

Kangaroo harvest quotas for Victoria, 2025

M.P. Scroggie & P.D. Moloney

December 2024

Arthur Rylah Institute for Environmental Research Technical Report Series No. 384



Arthur Rylah Institute for Environmental Research
Department of Energy, Environment and Climate Action
PO Box 137, Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.ari.vic.gov.au

Citation: Scroggie, M.P. and Moloney P.D. (2024). Kangaroo harvest quotas for Victoria, 2025. Arthur Rylah Institute for Environmental Research Technical Report Series No. 384. Department of Energy, Environment and Climate Action, Heidelberg, Victoria.

Front cover photo: Eastern Grey Kangaroo (Justin Cally)

ISSN 1835-3835 (pdf)
ISBN 978-1-76176-023-5 (pdf)

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.



© The State of Victoria Department of Energy, Environment and Climate Action December 2024.

Creative Commons

This work is licensed under a Creative Commons Attribution 4.0 International licence, visit the [Creative Commons website](http://creativecommons.org/licenses/by/4.0/) (<http://creativecommons.org/licenses/by/4.0/>).

You are free to re-use the work under that licence, on the condition that you credit the State of Victoria as author. The licence does not apply to any images, photographs or branding, including the Victorian Coat of Arms, and the Victorian Government, the Department and the ARI logos.

Disclaimer

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Accessibility

To receive this document in an alternative format, phone the Customer Service Centre on 136 186, email customer.service@deeca.vic.gov.au, or contact National Relay Service on 133 677. Available at [DEECA website](http://www.deeca.vic.gov.au) (www.deeca.vic.gov.au).

Kangaroo harvest quotas for Victoria, 2025

Michael P. Scroggie and Paul D. Moloney

Arthur Rylah Institute for Environmental Research
Department of Energy, Environment and Climate Action
123 Brown Street, Heidelberg, Victoria 3084

Arthur Rylah Institute for Environmental Research
Technical Report Series No. 384

Acknowledgements

This work was funded by the Biodiversity Division, Department of Energy, Environment and Climate Action, Victoria.

We thank Bali Forbes and Vural Yazgin for their assistance throughout the project and for the provision of data, suggestions and advice. The aerial survey and ground survey data on which the kangaroo abundance estimates are based was collected by EcoKnowledge Pty Ltd and Macropus Consulting respectively. We thank Mark Lethbridge and Graeme Coulson in particular for their work in planning and executing the collection of the field data. Bali Forbes, Darcy Shilling-Walsh, Sarah Martin and Vural Yazgin (DEECA, Biodiversity Division) along with Jenny Nelson, Carlo Pacioni, Pia Lentini and Jemma Cripps (ARI) provided helpful comments on drafts of this report and much additional advice and support.

Contents

Acknowledgements	ii
Summary	4
1 Introduction	8
2 Methods	10
Kangaroo abundance estimates for 2024	10
Total recommended maximum take of grey kangaroos for 2025	10
Forecasting numbers of kangaroos to be taken under ATCW permits during 2025	10
KHP harvest quotas for 2025	11
3 Results	12
Total recommended take for grey kangaroos for 2025	12
Forecast numbers of grey kangaroos predicted to be taken under ATCW permits during 2025	13
Commercial harvest quotas for 2025	16
Conclusions	19
References	20

Summary

Context:

In Victoria, grey kangaroos (both Eastern Grey Kangaroo, *Macropus giganteus* and Western Grey Kangaroo, *M. fuliginosus*) are commercially harvested under the *Victorian Kangaroo Harvest Management Plan 2024-2028* (KHMP 2024-2028, DEECA 2023) which replaces the earlier 2021-2023 plan (DELWP 2020). The KHMP outlines the standards and rules for the commercial harvesting of kangaroos in Victoria and considers relevant State and Commonwealth legislation, which dictates that commercial harvesting of wild kangaroos must be sustainable and humane. The KHMP also provides for the commercial harvest of grey kangaroos in designated harvest zones.

The KHMP is implemented through the Kangaroo Harvesting Program (KHP), which allows for the ecologically sustainable and humane commercial harvesting of wild grey kangaroo populations in the state. To ensure the ecological sustainability of the program, there is a need to regularly set harvest quotas for the KHP. The harvest quotas consider both kangaroos harvested commercially under the KHP, and the predicted number of grey kangaroos permitted to be controlled within each harvest zone through the Authority to Control Wildlife (ATCW) permit system under the *Wildlife Act 1975*. This ensures that the total take does not exceed the ecologically sustainable criteria recommended in Scroggie and Ramsey (2020).

Aims:

The aim of this project was to use updated abundance estimates for each grey kangaroo species derived from the 2024 aerial survey program to determine the recommended maximum total take (i.e. total quota) of Eastern and Western Grey Kangaroos for the 2025 calendar year, and to apportion the allowable total quota between the commercial KHP program and the predicted numbers of ATCW permits.

Methods:

Aerial surveys of the non-forested parts of Victoria were undertaken during September 2024. These surveys were supplemented with simultaneous ground surveys of the area occupied by both grey kangaroo species in order to estimate the proportions of Eastern and Western Grey Kangaroos in each harvest zone. In combination, these two datasets allowed for statistical estimation of the number of kangaroos present within each of the five harvest zones. The number and boundaries of the harvest zones changed with the initiation of the new KHMP to improve administration of the KHP, and to exclude a further ten municipalities on the urban fringe of Melbourne from commercial harvesting (Figure S1). The total quota (ATCW and KHP combined) was specified as 10% of the estimated abundance within each harvest zone, with separate quotas being calculated for Eastern and Western Grey Kangaroos. The number of each species that would be culled in each zone during 2025 under an ATCW permit was forecast from historical ATCW permit data using time-series modelling, with the remainder of the total allowable 10% take being allocated to the KHP.

