



# Kangaroo harvest quotas for Victoria, 2023

D.S.L. Ramsey

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## Summary

### Context:

The Victorian Kangaroo Harvest Management Plan (KHMP) 2021-2023 sets the requirements for the operation of Victoria's Kangaroo Harvesting Program (KHP), which supports the ecologically sustainable commercial harvesting of wild grey kangaroo (Eastern Grey Kangaroo, *Macropus giganteus* and Western Grey Kangaroo, *M. fuliginosus*) populations in the state. The KHMP permits the commercial harvest of grey kangaroos on private land in designated harvest zones. To support the implementation of this policy, there is a requirement to set harvest quotas for the KHP. The harvest quotas allow for the take of grey kangaroos through the Authority to Control Wildlife (ATCW) permit process 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 recommend the total annual sustainable take of Eastern and Western Grey Kangaroos for 2023 and apportion the total take between the ATCW permit process and the KHP.

### Methods:

Aerial surveys to estimate the abundance of Eastern and Western Grey kangaroos were undertaken during September/October 2022 within the seven kangaroo harvest zones (Figure S1). The annual total recommended take for 2023 was set at 10% of the estimated abundance, separately for each harvest zone. The predicted number of kangaroos authorised for control under the ATCW permit process in 2023 was estimated by analysing the historical ATCW grey kangaroo numbers using time-series models. The annual total recommended take was then apportioned between the numbers predicted to be taken under ATCW permits, with the remainder allocated to the KHP.

