5	0.24

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 2021 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).

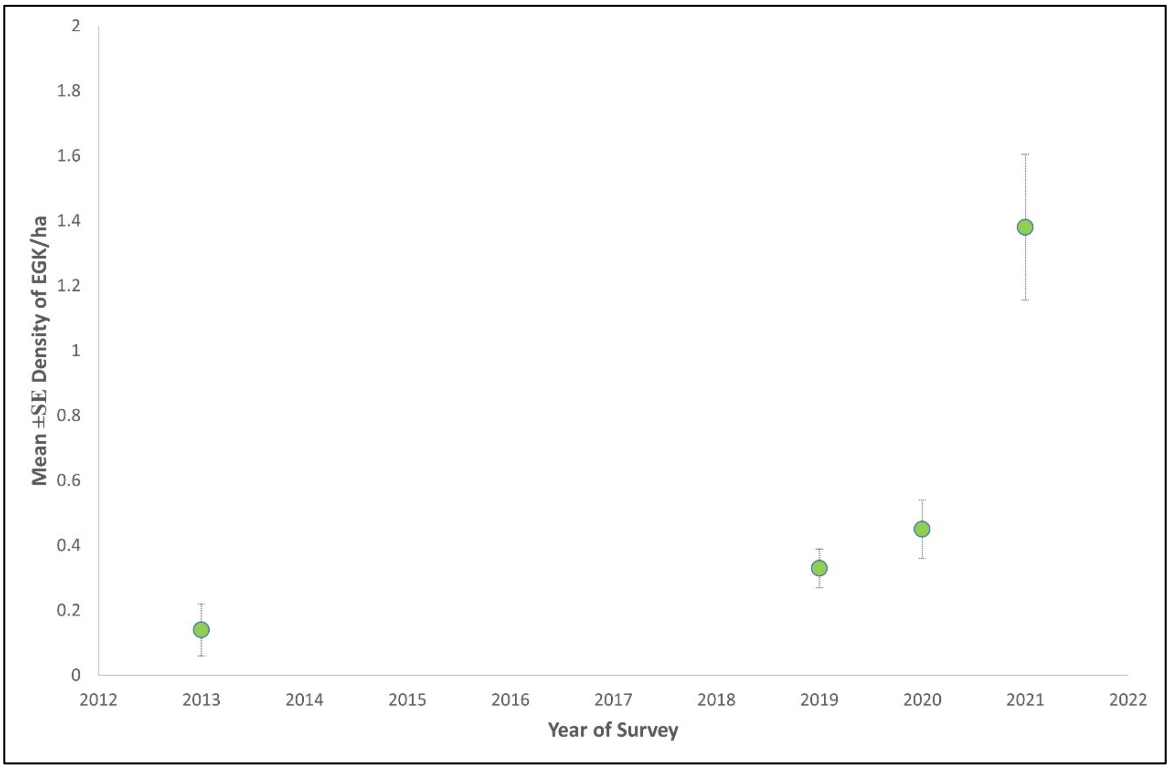

Figure 5. The average density (±S.E., EGK/ha) of Eastern Grey Kangaroos at Winton Wetlands Reserve, surveyed in Spring 2013, 2019, 2020 and 2021.

