



Kangaroo harvest quotas for Victoria, 2024

D.S.L. Ramsey

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Acknowledgment

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We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.



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Summary

Context:

The Victorian Kangaroo Harvest Management Plan (KHMP) 2024–2028 outlines the standards and rules for the commercial harvesting of kangaroos. It considers relevant State and Commonwealth legislation and importantly requires that any commercial kangaroo harvesting is sustainable and humane. The KHMP is administered through the Kangaroo Harvesting Program (KHP), which supports the ecologically sustainable and humane commercial harvesting of wild grey kangaroo (Eastern Grey Kangaroo, *Macropus giganteus* and Western Grey Kangaroo, *M. fuliginosus*) populations in the state.

The KHMP provides for the commercial harvest of grey kangaroos on private land in designated harvest zones. To ensure sustainability of grey kangaroo populations in Victoria, there is a requirement to set harvest quotas for the KHP. The harvest quotas consider the predicted number of grey kangaroos permitted to be controlled through the Authority to Control Wildlife (ATCW) permit system so that the total take does not exceed ecological sustainable criteria.

Aims:

The aim of this project was to use the results from the recent 2022 kangaroo aerial survey to set the annual recommended maximum total take of Eastern and Western Grey Kangaroos for 2024 and apportion the total take between the ATCW permit system and the KHP.

Methods:

Aerial surveys to estimate the abundance of Eastern and Western Grey Kangaroos were undertaken during September/October 2022 within seven kangaroo harvest zones (Figure S1). The annual recommended maximum total take for 2024 was set at 10% of the estimated abundance from the 2022 survey, separately for each harvest zone. The predicted number of kangaroos permitted for control under the ATCW permit system in 2024 was estimated by analysing the historical ATCW grey kangaroo numbers using time-series models. The annual recommended maximum total take was then apportioned between the numbers predicted to be taken under ATCW permits, with the remainder allocated to the KHP.

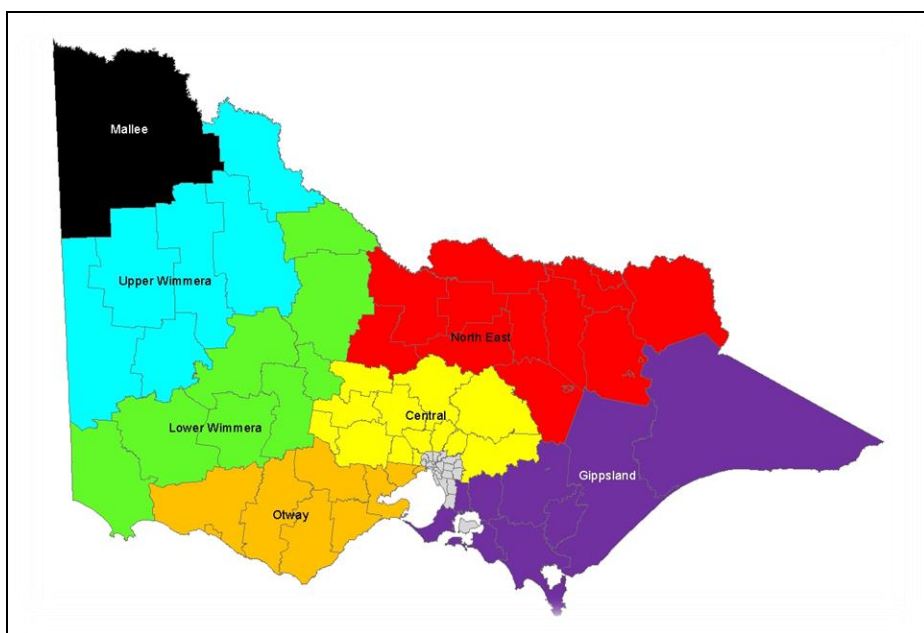


Figure S1. Kangaroo harvest management zones in Victoria. Each zone is formed by amalgamating groups of ecologically similar local government areas. The grey shaded areas are not subject to harvest. Colour-coding of harvest management areas matches the colours of the tags attached to carcasses during commercial harvesting operations.

Results:

The estimated total abundance of grey kangaroos from the 2022 aerial survey within the seven harvest management zones was 2,363,850 (95% confidence interval: 1,889,300–2,957,550). The recommended maximum total take for 2024 was assessed as 236,350 grey kangaroos, comprising 215,200 Eastern Grey Kangaroos and 21,150 Western Grey Kangaroos. The predicted number of grey kangaroos permitted for control under the ATCW permit system for 2024 was estimated to be 80,700, comprising approximately 34% of the total recommended take. After adjusting for the number predicted to be taken through ATCW permits, the allocation of grey kangaroos for the KHP for 2024 was 155,650.