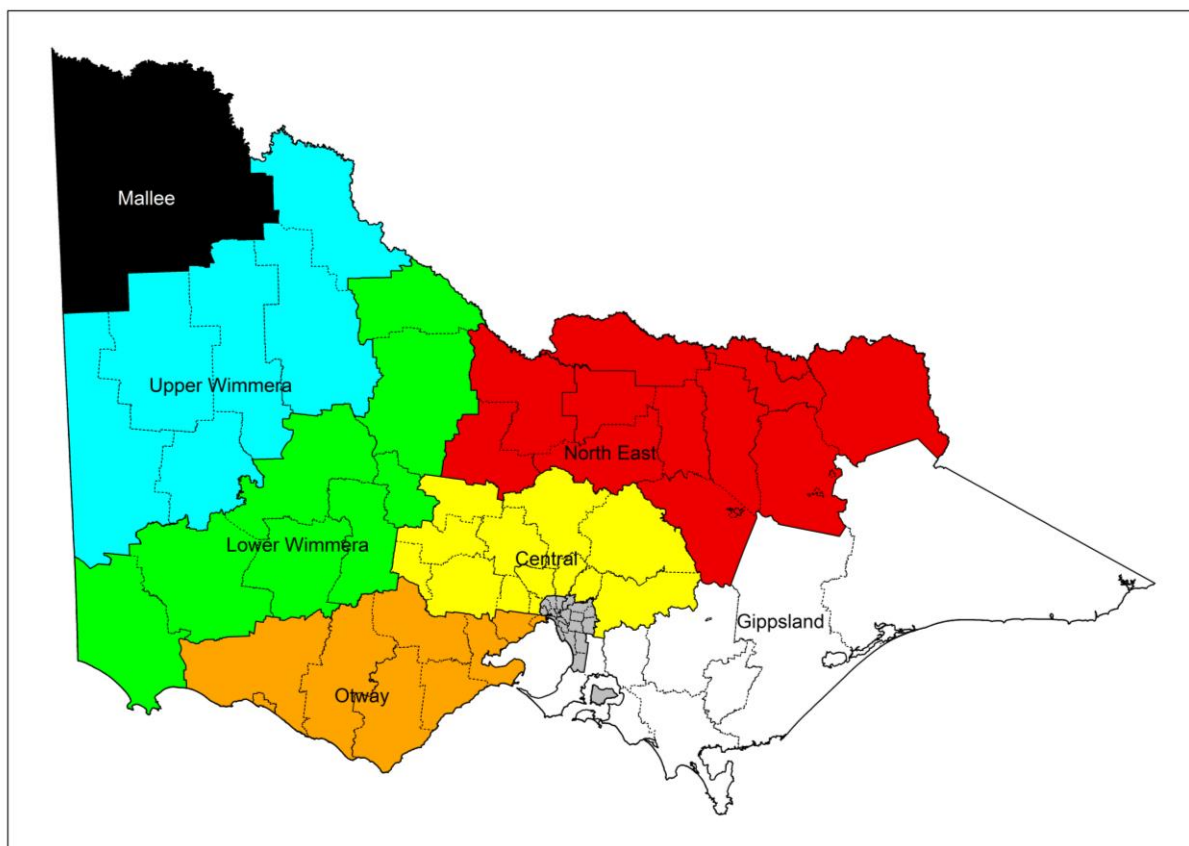


Figure S1. Kangaroo harvest management zones in Victoria. Each zone is formed by amalgamating groups of ecologically similar local government areas. The grey shaded areas are not subject to harvest. Colour-coding of harvest management areas matches the colours of the tags attached to carcasses during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

## Results:

The estimated total abundance of grey kangaroos within the seven harvest management zones was 2,363,850 (95% confidence interval: 1,889,300–2,957,550). The total recommended take for 2023 was assessed as 236,350 grey kangaroos, comprising 215,200 Eastern Grey Kangaroos and 21,150 Western Grey Kangaroos. Predicted numbers of grey kangaroos authorised for control under the ATCW permit process was estimated to be 69,600, comprising approximately 29% of the total recommended take for 2023. After adjusting for the numbers predicted to be taken through ATCW permits, the allocation of grey kangaroos for the KHP for 2023 was 166,750.

## Conclusions and implications:

The abundance of grey kangaroos within the non-forested parts of Victoria has increased by approximately 24% compared with that reported from the 2020 aerial survey. This increase has resulted in a similar increase in the total recommended take of grey kangaroos for 2023. The number of grey kangaroos predicted to be taken under ATCW permits for 2023 was slightly higher than in 2022, but is expected to be a smaller fraction of the total grey kangaroo population allowing a higher allocation for the KHP. The total take of grey kangaroos through both the ATCW permit process and KHP during 2020 and 2021 (and imputed to the end of 2022) amounted to around 6% of the total grey kangaroo population estimated for each of those years. Hence, total take over the last three years has remained below the maximum allowable harvest fraction of 10%.

For the 2023 calendar year, a total take of 236,350 grey kangaroos is recommended under the KHP and ATCW permit system. The total recommended take of grey kangaroos in each harvest management zone, apportioned between the KHP and ATCW permit process, is shown in Table S1.

**Table S1. Total recommended take of grey kangaroos, predicted ATCW numbers and recommended quotas for the KHP in 2023 by harvest zone. Values are rounded to the nearest 50.**

Zone	Total take	Predicted ATCW	KHP quota
Mallee	5,600	4,050	1,550
Upper Wimmera	20,950	2,100	18,850
Lower Wimmera	55,600	14,500	41,100
Otway	18,900	3,400	15,500
Central	82,050	16,950	65,100
North East	35,600	24,550	11,050
Gippsland	17,650	4,050	13,600
<b>Total</b>	<b>236,350</b>	<b>69,600</b>	<b>166,750</b>

# 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 total recommended take of kangaroos in each harvest zone includes that taken by the KHP (KHP quota) and any kangaroos taken 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 DELWP. 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 total recommended take is divided between 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% total recommended 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). 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.