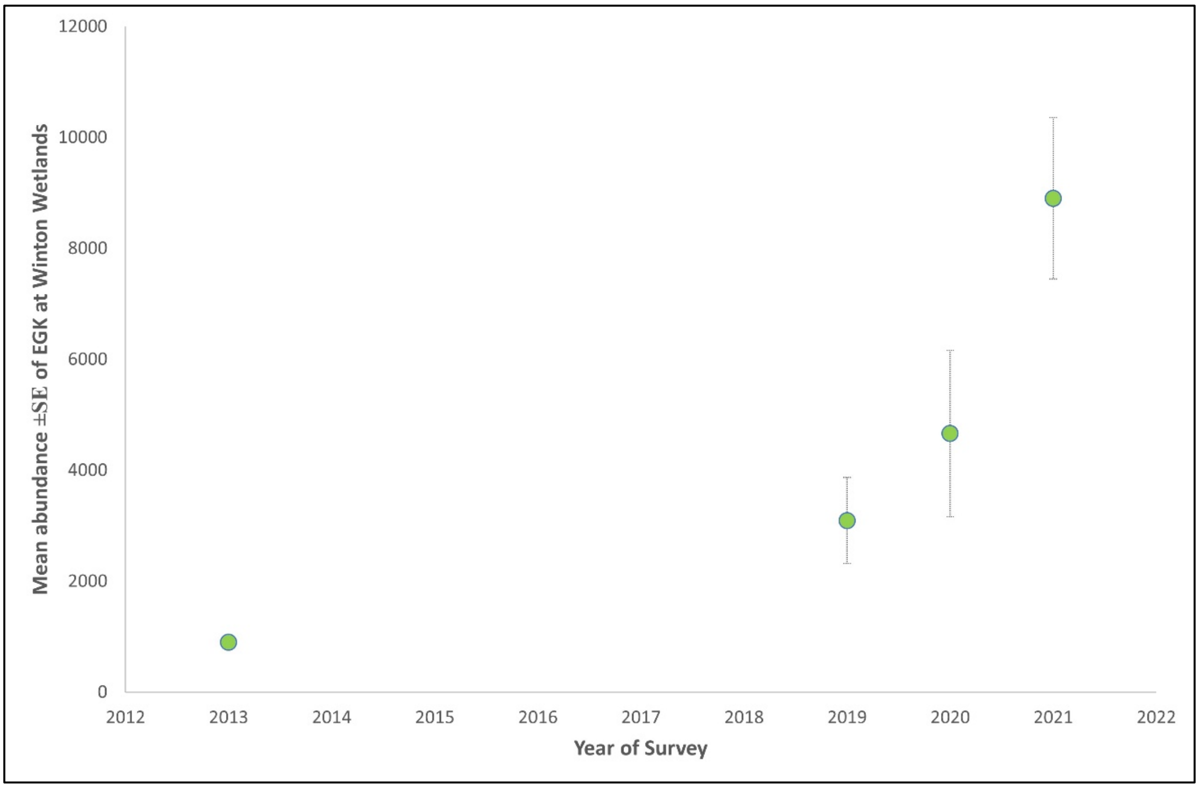

Figure 6. The average estimated abundance (±S.E.) of Eastern Grey Kangaroos at Winton Wetlands Reserve, surveyed in Spring 2013, 2019, 2020 and 2021.