Conclusions and implications:

The number of grey kangaroos predicted to be taken under ATCW permits for 2024 was higher than in 2023, most likely due to higher kangaroo abundance, which has resulted in a reduced allocation for the KHP. In particular, the take under ATCW permits predicted for the Mallee zone exceeded the total recommended maximum take for that zone. Given there is currently no mechanism available to limit permits under the ATCW permit system, this has resulted in zero allocation for the KHP for the Mallee zone. The total take of grey kangaroos through both the ATCW permit system and KHP between 2020 and 2023 (and imputed to the end of 2023) amounted to around 6% of the total grey kangaroo population estimated for each of those years in Victoria. Hence, the annual total take over the last four years has remained below the maximum allowable harvest fraction of 10%.

Recommendations:

- For the 2024 calendar year, a maximum total take of 236,350 grey kangaroos is recommended under the KHP and ATCW permit system. The maximum total recommended take of grey kangaroos in each harvest management zone, apportioned between the KHP and ATCW permit system, is shown in Table S1.
- Due to predicted take under the ATCW permit being higher than the recommended total take for the Mallee harvest zone, no commercial harvest is recommended for this zone in 2024.
- Kangaroos permitted for control under the ATCW permit system should be carefully monitored in the Mallee harvest zone to ensure demand does not exceed the maximum recommended sustainable take.

Table S1. Recommended total take of grey kangaroos, predicted Authority to Control Wildlife (ATCW) numbers and recommended quotas for the Kangaroo Harvesting Program (KHP) in 2024, by harvest zone. Values are rounded to the nearest 50.

Zone	Total take	Predicted ATCW	KHP quota
Mallee	5,600	6,300	0
Upper Wimmera	20,950	2,450	17,800
Lower Wimmera	55,600	16,600	39,000
Otway	18,900	3,550	15,350
Central	82,050	20,350	61,700
North East	35,600	27,500	8,100
Gippsland	17,650	3,950	13,700
Total	236,350	80,700	155,650

1 Introduction

Victoria's commercial Kangaroo Harvesting Program (KHP) commenced on 1 October 2019, underpinned by the regulatory guidelines detailed in the *Victorian Kangaroo Harvest Management Plan 2021–2023* (DELWP 2020). The program enables authorised harvesters to take kangaroos for commercial purposes in designated areas of Victoria. The commercial take is limited by quotas, set across seven commercial harvesting zones, which are based on ecologically sustainable criteria (Scroggie and Ramsey 2019). The maximum recommended total take of kangaroos in each harvest zone includes that taken through the KHP (KHP quota) and any kangaroos permitted for control under the Authority to Control Wildlife (ATCW) provisions of the *Wildlife Act 1975* (Victoria). Under the ATCW provisions, kangaroos can be legally culled by landholders after being issued a permit by Department of Energy, Environment and Climate Action (DEECA). To ensure the sustainability of kangaroo populations in the state, it is essential that the maximum number of kangaroos that are permitted to be taken under the KHP and ATCW each year is determined on clear ecological criteria, with administrative and regulatory controls in place to ensure that populations are not overexploited.

Scroggie and Ramsey (2019) developed quotas based on a policy of allowing a maximum harvest fraction of 10% of the estimated kangaroo population in each calendar year. Proportional harvest rates of 10% were recommended for the two kangaroo species that can be harvested in Victoria: Eastern Grey Kangaroo (*Macropus giganteus*) and Western Grey Kangaroo (*M. fuliginosus*). The recommended maximum total take is divided among seven harvest management zones, based on the proportion of the total state population in each zone. Because the total take for each harvest zone includes take through both the KHP and ATCW, the regulatory framework needs to include mechanisms for apportioning the total take between these two categories.

The 10% maximum total take of kangaroos recommended by Scroggie and Ramsey (2019) is conservative; total take in other states is typically set at 15% (Hacker et al. 2004; McLeod et al. 2004; Lunney et al. 2018). However, the 10% take reflects the depauperate data on kangaroo population dynamics from Victoria in comparison with other states. Most available data and analyses pertinent to setting kangaroo harvest quotas have been collected from populations of Red Kangaroos (*Osphranter rufus*), Western Grey Kangaroos and Euros (*Macropus robustus*) inhabiting arid and semi-arid ecosystems, including rangeland ecosystems in New South Wales, Queensland and South Australia, from which long time-series of population monitoring data are available (i.e. more than 10 years). These long-term data have been used to calibrate stochastic population models for assessing the ecological risks associated with harvesting policies for arid-zone kangaroo populations (e.g. Caughley et al., 1987). Such models combine time-series observations of abundance or density of kangaroos with harvest statistics and data on presumed drivers of kangaroo demography (such as rainfall and pasture availability) to infer relationships between the rate at which kangaroo populations increase, and spatially and temporally varying factors such as density dependence, resource availability and harvest offtake.