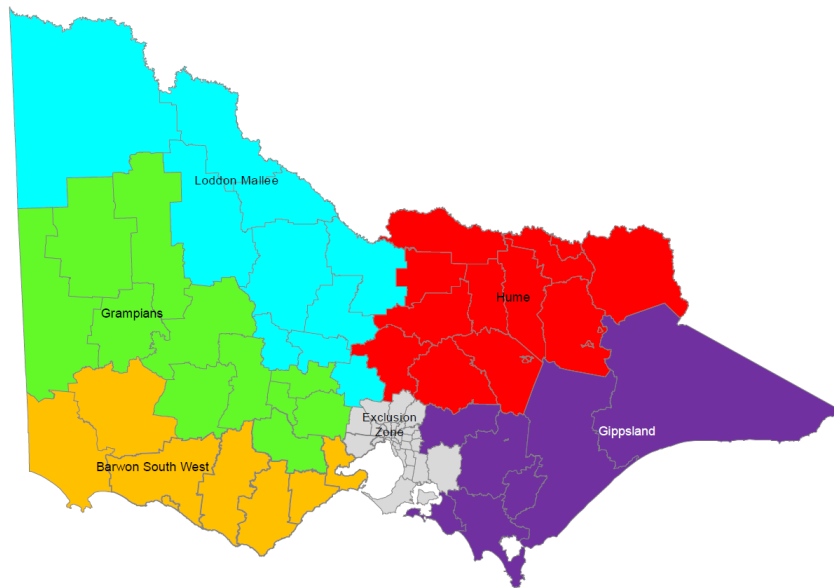


Figure S1. New kangaroo harvest zones for Victoria from 2025.

The new zoning that applies from 2025 under the KHMP 2024-2028. Note the presence of an exclusion zone including an additional ten local government areas (LGAs) on the periphery of Melbourne where no commercial harvesting will be permitted from 2025 onwards. ATCW control is still permitted in the exclusion zone.

Results:

The total abundance of grey kangaroos across the area covered by the five harvest zones was estimated at 2.078 million, comprising 211,000 Western Greys, and 1.87 million Eastern Greys. Based on the recommended total take of 10%, the total quota for 2025 across the five harvest zones was set at 21,100 Western Greys and 186,700 Eastern Greys (a total of 207,800 grey kangaroos). The total number of grey kangaroos forecast to be controlled under the ATCW permit system across the five harvest zones for the 2025 calendar year was 84,550 Eastern Greys and 7,650 Western Greys (totalling 90,200), comprising approximately 44% and 36% respectively of the total recommended culling quotas. After subtracting the number forecast to be taken under ATCW provisions, the 2025 commercial quota allocation of grey kangaroos is 117,600, including 104,150 Eastern Greys and 13,450 Western Greys.

Conclusions and implications:

The abundance of grey kangaroos within the survey area (the non-forested parts of Victoria) has remained relatively stable since the last survey in 2022. At that time, the total reported abundance was 2.36 million grey kangaroos, and the 2024 survey has led to a very similar total abundance estimate of 2.30 million. This change in abundance is considered negligible relative to the total size of the population and is within the margin of error of the respective statistical approaches. It should be noted that the 2024 estimate included 228,000 Eastern Greys in the ten local government areas (LGAs) which, as of 2024, are no longer included in the harvest zones, and are therefore not included in the quota calculation, but were included in the above estimate of total abundance. The total number of grey kangaroos predicted to be taken in 2025 under the ATCW provisions is 90,200. If the forecast proves accurate, this will result in approximately 43% of the recommended total take within the harvest zones being taken under ATCW permits, with the remainder allocated to the KHP.

Under scenarios where the ATCW forecast proves accurate, or where the ATCW forecast is surpassed by either 10 or 20%, there is still scope for all zones to allocate some quota to the KHP. Totals quotas, and allocations to ATCW and KHP under each of these three scenarios, are given in Tables S1-S3 below.

Recommendations

- We recommend a total quota of 186,700 Eastern Grey Kangaroos and 21,100 Western Grey Kangaroos for the area covered by the five harvest zones for the KHP and ATCW processes

combined. The recommended apportionment of these total quotas between harvest zones and the two grey kangaroo Species is specified in Table S1 below.

- We recommend that the issuing of ATCW permits for each zone be monitored throughout the year so that commercial quotas can be adjusted if take through ATCW permits is higher than predicted. This will help to ensure, as much as possible, that take via the KHP does not contribute to the 10% recommended total take being exceeded for any one zone or species.
- Alternative quota scenarios are provided (Tables S2 and S3), illustrating the effect of small to moderate exceedances of the ATCW forecast on commercial quotas. We recommend that these be used as guidance by decision-makers in determining the final commercial quotas.
- The 10 and 20% ATCW exceedance scenarios given below in Tables S2 and S3 may form a good position for initial quota-setting and provide insurance against ATCWs exceeding the forecasts.

Table S1. Total recommended take of grey kangaroos (10% of the estimated total abundance), and the number forecast to be taken under ATCW provisions. ATCW %: ATCW take as a percentage of the allowable total, EGK: Eastern Grey Kangaroo, WGK: Western Grey Kangaroo. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Total Quota	Forecast ATCW	KHP	ATCW %
Barwon South-West	EGK	24,900	14,700	10,200	59.0
	WGK	1,200	550	650	45.8
Grampians	EGK	27,300	13,450	13,850	49.3
	WGK	11,200	900	10,300	8.0
Loddon Mallee	EGK	40,800	14,650	26,150	35.9
	WGK	8,700	6,200	2,500	71.3
Hume	EGK	77,100	35,450	41,650	46.0
	WGK	-	-	-	-
Gippsland	EGK	16,600	4,300	12,300	25.9
	WGK	-	-	-	-
TOTAL	EGK	186,700	82,550	104,150	44.2
	WGK	21,100	7,650	13,450	36.2