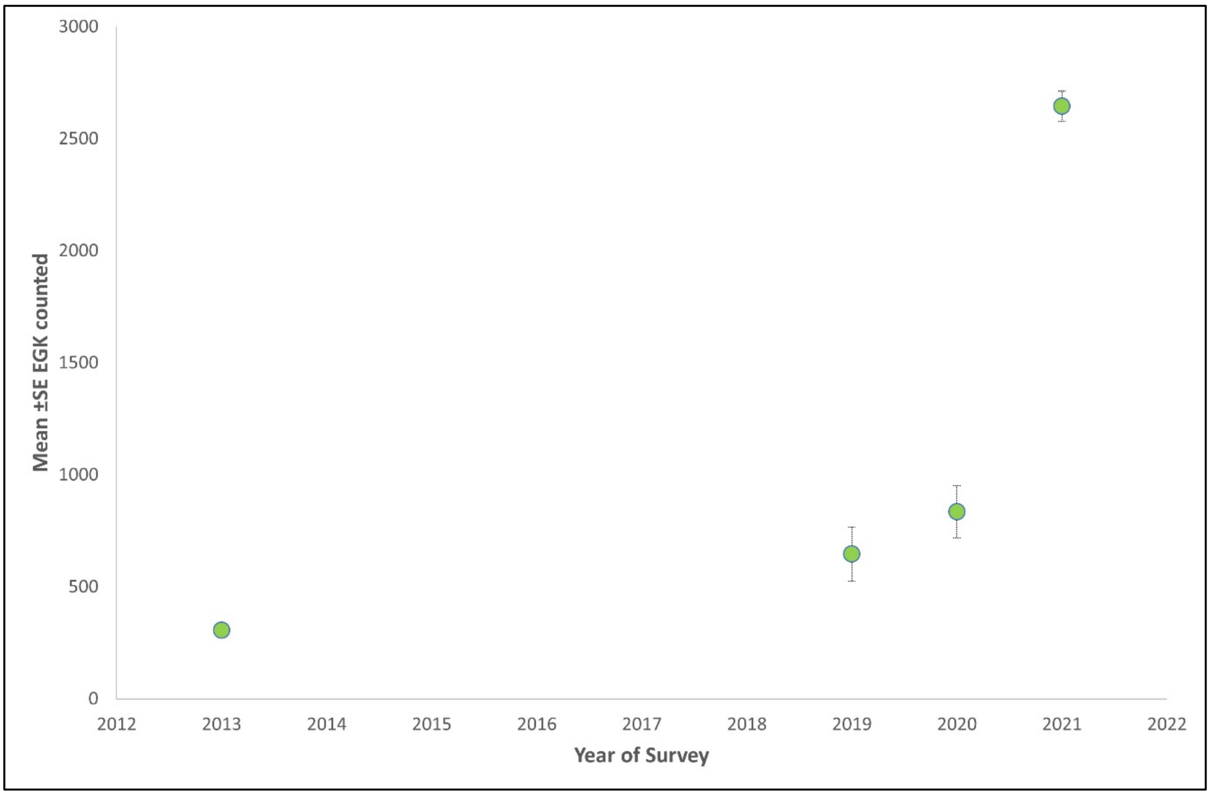

Figure 7. The average number (±S.E.) of Eastern Grey Kangaroos counted during spring surveys at Winton Wetlands Reserve (surveyed in Spring 2013, 2019, 2020 and 2021).

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 8) at Winton Wetlands could be one factor driving the increase in EGK densities measured in the 2021 surveys.

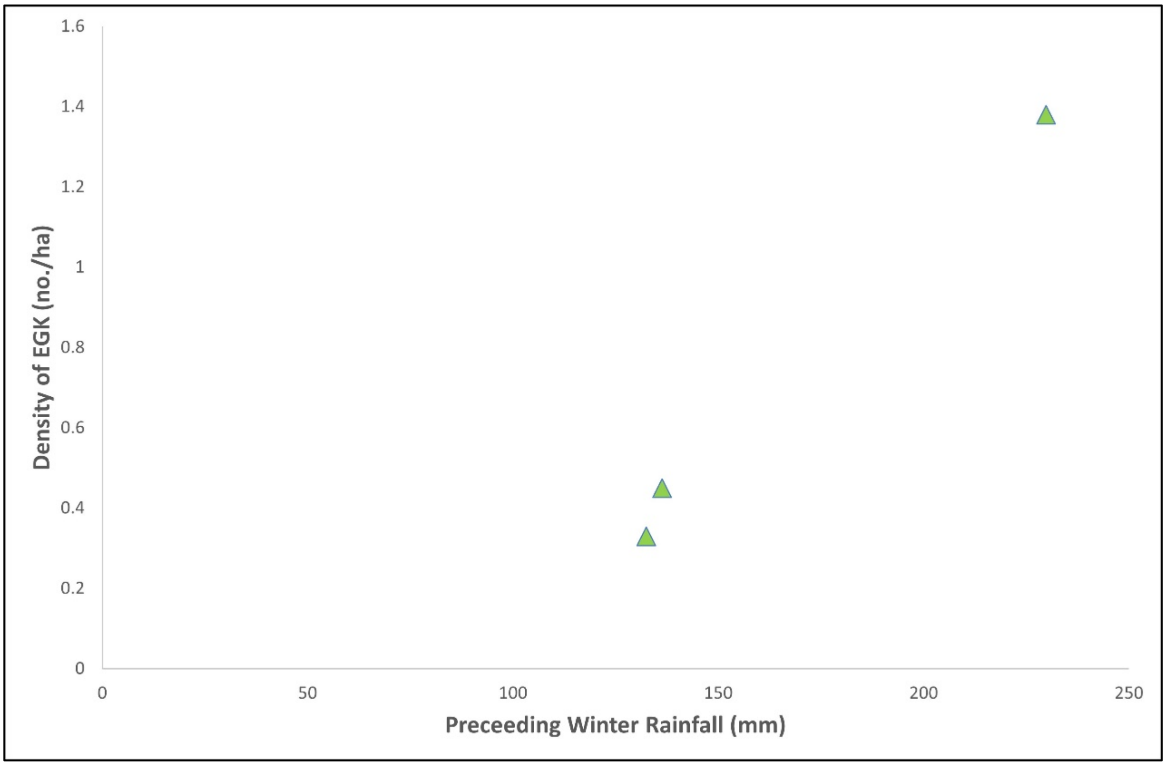

Figure 8. The average density of Eastern Grey Kangaroos counted during spring surveys at Winton Wetlands Reserve in relation to preceding winter rainfall (rainfall total recorded at Benalla Airport June, July, August 2021).