A similar model for examining the effect of spatially varying harvest has been developed for grey kangaroos in Victoria (Scroggie and Ramsey 2020). However, this model relied on ecological and demographic information collected from kangaroo populations elsewhere, because of a lack of comparable time-series abundance data for kangaroo populations in Victoria. As harvest and abundance monitoring data from Victoria accumulate, the spatial harvest model can be more reliably calibrated to represent the population dynamics of Victorian kangaroos, which should lead to greater confidence when using the model for management decisions, such as setting quotas. In the meantime, conservative quotas should be retained until adequate local monitoring data and management experience can be used to inform and validate the spatial harvest model for Victorian kangaroo populations.

This report presents an analysis to guide the setting of quotas for the commercial harvest of kangaroos through the KHP for the 2024 calendar year. The analysis is based primarily on estimates for the grey kangaroo population derived from aerial surveys conducted during September/October 2022. In Victoria, aerial surveys occur every two years and hence, recommended maximum total take is based on the most recent population estimate. Previous research has identified that the risks of overharvesting using a biennial survey frequency is low in mesic environments such as Victoria, especially when combined with a

conservative harvest fraction of 10% (Pople 2008). Additionally, we used historical ATCW permit information to predict the likely numbers of grey kangaroos permitted for control under the ATCW permit system during 2024, and subsequently applied these numbers to adjust the KHP quotas for each harvest zone.

2 Methods

2.1 Kangaroo abundance estimates

Moloney et al. (2017, 2018, 2021) used aerial survey data collected from the non-forested parts of Victoria (but including mallee vegetation types) to determine abundances of Red, Western Grey and Eastern Grey Kangaroos across the entire state (excluding metropolitan Melbourne). Full details of the survey methodology and interpretation are given in Moloney et al. (2017), Scroggie et al. (2017) and Moloney et al. (2018). The three kangaroo species are referred to hereafter as RK, WGK and EGK; GK refers to both grey kangaroos combined.

The aerial surveys were designed around seven harvest management zones, with transects allocated randomly within the zones in proportion to their areas. The boundaries of the zones were formed by amalgamating adjacent local government areas (LGAs) with similar ecological features, land use and climate (Figure 1, Table 1). Separate estimates of abundance for RKs and GKs were derived from the aerial surveys. In the west of the state, the geographic ranges of EGKs and WGKs overlap substantially (Caughley et al. 1984), and as the two species cannot be reliably distinguished from the air, the aerial surveys alone did not allow apportionment of the total grey kangaroo population between the two species. To resolve this uncertainty, vehicle transect surveys were conducted across the overlap zone to estimate the spatial variation in the proportions of EGKs and WGKs, allowing the total count of GKs within each of these strata to be divided between the two species (Moloney et al. 2021). Collectively, the results of these surveys are the most up-to-date and comprehensive information on the status of kangaroo populations in Victoria and provide a robust basis for determining ecologically sustainable harvest quotas.