Table S2. Alternative scenario for recommended take of grey kangaroos (10% of total abundance), in which the actual numbers controlled through ATCW permits exceed the forecast by 10%. ATCW %: ATCW take as a percentage of the allowable total, EGK: Eastern Grey Kangaroo, WGK: Western Grey Kangaroo. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Total Quota	Forecast ATCW +10%	KHP	ATCW %
Barwon South-West	EGK	24,900	16,150	8,750	64.9
	WGK	1,200	600	600	50.0
Grampians	EGK	27,300	14,800	12,500	54.2
	WGK	11,200	1,000	10,200	8.9
Loddon Mallee	EGK	40,800	16,100	24,700	39.5
	WGK	8,700	6,800	1,900	78.2
Hume	EGK	77,100	39,000	38,100	50.7
	WGK	-	-	-	-
Gippsland	EGK	16,600	4,700	11,900	28.3
	WGK	-	-	-	-
TOTAL	EGK	186,700	90,750	95,950	48.6
	WGK	21,100	8,400	12,700	39.8

Table S3. Alternative scenario for recommended take of grey kangaroos (10% of total abundance), in which the actual numbers controlled through ATCW permits exceed the forecast by 20%. ATCW %: ATCW take as a percentage of the allowable total, EGK: Eastern Grey Kangaroo, WGK: Western Grey Kangaroo. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Total Quota	Forecast ATCW + 20%	KHP	ATCW %
Barwon South-West	EGK	24,900	17,650	7,250	70.9
	WGK	1,200	650	550	54.2
Grampians	EGK	27,300	16,150	11,150	59.2
	WGK	11,200	1,050	10,150	9.4
Loddon Mallee	EGK	40,800	17,550	23,250	43.0
	WGK	8,700	7,450	1,250	85.6
Hume	EGK	77,100	42,550	34,550	55.3
	WGK	-	-	-	-
Gippsland	EGK	16,600	5,150	11,450	31.0
	WGK	-	-	-	-
TOTAL	EGK	186,700	99,050	87,650	53.0
	WGK	21,100	9,150	11,950	43.4

1 Introduction

In Victoria, grey kangaroos (both Eastern Grey Kangaroo, *Macropus giganteus* and Western Grey Kangaroo, *M. fuliginosus*) are commercially harvested under the *Victorian Kangaroo Harvest Management Plan 2024-2028* (KHMP 2024-2028, DEECA 2023) which replaces the earlier 2021-2023 plan (DELWP 2020). The KHMP outlines the standards and rules for the commercial harvesting of kangaroos in Victoria and considers relevant State and Commonwealth legislation, which dictates that commercial harvesting of wild kangaroos must be sustainable and humane.

Commercial harvesting of kangaroos in Victoria commenced in 2019 with the current regulatory guidelines outlined in the *Victorian Kangaroo Harvest Management Plan 2024-2028* (KHMP 2024-2028, DEECA 2023). From 2025 onwards, the KHMP introduces a number of changes that underpin the Kangaroo Harvesting Program (KHP). In particular, the original seven harvest zones utilised in the 2024 and earlier iteration of the KHP (KHMP 2021-2023) are replaced by five new zones, with different boundaries. In addition, commercial harvesting is now excluded from a further ten municipalities on the outskirts of metropolitan Melbourne. One change of significance is a move towards setting separate harvest quotas for Eastern Grey Kangaroos (*Macropus giganteus*, or 'Eastern Greys') and Western Grey Kangaroos (*Macropus fuliginosus*, or 'Western Greys'), to further ensure the ecologically sustainable management of populations. Full details of these changes can be found in the KHMP 2024-2028 (DEECA 2023), and will be highlighted where relevant in this report.

As with the previous plan, the new plan articulates an intention to undertake ecologically sustainable management of grey kangaroo populations in Victoria. As lethal control is widely used to manage the ecological and economic impacts of kangaroos, an overarching goal of the plan is to ensure harvesting is ecologically sustainable, and this is managed by setting the recommended maximum total take at 10% the total population abundance. There are two legal mechanisms that allow lethal control of kangaroos in Victoria. Firstly, the Authority to Control Wildlife (ATCW) provisions under the *Wildlife Act 1975* (Victoria) allow landholders to undertake legal culling of kangaroos on their land under a permit from DEECA's Conservation Regulator. Secondly, commercial harvesting of Eastern and Western Grey Kangaroos is permitted under a quota system (the KHP). These two mechanisms for permitting lethal control require coordinated management to ensure that the total harvest pressure is sustainable. The intention of the KHMP is that the total cull from both sources should not exceed the recommended maximum total take, with the available administrative and regulatory controls ensuring that populations are not over-harvested.

Scroggie and Ramsey (2019) developed a system for setting quotas based on a policy of the maximum proportion harvested in a given calendar year not exceeding 10% of the total population abundance. The total recommended take (10%) is divided between harvest zones (formerly seven, now five) and between the two grey kangaroo species in proportion to their total population sizes. Because the total number of kangaroos of a given species culled in each zone includes those taken under both ATCW and KHP processes, the regulatory framework includes mechanisms for apportioning the total take between these two systems.

The '10%' approach to quota-setting leads naturally to a decrease or increase in the number harvested as the population decreases or increases. In that sense, the approach is inherently conservative and will tend to reduce harvest pressure under conditions where kangaroo populations are in decline. The approach can also be considered conservative because of the 10% maximum harvest proportion that has been chosen for the harvest policy. Other Australian jurisdictions have long permitted harvesting of wild macropod populations at rates of up to 15% (Hacker *et al.* 2004; McLeod *et al.* 2004; Jonzén *et al.* 2010), mostly in more arid and variable climates than prevail in much of Victoria. There is little evidence of negative impacts on the long-term abundances of macropods in these interstate populations. For this reason alone, the sustainability of a 10% rate of harvest in Victoria seems well-supported. The sustainability of the 10% recommended maximum is also supported by population modelling undertaken by Scroggie and Ramsey (2020), which found that harvesting at this rate was unlikely to significantly affect the extinction risk of Victorian grey kangaroo populations.