4.3 Comparison with previous surveys and kangaroo densities elsewhere in Victoria/Australia

It is difficult to compare what we have found at Winton Wetlands in 2021 with anywhere else in Victoria as the next state-wide aerial surveys are not scheduled until 2022. Estimated EGK densities from aerial surveys of non-forested areas of the north east region (the region in which the reserve lies) 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). EGK abundance estimates have reduced from 288,000 for the north-east region in 2018 to 239,850 for the region in 2020 (Ramsay and Scroggie, 2020; Moloney et al., 2021). There are no direct results for comparison in 2021.

Whilst the EGK densities reported in this survey (1.38 EGK/ha) are far higher than those in the north-east region (in 2020), they are relatively low compared to areas where active kangaroo management activities are the norm. In the ACT, EGKs have been recorded at densities as high as 7 EGK/ha (Jerrabomberra Nature Reserve) and are largely >1 EGK/ha across all of the kangaroo management areas in the territory (ACT Government, 2017).

4.4 Aerial versus ground-based survey methods?

We expected to easily be able to positively identify macropods using the aerial thermal imaging video footage (Figure 9), however due to the quality of the footage, the flight height of the drone, and the output of the thermal imaging, there were several limitations to the accuracy of the aerial survey kangaroo count. Firstly, it is possible that other animals within the reserve could be mistaken for kangaroos, including wallabies, foxes, birds perched in trees, arboreal mammals, and livestock present on grazing leases. Secondly, although pouch young have been included in the on-ground survey counts, it is impossible to count pouch young on the aerial survey footage. Lastly, the thermal imaging displays a spatial distribution of temperature differences using a grayscale range from black representing the coldest areas and white representing the warmest. Surface water and woody vegetation retained heat, emitting more thermal radiation then the surrounding landscape. Consequently, surface water and woody vegetation is represented as brightly as the kangaroos in the aerial survey footage (Figure 9 and Figure 10). This made it impossible at times to differentiate between a kangaroo and a small body of water, or a fallen log.

Due to these difficulties, only kangaroos that we could positively identify to be kangaroos with a high degree of certainty (i.e., they were the right shape and size) were included in the analyses, while 'unknown' blobs that were possibly other animals or logs or puddles were noted but not included in the final analyses.

Figure 9. Aerial thermal imagery captured over transect C1. There are X? kangaroos in this image. The whitest blobs below the base of the dead tree are puddles of water.

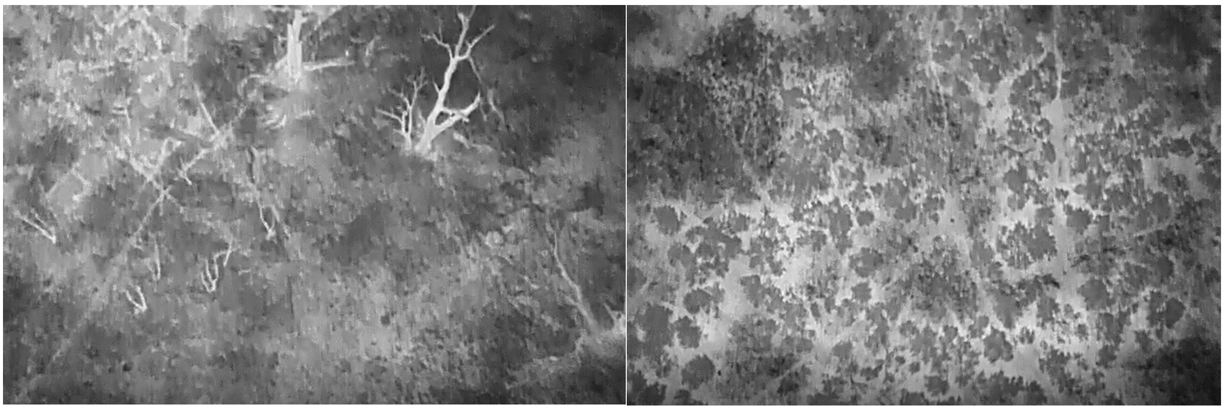

Figure 10. Aerial thermal imagery of a) woodland (with trees warmer than surrounds) and b) over water

There was a striking similarity between the densities of EGKs recorded in aerial (1.24 ± 0.18 EGK/ha) versus ground based (1.38 ± 0.22 EGK/ha) surveys. The similarity in the density results, along with the consistency of kangaroos counted during each individual survey, lends support to the notion that our ground surveys are not missing substantial amounts of macropods and that ground surveys are a perfectly acceptable method for future survey work. Recently published work by Coulson, Snape & Cripps (2021) suggests that distance sampling to achieve a 'density' estimate is an appropriate method of macropod surveys within a 'open' population of EGKs on a reserve of the scale and context of Winton Wetlands. It may, however, be worth repeating an aerial thermal survey during a drier period when there is less interference of water in the aerial footage captured.