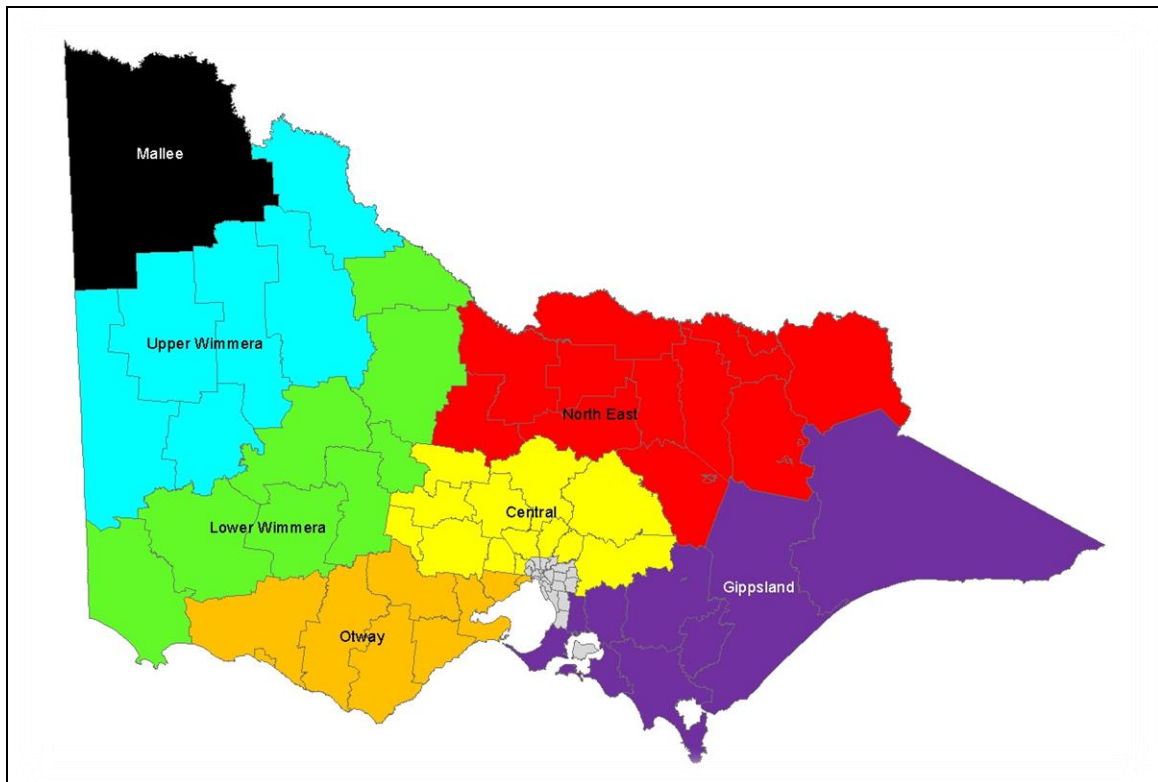


Figure 1. Kangaroo harvest management zones in Victoria. Each zone is formed by amalgamating groups of ecologically similar local government areas. The grey shaded areas are not subject to harvest. Colour-coding of harvest management areas matches the colours of the tags attached to carcasses during commercial harvesting operations.

Aerial surveys of kangaroos were undertaken in the seven harvest management zones from 19 September to 11 October 2022 along 150 transects, comprising around 3000 km of survey effort. The abundances of EGKs and WGKs within each harvest zone were estimated using line transect methods and design-based inference. Further details of these methods can be found in Moloney et al. (2021).

2.2 Recommended maximum total take of grey kangaroos for 2024

Abundance estimates for EGK and WGK for each harvest zone derived from the 2022 aerial survey were used to set the recommended maximum total take for the 2024 calendar year at 10% of the abundance estimates. The recommended maximum total take for grey kangaroos were then apportioned between WGK and EGK using the estimate of species composition derived from ground surveys in those zones where the two species overlap (Moloney et al. 2021).

The kangaroo take in each harvest zone from both ATCW permits and the KHP during 2023 were complete up to 30 September 2023. The total take for the entire calendar year was then inferred by imputing the numbers of ATCW permits issued and KHP allocated by one quarter, assuming the rate of uptake was similar to the previous three quarters, to accommodate the remaining portion of the calendar year.

2.3 Numbers of grey kangaroos taken under ATCW permits

Because it is not possible to know, at the outset of a harvest period, how many grey kangaroos are likely to be taken under ATCW permit provisions, the potential number of grey kangaroos taken under ATCW permits was predicted by analysing the historical time series of kangaroo numbers permitted for control under ATCW permits.

Historical numbers of grey kangaroos permitted for control under ATCW permit provisions (hereafter ATCW numbers) were available for each harvest zone from January 2002 to 30 September 2023. As mentioned in section 2.2, the total take for the 2023 calendar year was estimated by imputing ATCW permits and the KHP uptake for the final quarter of 2023.

The historical time series of ATCW numbers for each zone were modelled using an exponential smoothing state-space (ETS) model (Holt 2004) as well as an autoregressive integrated moving average (ARIMA) model (Hyndman and Athanasopoulos 2021). Both models attempt to find trends in the time series for the purpose of forecasting (predicting) into the future. Exponential smoothing models weight observations, with weights decaying exponentially with time. Hence, the ETS models place greater weight on more recent observations. ARIMA models employ both autoregressive and moving average components for smoothing and prediction. We fitted both ETS and ARIMA models to the time series of ATCW numbers and examined their relative predictive accuracy by examining the mean absolute scaled error (MASE) of the fitted models (Hyndman and Athanasopoulos 2021). The best-fitting model for each zone was then used to predict the likely number of kangaroos authorised under ATCW permits for the 2024 calendar year.

2.4 KHP harvest quotas for 2024

Once the predicted number of grey kangaroos permitted for control under ATCW permit provisions in 2024 was estimated, the recommended maximum total take of both WGK and EGK for 2024 was apportioned between the predicted ATCW numbers and the KHP by subtracting the predicted ATCW numbers from the total take, separately for each harvest zone. Hence, KHP quotas in each harvest zone apply to take from both species (i.e. grey kangaroos).

3 Results

3.1 Recommended maximum total take of grey kangaroos for 2024

The abundance estimates for grey kangaroos in each harvest zone derived from the 2022 aerial survey is given in Table 1. The imputed take of grey kangaroos for the 2023 calendar year through both the ATCW permit system and the KHP amounted to 159,610 kangaroos, which was approximately 6.8% of the estimated abundance for 2022 (Table 2). However, the total take for some harvest zones, such as the Mallee and North East was relatively high (Table 2). This was similar to the total proportional take for 2020 and 2021 (6.1 and 6.4%), but higher than in 2022 (5.2%) (Figure 2). Based on these estimates, the maximum allowable take of grey kangaroos for 2024, using a maximum proportional offtake of 10%, is given in Table 3.