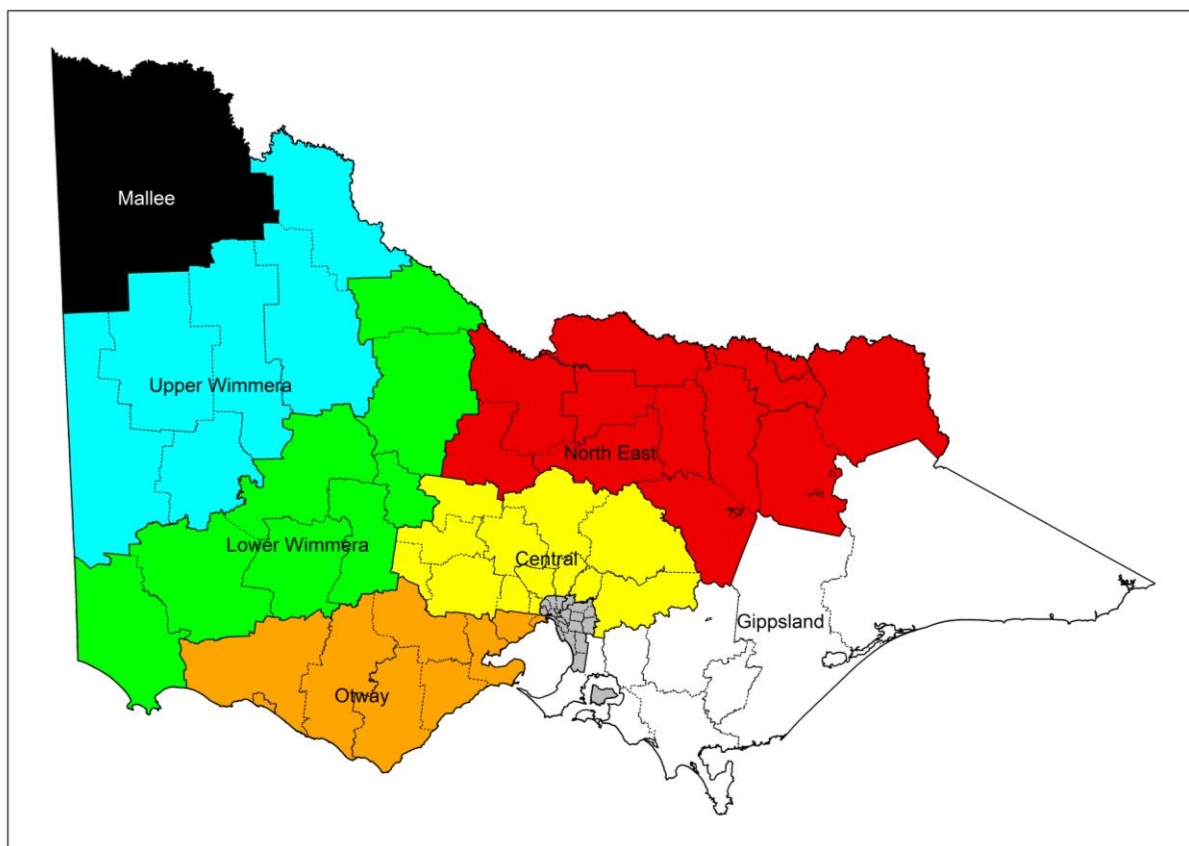
This report presents an analysis to guide the setting of quotas for the commercial harvest of kangaroos through the KHP for the 2023 calendar year. The analysis is based primarily on estimates for the grey kangaroo population derived from aerial surveys conducted during September/October 2022. Detailed results from the aerial surveys will be made available in a separate report. We used historical ATCW permit information to predict the likely numbers of grey kangaroos authorised for control under ATCW permits in 2023, 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, EGK and WGK; 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 Total recommended take of grey kangaroos for 2023**

Abundance estimates for EGK and WGK for each harvest zone derived from the 2022 aerial survey were used to set the total recommended take for the 2023 calendar year at 10% of the abundance estimates. The total recommended 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 2022 were complete up to 30 September 2022. 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 is predicted by analysing the historical time series of kangaroo numbers authorised for control under ATCW permits.

Historical numbers of grey kangaroos authorised for control under ATCW permit provisions (hereafter ATCW numbers) were available for each harvest zone from January 2002 to 30 September 2022. As mentioned in section 2.2, the total take for the 2022 calendar year was estimated by imputing ATCW permits and the KHP uptake for the final quarter of 2022.

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 2019). 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 2019). The best-fitting model for each zone was then used to predict the likely number of kangaroos authorised under ATCW permits for the 2023 calendar year.

## **2.4 KHP harvest quotas for 2023**

Once the predicted number of grey kangaroos authorised for control under ATCW permit provisions in 2023 was estimated, the total recommended take of both WGK and EGK for 2023 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 Total recommended take of grey kangaroos for 2023