This report presents an analysis to help decision-makers to set the commercial harvest quotas for Eastern and Western Grey Kangaroos in Victoria for the 2025 calendar year. We present a brief summary of the results of a new aerial survey of the Victorian grey kangaroo population, which allows updating of previous estimates of abundance for the state, and for the individual harvest zones. Detailed results of the aerial survey will be presented in a separate, more detailed report (Scroggie and Moloney in prep.). Historical ATCW data was collated to forecast the number of ATCW permits expected to be issued during 2025 for each harvest zone and species. In combination, these two data sources (kangaroo abundance surveys, and forecast of numbers of ATCW permits) allowed us to estimate the recommended total take of kangaroos for

each zone/species, and to apportion these recommended totals between the ATCW and KHP processes. In doing so, recommended harvest quotas for each zone for the two grey kangaroo species are obtained and can be used by decision-makers in setting the final commercial quota figures.

2 Methods

Kangaroo abundance estimates for 2024

In previous years of the KHP, quota setting has been supported by a combination of aerial surveys and simultaneous ground surveys, to assist with apportionment of the total grey kangaroo population between Eastern and Western Grey components (Moloney *et al.* 2017; Moloney *et al.* 2018; Moloney *et al.* 2021; Moloney *et al.* 2023). These surveys have been used to estimate abundances of Eastern Grey, Western Grey and Red Kangaroos across the entire state, with the exception of highly urbanised areas, and areas vegetated with thicker forests. Full details of those previous surveys are given in the papers cited above.

The analysis methodology used during these earlier surveys involved simple design-based estimation, where a sample of randomly placed aerial transects within each harvest zone yielded a sample of estimates of transect-level kangaroo densities. These sample densities were then averaged over the entire zone to estimate the density and abundance of kangaroos. Apportionment between Eastern and Western Greys was on the basis of a spatial model of the geographical distributions of these two species.

Subsequently, further research has allowed for the development of a revised method of population estimation that uses model-based distance sampling (Buckland *et al.* 2016) from the aerial transect data (Scroggie *et al.* in press). This approach fits a model which relates the transect-level abundances to a range of habitat covariates to allow for prediction of kangaroo abundance across a fine-grained grid of locations across the state. This more sophisticated analysis methodology has the advantage that estimation of abundance is possible for any defined area of habitat in Victoria, and is of particular utility given the changes made to the harvest zones from 2025 (Figure S1) in the KHMP 2024-2028 (DEECA 2023). This is because it allows for data collected according to the existing survey design to provide valid estimates of abundance for the new harvest zones without any need to alter the design.

Apportionment of the total grey kangaroo population estimate between Eastern and Western Greys is conducted based on a spatial model fitted to simultaneously collected ground survey data for these two species, supplemented with recent data from government wildlife atlas databases (Victorian Biodiversity Atlas and Atlas of Living Australia). In this report we rely on model-based estimates of total abundance for Eastern and Western Grey Kangaroos to infer the current population status of the two species within the five new harvest zones, and to provide a basis for setting ecologically sustainable quotas. Full details of the survey and analysis that yielded these population estimates will be provided in a separate report (Scroggie and Moloney in prep).

Total recommended maximum take of grey kangaroos for 2025

Abundance estimates for the two grey kangaroo species for each of the five new harvest zones derived from the 2024 aerial survey were used to set the total recommended take for the forthcoming 2025 calendar year, based on the principle of the maximum total take being limited to 10% of the estimated abundance. Separate total quotas were calculated for Eastern Grey Kangaroos (EGK) and Western Grey Kangaroos (WGK) for each of the five harvest zones. For the newly developed exclusion zone comprising municipalities on the urban fringe of Melbourne (see Figure S1), harvesting under the KHP is not permitted.

Forecasting numbers of kangaroos to be taken under ATCW permits during 2025

It is not possible to know in advance exactly how many ATCW permits to control grey kangaroos of either species may be granted for a given harvest zone in a forthcoming year, as this is subject to demand for permits from landholders, which is known to vary significantly over time. As in previous quota-setting work, we have adopted the approach of forecasting the likely number of ATCW permits to be granted for the two species of grey kangaroos during the calendar year 2025 based on time-series modelling of historical ATCW permit numbers. Historical ATCW data was available for each KHP harvest zone for the years 2019-2024, and ATCW data for 2024 was limited to the first 9 months of the calendar year. The likely numbers for the remaining three months of 2024 were imputed and then used in the time-series models.

The time series for each species/zone was modelled using two distinct time-series models. Firstly, an exponential smoothing state space (ETS) model (Holt 2004), and secondly an autoregressive integrated moving average (ARIMA) model (Hyndman and Athanasopoulos 2004). These are both widely used time-series models which have proven to be suitable for short-range forecasting in a variety of contexts. ETS models are based on exponential weights, which leads to greater weight being placed on more recent data in deriving the forecasts. ARIMA models are more flexible and produce forecasts by combining the influence of

autoregressive and moving average components in the data. We compared the predictive performance of the two models for each time series based on the mean absolute scaled error (MASE) and selected the best model for each zone/species time-series to produce forecasts of the ATCW numbers for the 2025 calendar year.

To allow decision-makers to consider the risks of actual ATCW numbers exceeding the forecasts for any given zone/species, we also calculated quotas under scenarios where actual ATCW numbers prove to be either 10% or 20% higher than forecast (see Results, Tables 6 and 7). These figures can be considered alternative scenarios for consideration by policymakers when setting the final harvest quotas. Allocation of higher-than-forecast numbers to the ATCW component of the quota involves subsequently reducing the maximum KHP component of the quota if the overall total take of 10% is not to be exceeded.

KHP harvest quotas for 2025

With the forecasts of numbers authorised for control under ATCW for each zone/species in hand, and the total recommended take derived as 10% of estimated total abundance, the recommended commercial quota for each species/zone combination is simply calculated as:

$$\text{Commercial Quota (KHP)} = \text{Total recommended take} - \text{ATCW prediction}$$

3 Results

Total recommended take for grey kangaroos for 2025

Model-based abundance estimates derived from the 2024 aerial and ground surveys are given in Table 1. To allow for comparison with total population estimates made in previous years the estimates include the ten local government areas (LGAs) which were included in the KHP in previous years, but which will be excluded from the 2025 quota. Separate estimates are derived for each species and each harvest zone. Across the entire area surveyed, the estimated total abundance for both grey kangaroo species combined was 2.31 million (95% CI 1.95 – 2.79 million). This represents a very slight (~ 3%) decline in comparison to the results of the 2022 survey, when a total grey kangaroo abundance of 2.36 million was estimated (Moloney *et al.* 2023). The difference in total estimated abundances is well within the margin of error for analytical approaches used. Considering the grey kangaroo species separately, our findings indicate that both have undergone changes of similarly small magnitude, with Eastern Greys declining from 2.15 to 2.09 million (~ 3%) and Western Greys declining from 218 to 212 thousand (~ 3%) (Moloney *et al.* 2023).