Table 1. Grey kangaroo abundances in seven harvest zones covering the non-forested part of Victoria, estimated from aerial surveys undertaken in 2022 (Estimate). SE – Standard error, LCL, UCL – lower and upper 95% confidence intervals. Estimates are rounded to the nearest 50.

Harvest zone	Estimate	SE	LCL	UCL
Mallee	55,900	13,449	34,000	91,850
Upper Wimmera	209,650	66,719	111,500	394,100
Lower Wimmera	556,050	142,804	330,100	936,700
Otway	189,200	81,323	78,800	454,500
Central	820,550	114,884	602,900	1,116,800
North East	355,950	163,663	144,550	876,600
Gippsland	176,550	43,488	106,000	294,050
Statewide total	2,363,850	271,134	1,889,300	2,957,550

Table 2. Take of kangaroos from the Kangaroo Harvesting Program (KHP) and Authority to Control Wildlife (ATCW) permit process for the 2023 calendar year and the estimated take as a percentage (%) of the 2022 kangaroo abundance. The take for both ATCW and KHP was imputed for the last quarter of the 2023 calendar year.

Harvest zone	ATCW	KHP	Total	%
Mallee	6436	1196	7632	13.7
Upper Wimmera	2159	4732	6891	3.3
Lower Wimmera	16512	22723	39235	7.1
Otway	4461	9203	13664	7.2
Central	16981	28180	45161	5.5
North East	27673	6657	34330	9.6
Gippsland	3908	8789	12697	7.2
Statewide total	78,130	81,480	159,610	6.8

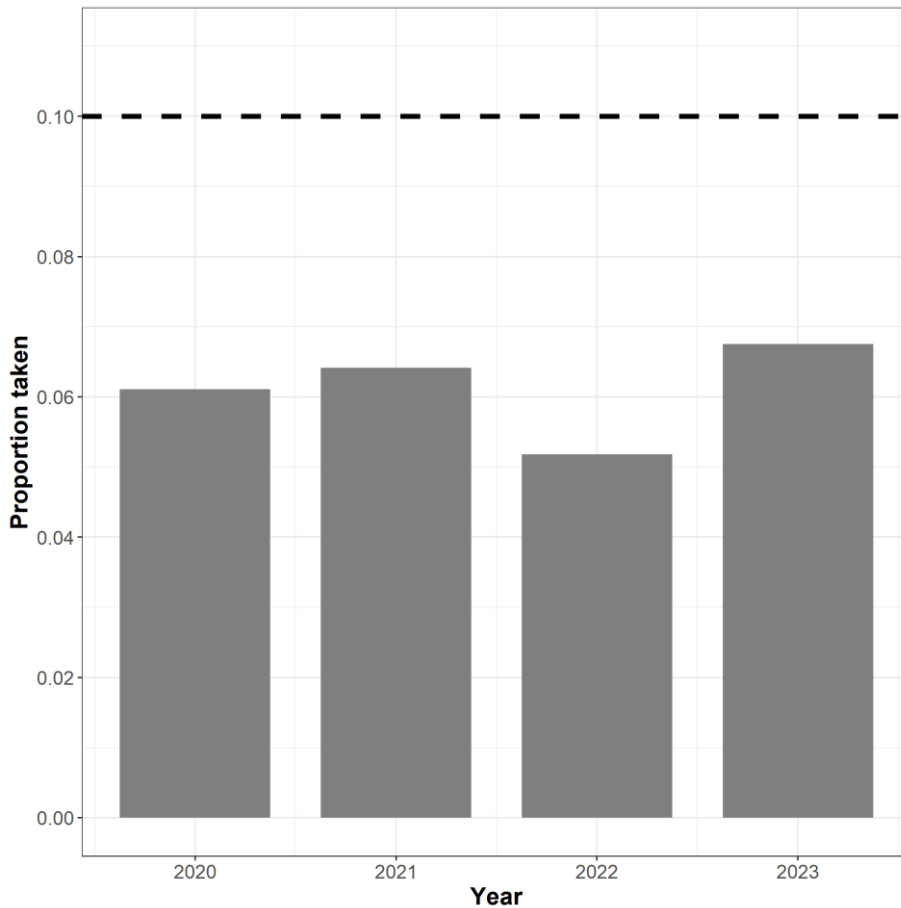


Figure 2. The proportion of the total population of grey kangaroos taken through either the Authority to Control Wildlife (ATCW) permit process or Kangaroo Harvesting Program (KHP) from 2020–2023. Dashed line indicates the maximum allowable take of 10%.

Table 3. Recommended maximum total take of grey kangaroos in 2024 by harvest zone. Totals include all predicted take under both Authority to Control Wildlife (ATCW) and Kangaroo Harvesting Program (KHP) allocations for the period 1 January – 31 December 2024. Recommended maximum total takes are set at 10% of the population per year and are rounded to the nearest 50.