The abundance estimates for grey kangaroos in each harvest zone derived from the 2020 and 2022 aerial surveys are given in Table 1. The estimate for grey kangaroos in 2022 indicates that grey kangaroo populations have generally increased by around 24% from the 2020 estimate. Point estimates of abundance have shown notable increases in five harvest zones, a decrease in one zone (Otway), and negligible change in the remaining zone (Gippsland) (Table 1). The imputed take of grey kangaroos for the 2022 calendar year through both the ATCW permit process and the KHP amounted to 132,225 kangaroos, which was approximately 6% of the estimated abundance for 2022 (Table 2). This was similar to the total proportional take in 2020 and 2021 (Figure 2). Based on these estimates, the maximum allowable take of grey kangaroos for 2023, 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 2020 and 2022 (Estimate). SE – Standard error of the 2022 estimate, LCL, UCL – lower and upper 95% confidence intervals for the 2022 estimate. Estimates are rounded to the nearest 50.**

Harvest zone	2020 Estimate	2022 Estimate	SE	LCL	UCL
Mallee	37,300	55,900	13,449	34,000	91,850
Upper Wimmera	138,100	209,650	66,719	111,500	394,100
Lower Wimmera	427,700	556,050	142,804	330,100	936,700
Otway	236,950	189,200	81,323	78,800	454,500
Central	658,950	820,550	114,884	602,900	1,116,800
North East	239,850	355,950	163,663	144,550	876,600
Gippsland	172,700	176,550	43,488	106,000	294,050
<b>Statewide total</b>	<b>1,911,550</b>	<b>2,363,850</b>	<b>271,134</b>	<b>1,889,300</b>	<b>2,957,550</b>

**Table 2. Forecast kangaroo take from the Kangaroo Harvesting Program (KHP) and Authority to Control Wildlife (ATCW) permit process for the 2022 calendar year and the estimated take as a percentage (%) of the 2022 kangaroo abundance.**

Harvest zone	ATCW	KHP	Total	%
Mallee	1,403	500	1,903	3
Upper Wimmera	1,504	7,289	8,793	4
Lower Wimmera	12,475	22,543	35,018	6
Otway	3,520	8,843	12,363	7
Central	12,851	26,312	39,163	5
North East	23,052	2,053	25,105	7
Gippsland	3,129	6,751	9,880	6
<b>Statewide total</b>	<b>57,934</b>	<b>74,291</b>	<b>132,225</b>	<b>6</b>

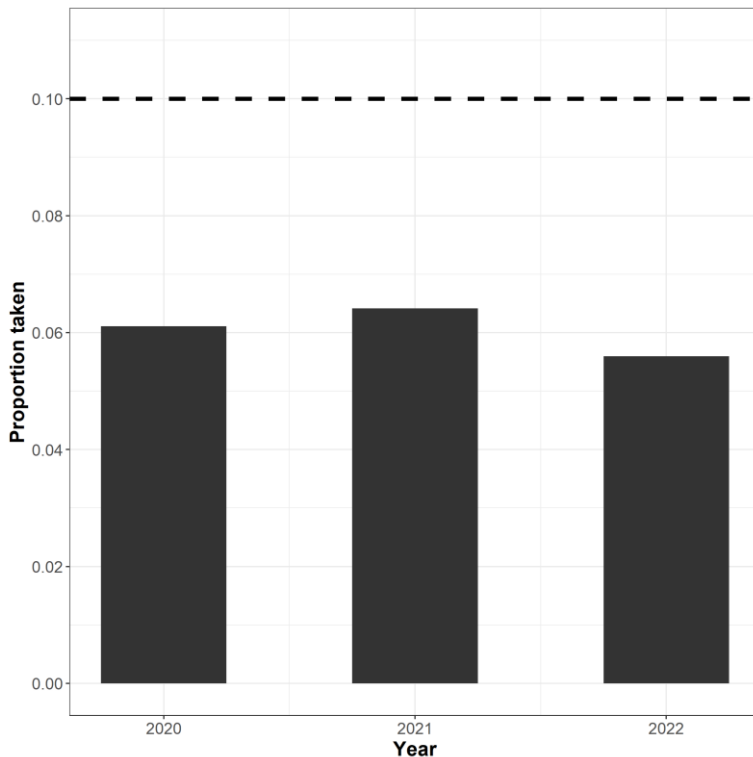


Figure 2. The proportion of the total population of grey kangaroos taken through either the ATCW permit process or KHP from 2020–2022. Dashed line indicates the maximum allowable take of 10%.

Table 3. Total recommended take of grey kangaroos in 2023 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 2023. Recommended 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
<b>Statewide total</b>	<b>215,200</b>	<b>21,150</b>	<b>236,350</b>

### 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 North East zones. The best fitting model for each zone was subsequently used to predict numbers likely to be taken under the ATCW permit process in 2023 (Figure 3). However, predictions were rather imprecise for some zones, such as for the Mallee and Otway zones (Table 5; Figure 3).