It should be noted that the 2022 population estimates were based on the previous design-based approach to analysis (density averaging across each zone). While design- and model-based approaches to abundance estimation should yield generally similar results (Scroggie *et al.* in press), it is possible that part of the difference between the 2022 and 2024 population estimates may be attributable to differing analytical methodologies. The implications of the change from design-based to model-based inference are discussed more fully in Scroggie *et al.* (in press), and in an accompanying report, where we present the full results of the analysis of the 2024 kangaroo surveys (Scroggie and Moloney in prep).

Table 1. Estimated abundances of grey kangaroos for the five harvest zones, and LGAs which are now included in the harvest exclusion zone that surrounds the Melbourne metropolitan area. Totals are computed for the full survey area (including the now excluded LGAs) and for the area covered by the five harvest zones only.

Abundances were estimated from aerial surveys undertaken in 2024, with ground surveys used to apportion the abundance estimates between Eastern and Western Greys. SE: standard error, LCL and UCL: lower and upper 95% confidence limits of the estimates, respectively. Estimates are rounded to the nearest 1,000 kangaroos. No estimate for WGK is provided for zones where Western Greys are absent (Gippsland, Hume, Exclusion Zone).

Zone	Species	Estimate	SE	LCL	UCL
Barwon South-West	EGK	249,000	43,423	180,000	337,000
	WGK	12,000	3,189	7,000	19,000
Grampians	EGK	273,000	41,936	204,000	366,000
	WGK	112,000	22,983	75,000	164,000
Loddon Mallee	EGK	408,000	75,486	286,000	572,000
	WGK	87,000	16,186	59,000	123,000
Hume	EGK	771,000	104,702	583,000	993,000
	WGK	-	-	-	-
Gippsland	EGK	166,000	29,300	116,000	226,000
	WGK	-	-	-	-
TOTAL (less exclusion zone)	EGK	1,866,000	168,853	1,568,000	2,222,000
	WGK	212,000	32,514	156,000	281,000
Ten LGAs now part of the Exclusion Zone	EGK	228,000	69,188	135,000	393,000
	WGK	-	-	-	-
TOTAL (entire survey area which includes ten LGAs no longer part of the KHP)	EGK	2,094,000	199,547	1,758,000	2,545,000
	WGK	212,000	32,514	156,000	281,000

Based on the population estimates provided in Table 1, we calculated the recommended maximum total take (ATCW+KHP) for each species/harvest zone combination (Table 2). These are simply calculated as 10% of the total estimated abundance. No recommended total take for Western Greys was calculated for the Hume, Gippsland and Exclusion Zone areas, as Western Grey Kangaroos are entirely absent from these areas. For completeness, we also computed the recommended maximum take for the exclusion zone, although commercial harvesting is not permitted in this area.

Table 2. Recommended maximum total take of grey kangaroos for 2025. Totals include all predicted take under both ATCW and the Kangaroo Harvesting Program (KHP) allocations for the period 1 January – 31 December 2025. Recommended maximum total takes are set at 10% of the population per year and are rounded to the nearest 50.

Zone	Eastern Grey Kangaroo	Western Grey Kangaroo	Grey Kangaroos Combined
Barwon South-West	24,900	1,200	26,100
Grampians	27,300	11,200	38,500
Loddon Mallee	40,800	8,700	49,500
Hume	77,100	-	77,100
Gippsland	16,600	-	16,600
TOTAL	186,700	21,100	207,800
Ten LGAs now part of the Exclusion Zone	22,800	-	22,800
TOTAL (entire survey area which includes ten LGAs no longer part of the KHP)	209,500	21,100	230,600

Forecast numbers of grey kangaroos predicted to be taken under ATCW permits during 2025

The ETS and ARIMA time-series models were fitted to historic (2019-2025) ATCW permit data for the two grey kangaroo species from each of the harvest zones as described in the methods. Selection between the two models for each time-series was on the basis of mean absolute scaled error (MASE), with the better (lower) MASE score indicating the preferred model in each case (Table 3).

The forecast ATCW values are illustrated alongside the historic data in Figures 1 and 2, which cover Eastern Greys and Western Greys respectively. The 2025 forecasts themselves (along with 95% confidence intervals) are tabulated in Table 4.

Table 3. Predictive accuracy, expressed as the mean absolute scaled error (MASE), for two models (ETS and ARIMA) fitted to the time series of ATCW permit numbers for the years 2019 - 2024. Lower values (boldface) indicate the models with the best predictive accuracy for each species/zone.

Zone	Species	ETS	ARIMA
Barwon South-West	EGK	0.883	0.976
	WGK	0.559	1.072
Grampians	EGK	0.985	0.963
	WGK	0.544	0.760
Loddon Mallee	EGK	0.916	0.914
	WGK	0.912	0.790
Hume	EGK	0.935	0.935
	WGK	-	-
Gippsland	EGK	0.914	0.910
	WGK	-	-
Ten LGAs now part of the Exclusion Zone	EGK	0.921	0.897
	WGK	-	-

Table 4. Forecast ATCW permit numbers for 2025 for each harvest zone and species. For completeness we have also forecast ATCW numbers for the newly excluded LGAs. Numbers are rounded to the nearest 50 kangaroos. LCL: lower 95% confidence limit, UCL: upper 95% confidence limit.