Harvest zone	Eastern Grey Kangaroo	Western Grey Kangaroo	Grey kangaroos combined
Mallee	700	4,900	5,600
Upper Wimmera	9,900	11,050	20,950
Lower Wimmera	50,400	5,200	55,600
Otway	18,900		18,900
Central	82,050		82,050
North East	35,600		35,600
Gippsland	17,650		17,650
Statewide total	215,200	21,150	236,350

3.2 Numbers of grey kangaroos taken under ATCW permits

Based on the MASE accuracy measure, the ARIMA model including both autoregressive and moving average components was generally the preferred model for ATCW numbers because of its better predictive accuracy than the ETS model (Table 4). However, the ETS model had slightly better predictive accuracy for ATCW numbers in the Gippsland and Mallee zones. The best fitting model for each zone was subsequently used to predict numbers likely to be taken under the ATCW permit process in 2024 (Figure 3). However, predictions were rather imprecise for some zones, such as for the Mallee and Lower Wimmera zones (Table 5; Figure 3).

The numbers of grey kangaroos predicted to be controlled under ATCW permits in 2024 are lower than the recommended maximum total take for each zone, except for the Mallee zone, where ATCW take is predicted to exceed the recommended take. Overall predicted take under ATCW permits amounts to 3.4% of the total population abundance of grey kangaroos estimated in 2022 (Table 5). Generally, there has been slight increases in the number of kangaroos permitted for control through ATCW provisions during 2023, compared with the number permitted for control during 2022 (Figure 3).

Table 4. Predictive accuracy expressed as the mean absolute scaled error (MASE) for two models (ETS and ARIMA) fitted to the time series of Authority to Control Wildlife (ATCW) permit numbers between 2002 and 2023. Lower values (bolded) indicate models with better predictive accuracy.

Zone	ETS	ARIMA
Mallee	0.75	0.76
Upper Wimmera	1.11	0.87
Lower Wimmera	0.98	0.77
Otway	0.76	0.76
Central	1.02	0.83
North East	0.99	0.95
Gippsland	0.76	0.85