Given that aerial surveys cost WWCOM $8000 per night, it is as such far more feasible, accurate and cost effective to be continuing our ground-based surveys in the long term (estimated total cost per year $1750-$2000 including labour, fuel, and analyses/reporting).

5 Macropod management actions at Winton Wetlands

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

Our data collected during 2019, 2020 and 2021 show that estimated kangaroo densities at Winton Wetlands (1.38 EGK/ha) are indeed steadily increasing and are now above that of the 0.9-1 kangaroo per hectare recommended by the ACT Government for the management of grassland/open woodland vegetation (ACT Government, 2017). These findings suggest that we need to be mindful of the density increase and monitor our on-ground revegetation works such that we track any negative impacts on our restoration progress.

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 on Winton Wetlands reserve, we have little *quantified* understanding of the impact of herbivory on our restoration efforts. In a discussion with Andie Guerin from the Regent Honeyeater Project, he highlighted that as kangaroo densities have increased:

- There has been an increase in damage to newly planted tubestock by kangaroos (and hares) and there is now an increased necessity for using taller (900mm) guards during tree planting work. This is increasing the on-ground cost of revegetation work on the reserve.
- There has been increasing physical damage to tree guards and stakes (kangaroo strikes)
- The 'tastier' shrub species are struggling to establish due to selective kangaroo browsing and are struggling to reach a height beyond 900mm high.

The use of the taller guards has increased survivorship of RHEP planting work over the past 2 years. Data collected by Andie Guerin at 4 revegetation sites over 121 ha of reserve indicated that on average there was 89 % survivorship of the tubestock planted across these 4 sites at 2 years post planting. We will continue to track the success and survivorship of these plants, as well as newly planting areas as they are established, via recording survivorship data and analysing photos collected through annual photopoint monitoring.

WWCoM has seen the successful development of canopy vegetation through the 2014/15 large scale revegetation works and has also observed highly successful tubestock and direct seeding works conducted by GBCMA in 2017 along the Lunette.

Andie has also suggested that strategically planting canopy vegetation close to existing old trees or fence posts is decreasing the amount of kangaroos striking and damaging tree guards and stakes. This method is of no use in the establishment of mid storey species as there are not enough natural objects in the landscape in which to plant next to. He has also suggested that they may trial the use of temporary fencing in some instances in order to take the pressure of the youngest plants.

With all of this information in mind, **our new research and development** plan will include 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 the fencing) to some of these negative impacts. These research opportunities will be circulated to local universities in an effort to engage post graduate student participation.

Our **updated revegetation plan** will include goals for pasture and revegetation outcomes and suggest how, through measuring pasture and revegetation outcomes, we can make a better informed decision with regards to the necessity of local kangaroo culls.

5.2.2 Increased road collisions

There has 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 collisons would be to reduce the speed limit along Lake Mokoan Road. Winton Wetlands would support the local neighbours in a bid to reduce the speed limit along the length of the road to 80km/h. 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.

5.3 Ongoing macropod population monitoring and management at Winton Wetlands

Due to the fact that kangaroos are highly mobile grazing 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.

The recently released statement on "Improving Kangaroo Management" recognises the need to apply kangaroo management methods at larger scales (Read et al., 2021). It states the need for a 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 we have a far larger population dwelling on the reserve compared with 2019 and 2020. This may indeed be the case; however, we would encourage the readers of this report to consider the true drivers of this density increase. The increase in rainfall and hence food resource availability (and resulting increase in successful breeding), combined with the marked decrease in available 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 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 'booms' and 'busts' in both kangaroo populations and their associated available food and habitat resources. To gain a more complete understanding of the nuances in local kangaroo population fluctuations, we need to gather further years of information – three years is by no means a long-term trend. 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 will be vital to establishing any potential culling targets within the region, should the need exist to conduct those activities in the future.

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 (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 27 staff hours total to complete the field component of the survey work (three staff for three 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 $1500-$2000 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. *Oecologica* **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 Ecol*ogy **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 desnities 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 Environment, Land, Water and Planning (2019). Victorian Kangaroo Harvest Management Plan 2019. 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.

Dorrough, 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.

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.

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.
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.