Zone	Species	Forecast ATCW	LCL	UCL
Barwon South-West	EGK	14,700	8,300	21,500
	WGK	550	350	900
Grampians	EGK	13,450	8,300	26,350
	WGK	900	300	1,300
Loddon Mallee	EGK	14,650	11,000	19,800
	WGK	6,200	950	13,350
Hume	EGK	35,450	21,100	61,800
	WGK	-	-	-
Gippsland	EGK	4,300	2,550	6,950
	WGK	-	-	-
Ten LGAs now part of the Exclusion Zone	EGK	2,300	1,200	3,650
	WGK	-	-	-

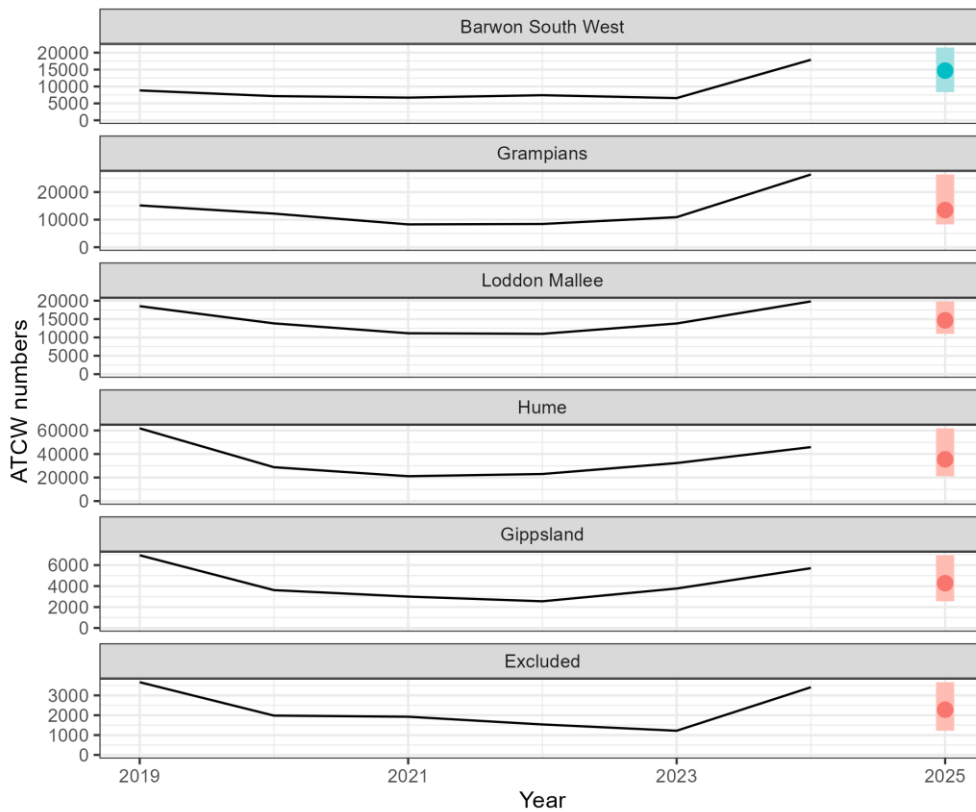


Figure 1. Time series of Eastern Grey Kangaroos controlled under ATCW permits for each harvest zone from 2019 to 2024. The ATCW numbers presented for 2025 (estimate \pm 90% confidence interval) were predicted by the ARIMA model (red circle and shading) and the ETS model (blue circle and shading).

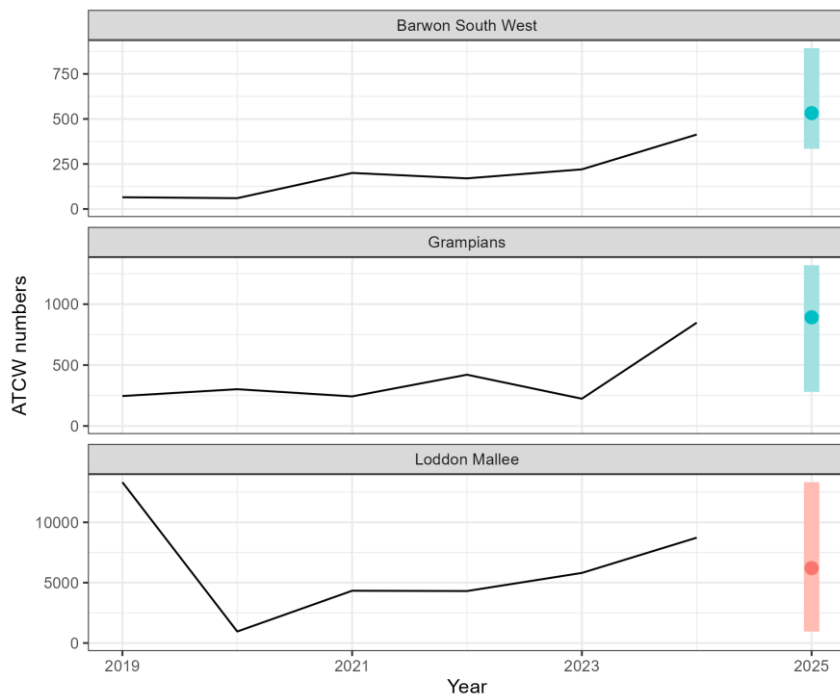


Figure 2. Time series of Western Grey Kangaroos controlled under ATCW permits for each harvest zone from 2019 to 2024. The ATCW numbers presented for 2025 (estimate \pm 90% confidence interval) were predicted by the ARIMA model (red circle and shading) and the ETS model (blue circle and shading).

Commercial harvest quotas for 2025

Commercial harvest quotas were calculated from the recommended total take (Table 2) and the forecast ATCW estimates (Table 4). After deducting the forecast ATCW totals from the maximum recommended total take, the remaining number of kangaroos was allocated to the KHP (Table 5). Alternative scenarios where the ATCW numbers exceeded the forecasts by 10 or 20% are also provided to allow decision-makers to consider the consequences of higher than expected ATCW uptake. Decisions to set the commercial quota on the basis of ATCW forecast will not affect the recommended total take, as any increases in ATCW are compensated for by reduced KHP allocations.