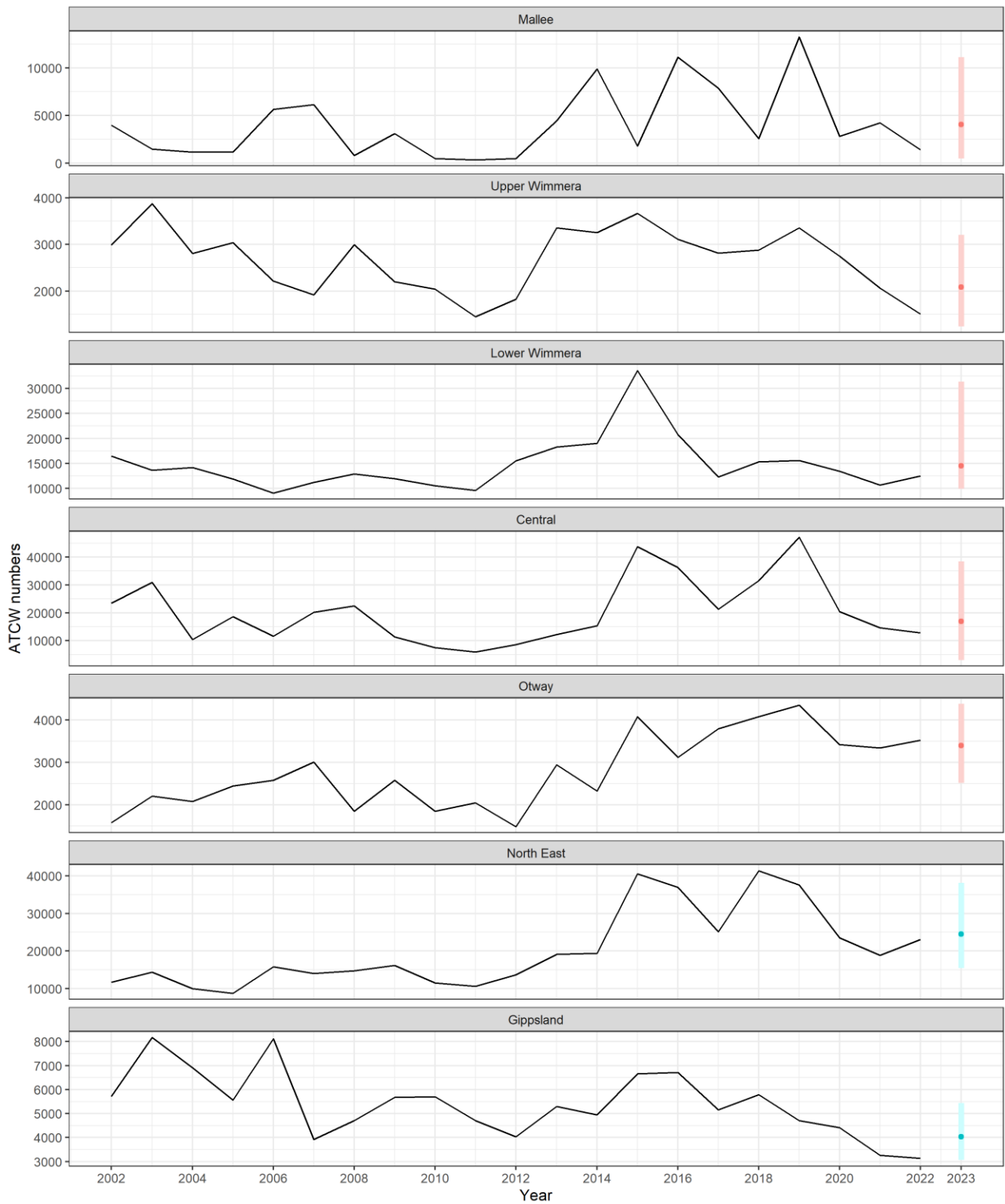
The numbers of grey kangaroos predicted to be taken under ATCW permits in 2023 are lower than the total recommended take for each zone, amounting to 3.4% of the total population abundance of grey kangaroos

(Table 5). Generally, declines in the number of kangaroos taken through ATCW provisions have been noted in most harvest zones since the introduction of the KHP in 2020 (Figure 3).