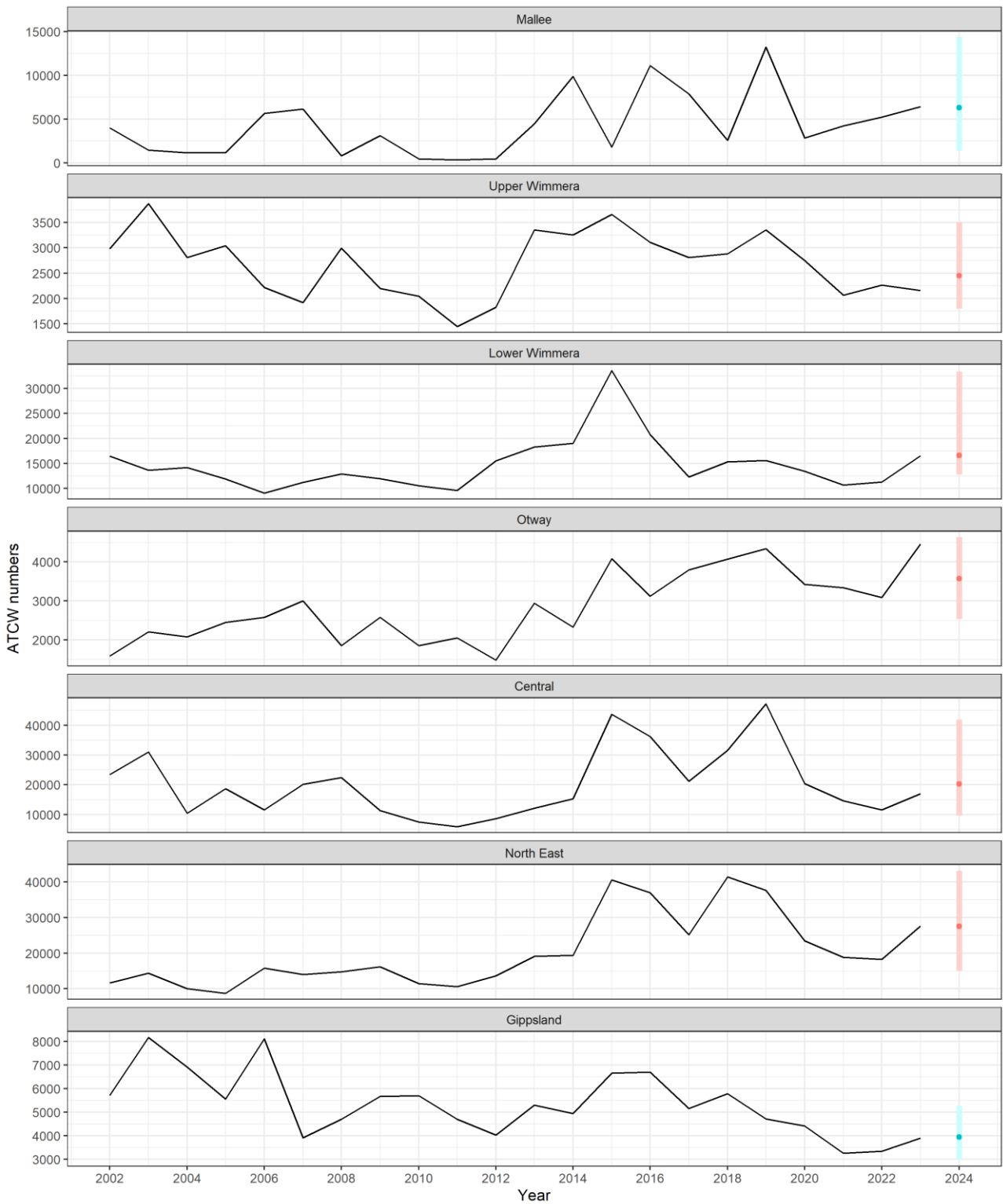


Figure 3. Time series of grey kangaroos taken under Authority to Control Wildlife (ATCW) permits for each harvest zone from 2002 to 2023. The predicted ATCW numbers for 2024 (\pm 90% confidence interval) are that predicted by the ARIMA model (red circle and shading) and the ETS model (blue circle and shading).

Table 5. The recommended maximum total take of grey kangaroos for 2024 compared with the predicted Authority to Control Wildlife (ATCW) numbers derived from the ETS and ARIMA time-series models. LCL, UCL – lower and upper 95% confidence intervals for the predicted ATCW. The ATCW (%) indicates the predicted ATCW numbers in 2024 as a percentage of the kangaroo abundance in the zone, based on the 2022 aerial survey estimates.

Zone	Total take	Predicted ATCW	LCL	UCL	ATCW (%)
Mallee	5,600	6,300	1,350	14,400	11.3
Upper Wimmera	20,950	2,450	1,800	3,500	1.2
Lower Wimmera	55,600	16,600	12,800	33,350	3.0
Otway	18,900	3,550	2,550	4,650	1.9
Central	82,050	20,350	9,600	41,850	2.5
North East	35,600	27,500	15,100	43,200	7.7
Gippsland	17,650	3,950	2,950	5,300	2.2
Total	236,350	80,700	46,150	146,250	3.4

3.3 KHP harvest quotas for 2024

Based on the calculation of the recommended maximum total take for grey kangaroos for each harvest zone (Table 3) and the expected numbers of grey kangaroos taken under ATCW permits in each zone for 2024 (predicted ATCW: Table 5), the take was apportioned between the KHP quota and ATCW permit system (Table 6). After adjusting for the predicted ATCW take, the total quota allocated to the KHP for 2024 was 155,650 grey kangaroos (Table 6). This is lower than the total quota recommended for 2023 (166,750), due to the higher take through ATCW permits predicted for 2024. Since the take through ATCW permits for the Mallee zone was predicted to be above the recommended take, no KHP quota has been allocated for that zone. To balance the additional 700 kangaroos predicted to be taken from the Mallee zone, an adjustment to the estimated KHP quota for the adjacent Upper Wimmera zone was made to ensure that the total take (KHP + ATCW) did not exceed the total take for the state. This was achieved by subtracting 700 grey kangaroos from the KHP quota for this zone.

Table 6. Recommended maximum total take of grey kangaroos, predicted Authority to Control Wildlife (ATCW) numbers and recommended quotas for the Kangaroo Harvesting Program (KHP) in 2024, by harvest zone. Values are rounded to the nearest 50.

Zone	Total take	Predicted ATCW	KHP quota
Mallee	5,600	6,300	0
Upper Wimmera	20,950	2,450	17,800
Lower Wimmera	55,600	16,600	39,000
Otway	18,900	3,550	15,350
Central	82,050	20,350	61,700
North East	35,600	27,500	8,100
Gippsland	17,650	3,950	13,700
Total	236,350	80,700	155,650

4 Conclusions

The recommended maximum total take (*total quota*) of grey kangaroos for 2024 was assessed based on the abundance estimates derived from the 2022 aerial survey, as recommended by Ramsey and Scroggie (2021). This is because there have only been four aerial surveys conducted to date that are available to calibrate the existing kangaroo harvest model, which is likely to require at least eight surveys to enable adequate calibration (Ramsey and Scroggie, 2021). In the meantime, it was recommended that the total recommended take be set using the most recent aerial survey estimates (Ramsey and Scroggie, 2021). It has also been previously demonstrated that biennial frequency of aerial surveys should not increase risks of overharvesting in mesic environments such as Victoria (Pople 2008). The next aerial survey will occur in late 2024 and hence, the harvest quotas for 2025 will be set using the abundance estimates derived from that survey. If environmental conditions deteriorate substantially before then, it is recommended that the take of grey kangaroos be reviewed in each harvest zone to either reduce or halt further take until conditions improve.