The proportion of the total recommended take attributed to ATCW varied between 8% for Western Greys in the Grampians zone, and 71% for Western Greys in the Loddon Mallee Zone. Overall, we anticipated that 40% of the recommended total take for Eastern Greys and 36.2% of the recommended total take for Western Greys would be in the form of ATCW.

The total quota for both species combined was 230,600 kangaroos, comprising 209,500 Eastern Greys and 21,100 Western Greys. Once forecast ATCW had been accounted for each combination of zone and species, there remained sufficient total quota available to allocate some to the KHP.

Table 5. Total recommended take of grey kangaroos (10 % of total abundance) and the forecast number of ATCW permits. ATCW %: ATCW take as a percentage of the allowable total. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Allowable Total take	Forecast ATCW	KHP	ATCW %
Barwon South-West	EGK	24,900	14,700	10,200	59.0
	WGK	1,200	550	650	45.8
Grampians	EGK	27,300	13,450	13,850	49.3
	WGK	11,200	900	10,300	8.0
Loddon Mallee	EGK	40,800	14,650	26,150	35.9
	WGK	8,700	6,200	2,500	71.3
Hume	EGK	77,100	35,450	41,650	46.0
	WGK	-	-	-	-
Gippsland	EGK	16,600	4,300	12,300	25.9
	WGK	-	-	-	-
TOTAL	EGK	186,700	82,550	104,150	44.2
	WGK	21,100	7,650	13,450	36.2
Ten LGAs now part of the Exclusion Zone	EGK	22,800	2,300	0*	10.1
	WGK	-	-	-	-
TOTAL (entire survey area which includes ten LGAs no longer part of the KHP)	EGK	209,500	84,850	104,150	40.5
	WGK	21,100	7,650	13,450	36.2

*Commercial harvesting not permitted within the exclusion zone

Two alternative quota scenarios were considered in which the ATCW totals exceeded the forecast values by either 10 or 20 % for each zone and species. These are presented in Tables 6 and 7. These alternative scenarios are intended to help decision-makers to consider the implications for the harvesting program of possible exceedances of forecast ATCW totals. If exceedances are expected in a certain zone, then managers may elect to pre-emptively limit the commercial quota and stage the release of this to harvest operators throughout the course of the year to ensure that the total harvest for a given zone and species

does not exceed the total allowable take. Calculation of additional alternative scenarios with higher or lower ATCW forecasts are straightforward to calculate using simple arithmetic, meaning that managers can refine their strategy for allocating commercial quotas in light of available ATCW data and any other information that may allow prediction of the ultimate total number of ATCW permits that end up being issued for any given species or zone.

Table 6. Alternative scenario for recommended take of grey kangaroos (10 % of total abundance) if the actual numbers controlled through ATCW permits exceed the forecast by 10 %. ATCW %: ATCW take as a percentage of the allowable total. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Allowable total take	Forecast ATCW +10 %	KHP	ATCW %
Barwon South-West	EGK	24,900	16,150	8,750	64.9
	WGK	1,200	600	600	50.0
Grampians	EGK	27,300	14,800	12,500	54.2
	WGK	11,200	1,000	10,200	8.9
Loddon Mallee	EGK	40,800	16,100	24,700	39.5
	WGK	8,700	6,800	1,900	78.2
Hume	EGK	77,100	39,000	38,100	50.7
	WGK	-	-	-	-
Gippsland	EGK	16,600	4,700	11,900	28.3
	WGK	-	-	-	-
TOTAL	EGK	186,700	90,750	95,950	48.6
	WGK	21,100	8,400	12,700	39.8
Ten LGAs now part of the Exclusion Zone	EGK	22,800	2,500	0*	11.0
	WGK	-	-	-	-
TOTAL (entire survey area which includes ten LGAs no longer part of the KHP)	EGK	209,500	93,250	95,950	44.5
	WGK	21,100	8,400	12,700	39.8

*Commercial harvesting not permitted within the exclusion zone

Table 7. Alternative scenario for recommended take of grey kangaroos (10% of total abundance) if the actual numbers controlled through ATCW permits exceed the forecast by 20 %. ATCW %: ATCW take as a percentage of the allowable total. Numbers of kangaroos are rounded to the nearest 50.

Zone	Species	Allowable total take	Forecast ATCW + 20 %	KHP	ATCW %
Barwon South-West	EGK	24,900	17,650	7,250	70.9
	WGK	1,200	650	550	54.2
Grampians	EGK	27,300	16,150	11,150	59.2
	WGK	11,200	1,050	10,150	9.4
Loddon Mallee	EGK	40,800	17,550	23,250	43.0
	WGK	8,700	7,450	1,250	85.6
Hume	EGK	77,100	42,550	34,550	55.3
	WGK	-	-	-	-
Gippsland	EGK	16,600	5,150	11,450	31.0
	WGK	-	-	-	-
TOTAL	EGK	186,700	99,050	87,650	53.0
	WGK	21,100	9,150	11,950	43.4
Ten LGAs now part of the Exclusion Zone	EGK	22,800	2,750	0*	12.1
	WGK	-	-	-	-
TOTAL (entire survey area which includes ten LGAs no longer part of the KHP)	EGK	209,500	101,800	87,550	53.0
	WGK	21,100	9,150	11,950	43.4

*Commercial harvesting not permitted within the exclusion zone.

Conclusions

The 2024 aerial survey showed only a very slight decline in overall abundance of grey kangaroos (~3% for both species) in comparison to the 2022 survey, which is a statistically insignificant change that is well within margin of error of the survey methodology. Spatial patterns and temporal trends in abundance of Eastern and Western Grey Kangaroos across the state will be more thoroughly assessed in the associated report (Scroggie and Moloney in prep.) which fully details the results of the 2024 aerial survey and the analyses that were used to derive the abundance estimates used for quota-setting in this report.