**Table 4. Predictive accuracy expressed as the mean absolute scaled error (MASE) for two models fitted to the time series of Authority to Control Wildlife (ATCW) permit numbers between 2002 and 2022. Lower values (bolded) indicate models with better predictive accuracy.**

Zone	ETS	ARIMA
Mallee	0.78	<b>0.74</b>
Upper Wimmera	1.14	<b>0.88</b>
Lower Wimmera	1.08	<b>0.76</b>
Otway	0.75	<b>0.73</b>
Central	1.25	<b>0.85</b>
North East	<b>0.93</b>	0.95
Gippsland	<b>0.78</b>	0.90





**Figure 3. Time series of kangaroos taken under ATCW permits for each harvest zone from 2002 to 2022. The predicted Authority to Control Wildlife (ATCW) numbers for 2023 ( $\pm$  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 total recommended take of grey kangaroos for 2023 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 2023 as a percentage of the kangaroo abundance in the zone.**

Zone	Total take	Predicted ATCW	LCL	UCL	ATCW (%)
Mallee	5,600	4,050	450	13,250	7.2
Upper Wimmera	20,950	2,100	1,250	3,200	1
Lower Wimmera	55,600	14,500	10,800	17,750	2.6
Otway	18,900	3,400	2,500	4,650	1.8
Central	82,050	16,950	6,200	38,500	2.1
North East	35,600	24,550	15,450	38,100	6.9
Gippsland	17,650	4,050	3,050	5,600	2.3
<b>Total</b>	<b>236,350</b>	<b>69,600</b>	<b>37,250</b>	<b>95,750</b>	<b>3.4</b>

### 3.3 KHP harvest quotas for 2023

Based on the calculation of the total recommended 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 2023 (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 was 166,750 grey kangaroos (Table 6). Due to the higher population abundance of grey kangaroos in 2022 compared with in previous years, no adjustments to the estimated KHP quota were required to ensure that the total take (KHP + ATCW) did not exceed the total take for the state.

**Table 6. Total recommended take of grey kangaroos, predicted Authority to Control Wildlife (ATCW) numbers and recommended quotas for the Kangaroo Harvesting Program (KHP) in 2023 by harvest zone. Values are rounded to the nearest 50.**

Zone	Total take	Predicted ATCW	KHP quota
Mallee	5,600	4,050	1,550
Upper Wimmera	20,950	2,100	18,850
Lower Wimmera	55,600	14,500	41,100
Otway	18,900	3,400	15,500
Central	82,050	16,950	65,100
North East	35,600	24,550	11,050
Gippsland	17,650	4,050	13,600
<b>Total</b>	<b>236,350</b>	<b>69,600</b>	<b>166,750</b>

## 4 Conclusions

The abundance of grey kangaroos within the non-forested parts of Victoria has increased by approximately 24% compared with that reported from the 2020 aerial survey, with notable increases in the point estimates evident in five of the seven harvest zones. This increase has been most likely due to the mild and moderately wet conditions experienced in Victoria over the last two years. The increase in the population of grey kangaroos has resulted in an increase in the total allowable take of kangaroos, based on a maximum proportional offtake of 10% of the total population. 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 authorised to be taken under the ATCW permit process predicted for 2023 was higher than the number predicted for 2022. However, the total predicted take under the ATCW permit process was estimated to amount to around 3.4% of the total abundance of kangaroos. Since the forecast take under the ATCW provisions was lower than the maximum allowable take for all zones, the remaining take was allocated to the KHP. Hence, no adjustments were required to prevent exceeding the maximum allowable take.

Declines in the number of kangaroos taken through ATCW provisions have been noted in most harvest zones since the introduction of the KHP in 2020. This has most likely been due to kangaroos taken through the KHP that would have otherwise been taken through the ATCW permit process. This may be due to increasing awareness of the KHP by landholders as an alternative mechanism for achieving kangaroo control. Increased use of the KHP should result in more accurate tracking of the total take of grey kangaroos compared with the use of ATCW permits. In addition, increased use of the KHP should lead to less wastage of carcasses, improved animal welfare outcomes, and economic benefits for the state's commercial kangaroo harvesters.

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