Since the introduction of the KHP in 2020, the total take of kangaroos through either the ATCW permit process or KHP has averaged approximately 6% of the total population of grey kangaroos and hence, has been lower than the maximum 10% allowed. Therefore, the current evidence suggests that the recent take of grey kangaroos through both ATCW provisions and the KHP is well within sustainable limits.

In most harvest zones, the number of grey kangaroos permitted for control under the ATCW permit system predicted for 2024 was higher than the number predicted for 2023. In particular, the take under ATCW provisions for the Mallee zone was predicted to be greater than the total recommended take for that zone. Hence, there is no take allocated to the KHP for the Mallee zone. In addition, a further 700 grey kangaroos were subtracted from the KHP quota for the Upper Wimmera zone to ensure that the total take (KHP + ATCW) did not exceed the total recommended take for the state. The Upper Wimmera zone was chosen for this adjustment as this zone borders the Mallee zone and like this zone, contains significant numbers of Western Grey Kangaroos. The above adjustments notwithstanding, the total predicted take under the ATCW permit process was estimated to amount to around 3.4% of the total abundance of grey kangaroos.

Slight increases in the number of kangaroos taken through ATCW provisions during 2023 have been noted in most harvest zones. This has most likely been due to increases in kangaroo abundance, driven by the mild and moderately wet conditions experienced over much of Victoria over the last three years. Since the 2017 aerial survey, the grey kangaroo population has increased by approximately 10% per annum, with the total population increasing by around 68% over a 5-year period (Scroggie et al. 2023). Given that the KHP has been in operation since 2019, the grey kangaroo population has clearly been resilient to the introduction of commercial harvesting. However, it remains to be seen whether this level of resilience continues if environmental conditions become less favourable. The currently adopted approach of setting total recommended take as a proportion of the most recent population size provides a mechanism for limiting the impacts of culling when the population declines, as does the current policy of undertaking comprehensive aerial surveys of the population every two years (Scroggie et al. 2023).

5 References

- Caughley, G., Brown, B., Dostine, P. and Grice, D. (1984). The grey kangaroo overlap zone. *Wildlife Research* **11**(1), 1–10.
- Caughley, G., Shepherd, N. and Short, G. (1987). *Kangaroos, Their Ecology and Management in the Sheep Rangelands of Australia*. Cambridge University Press, Cambridge, United Kingdom.
- DELWP. (2020). *Victorian Kangaroo Harvest Management Plan*. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Hacker, R., McLeod, S., Druhan, J., Tenhumberg, B. and Pradhan, U. (2004). *Kangaroo management options in the Murray-Darling Basin*. Murray-Darling Basin Commission, Canberra, ACT.
- Holt, C. C. (2004). Forecasting seasonals and trends by exponentially weighted moving averages. *International Journal of Forecasting* **20**(1), 5–10.
- Hyndman, R. and Athanasopoulos, G. (2021). *Forecasting: Principles and Practice* (3rd ed.). OTexts: Melbourne, Australia. OTexts.com/fpp3 (accessed on 15 November 2023).
- Lunney, D., Purcell, B., McLeod, S., Grigg, G., Pople, T. and Wolter, S. (2018). Four decades of research and monitoring the populations of kangaroos in New South Wales: One of the best long-term datasets in Australia. *Australian Zoologist* **39**(4), 784–800. <https://doi.org/10.7882/AZ.2018.040>
- McLeod, S. R., Hacker, R. B. and Druhan, J. P. (2004). Managing the commercial harvest of kangaroos in the Murray-Darling Basin. *Australian Mammalogy* **26**, 9–22.
- Moloney, P. D., Ramsey, D. S. L. and Scroggie, M. P. (2017). *A state-wide aerial survey of kangaroos in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 286. 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, 2020: Results from the 2020 aerial and ground survey*. Arthur Rylah Institute for Environmental Research Technical Report No. 324. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Moloney, P. D., Scroggie, M. P. and Ramsey, D. S. L. (2018). *Revisiting the Victorian kangaroo aerial survey design*. Unpublished Client Report. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Pople, A. R. (2008). Frequency and precision of aerial surveys for kangaroo management. *Wildlife Research*, **35**(4), 340–348. <https://doi.org/10.1071/WR07066>
- Ramsey, D. S. L., & 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.
- Scroggie, M. P., Moloney, P. D. and Ramsey, D. S. L. (2017). *Design of an aerial survey to estimate the abundance of kangaroos in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report No. 280. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Scroggie, M. P., Moloney, P. D. and Ramsey, D. S. L. (2023). Spatio-temporal trends in the abundance of grey kangaroos in Victoria, Australia. *Wildlife Research* (submitted).
- Scroggie, M. P. and Ramsey, D. S. L. (2020). *A spatial harvest model for kangaroo populations in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 315. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Scroggie, M. P. and Ramsey, D. S. L. (2019). *Kangaroo harvest quotas for Victoria, 2020*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 308. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

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