It is important to note that this report is written to support quota decision-making following two major changes to the Kangaroo Harvesting Program in Victoria. Firstly, the zoning system has changed to include five zones only, as opposed to the seven zones used in previous years. This means that comparison of abundance and quota figures between this report and previous reports is not straightforward. Furthermore, the method used to estimate abundance has changed from the earlier design-based approach to a model-based approach, based on recent research that demonstrate several advantages of the latter (Scroggie *et al.* in press), including improved precision of abundance estimation and the ability to infer abundances for arbitrarily defined geographic areas within the study area. This latter feature of the new analysis method is of particular utility to this report, where the boundaries of the harvest zones have changed from previous years. A full explanation and exploration of the advantages of the model-based approach is presented in an accompanying report (Scroggie and Moloney in prep.), with only brief summary results presented here to support the quota-setting process.

Forecast total demand for ATCW permits across the survey area amounted to a total of 84,850 Eastern Grey Kangaroos and 7,650 Western Grey Kangaroos. If these forecasts prove correct, they will overall comprise 44 and 36% respectively of the maximum allowable quotas for the two species, with the remaining quota being potentially available for allocation to commercial harvesters under the KHP. At the individual zone level, the forecast ATCW values for every species/zone were in every case less than the total quota, meaning that the commercial quota is at least potentially available to be allocated to the KHP in all five harvest zones.

As well as providing quota scenarios here based on forecast ATCW figures, we have also provided two alternative quota scenarios in which the ATCW numbers prove to be either 10 or 20% higher than predicted. Under such scenarios, a greater proportion of the total quota is accounted for by ATCW, meaning that less quota can be allocated to the KHP process. We anticipate that these scenarios will prove useful to decision-makers in determining the final commercial quotas under circumstances where exceedance of the forecast ATCW total in one or more zones is judged to be a risk that they wish to hedge against. Progressive checking of ATCW allocations throughout the calendar year will allow periodic adjustment of the KHP quota to minimise the chances of the total harvest exceeding the recommended ecologically sustainable criterion of 10% of total abundance.

References

- Buckland ST, Oedekoven CS and Borchers DL (2016). Model-based distance sampling. *Journal of Agricultural, Biological, and Environmental Statistics* **21**, 58–75. doi:10.1007/s13253-015-0220-7
- DEECA (2023). *Victorian Kangaroo Harvest Management Plan 2024-2028*. Department of Energy, Environment and Climate Action, East Melbourne. Available at: https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0030/718167/Victorian-Kangaroo-Harvest-Management-Plan-2024-2028.pdf [accessed 27 November 2024]
- DELWP (2020). *Victorian Kangaroo Harvest Management Plan 2021-2023*. Department of Environment, Land, Water and Planning, East Melbourne. Available at: http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/495029/Kangaroo-harvest-management-plan-2020.pdf [accessed 12 June 2020]
- 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.
- Holt CC (2004). Forecasting seasonals and trends by exponentially weighted moving averages. *International Journal of Forecasting* **20**, 5–10. doi:10.1016/j.ijforecast.2003.09.015
- Hyndman RJ and Athanasopoulos G (2004). 'Forecasting: Principles and Practice' 2nd ed. (Otexts: Melbourne, Australia) Available at: <https://otexts.com/fpp2/> [accessed 27 November 2024]
- Jonzén N, Pople T, Knappe J and Sköld M (2010). Stochastic demography and population dynamics in the red kangaroo *Macropus rufus*. *Journal of Animal Ecology* **79**, 109–116. doi:10.1111/j.1365-2656.2009.01601.x
- McLeod S, Hacker R and Druhan J (2004). Managing the commercial harvest of kangaroos in the Murray-Darling Basin. *Australian Mammalogy* **26**, 9–22. doi:10.1071/AM04009
- Moloney PD, Ramsey DSL and Scroggie MP (2017). *A state-wide aerial survey of kangaroos in Victoria*. Arthur Rylah Institute for Environment Research Technical Report Series No. 268. Arthur Rylah Institute for Environmental Research, Heidelberg. Available at: https://www.ari.vic.gov.au/__data/assets/pdf_file/0007/122011/ARI-Technical-Report-286-A-state-wide-aerial-survey-of-kangaroos-in-Victoria.pdf [accessed 26 August 2019]
- Moloney PD, Ramsey DSL and Scroggie MP (2018). *State-wide abundance of kangaroos in Victoria: results from the 2018 aerial survey*. Arthur Rylah Institute for Environment Research Technical Report Series No. 296. Arthur Rylah Institute for Environmental Research, Heidelberg. Available at: https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0030/415596/Statewide_kangaroo_report_2018_FINAL.pdf [accessed 26 August 2019]
- Moloney PD, Ramsey DSL and Scroggie MP (2021). *State-wide abundance of kangaroos in Victoria: results from the 2020 aerial survey*. Arthur Rylah Institute for Environment Research Technical Report Series No. 324. Arthur Rylah Institute for Environmental Research, Heidelberg.
- Moloney PD, Ramsey DSL and Scroggie MP (2023). *State-wide abundance of kangaroos in Victoria, 2022*. Results from the 2022 aerial survey. Arthur Rylah Institute for Environment Research Technical Report Series No. 356. Arthur Rylah Institute for Environmental Research, Department of Energy, Environment and Climate Action, Heidelberg.
- Scroggie MP and Moloney PD (in prep.). *State-wide abundance of kangaroos in Victoria, 2024. Results from the 2024 aerial survey*. Arthur Rylah Institute for Environment Research Technical Report Series. Arthur Rylah Institute for Environmental Research, Heidelberg.
- Scroggie MP, Moloney PD and Ramsey DSL (in press). Spatio-temporal trends in the abundance of grey kangaroos in Victoria, Australia. *Wildlife Research*.

Scroggie MP and Ramsey DSL (2020). *A spatial harvest model for kangaroo populations in Victoria*. Arthur Rylah Institute for Environment Research Technical Report Series No. 315. Heidelberg.

Scroggie MP and Ramsey DSL (2019). *Kangaroo harvest quotas for Victoria, 2020*. Arthur Rylah Institute for Environment Research Technical Report Series No. 308. Arthur Rylah Institute for Environmental Research, Heidelberg. Available at:
https://www.ari.vic.gov.au/__data/assets/pdf_file/0019/453502/ARI-Technical-Report-308-Kangaroo-harvest-quotas-Victoria-2020.pdf [accessed 21 April 2020]

