The Impacts of the 2019/20 Bushfires on Eastern Grey Kangaroos in the North East and Gippsland Kangaroo Harvest Zones

D.S.L. Ramsey

April 2020



Arthur Rylah Institute for Environmental Research Technical Report Series No. 312





Acknowledgment

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.

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.



Arthur Rylah Institute for Environmental Research Department of Environment, Land, Water and Planning PO Box 137 Heidelberg, Victoria 3084 Phone (03) 9450 8600 Website: <u>www.ari.vic.gov.au</u>

Citation: Ramsey, D.S.L. (2020). The Impacts of the 2019/20 Bushfires on Eastern Grey Kangaroos in the North East and Gippsland Kangaroo Harvest Zones. Arthur Rylah Institute for Environmental Research Technical Report Series No. 312. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: Eastern Grey Kangaroo in burned bushland near Cobargo NSW, January 2020 (Source: Reuters).

© The State of Victoria Department of Environment, Land, Water and Planning 2020

This work is licensed under a Creative Commons Attribution 3.0 Australia licence. 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, the Victorian Government logo, the Department of Environment, Land, Water and Planning logo and the Arthur Rylah Institute logo. To view a copy of this licence, visit http://creativecommons.org/licenses/by/3.0/au/deed.en

Edited by Organic Editing

ISSN 1835-3827 (print) ISSN 1835-3835 (pdf)) ISBN 978-1-76077-915-3 (print) ISBN 978-1-76077-916-0 (pdf/online/MS word)

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

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136 186, email customer.service@delwp.vic.gov.au or contact us via the National Relay Service on 133 677 or www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au

The Impacts of the 2019/20 Bushfires on Eastern Grey Kangaroos in the North East and Gippsland Kangaroo Harvest Zones

D.S.L. Ramsey¹

¹Arthur Rylah Institute for Environmental Research 123 Brown Street, Heidelberg, Victoria 3084

Arthur Rylah Institute for Environmental Research Technical Report Series No. 312

Arthur Rylah Institute for Environmental Research Department of Environment, Land, Water and Planning Heidelberg, Victoria

Acknowledgements

I would like to thank Elizabeth Coluccio, Kirsty Greengrass (Biodiversity Division), Michael Scroggie, Jemma Cripps and Ben Fanson (Arthur Rylah Institute) for helpful comments on drafts of this report. This work was funded by the Biodiversity Division, DELWP.

ii

Contents

Ackn	Acknowledgements		
Sum	nary	5	
1	Introduction	6	
1.1	Aims	6	
2	Methods	7	
2.1	Direct impacts of bushfires on the kangaroo population	7	
2.2	Indirect impacts of bushfires on the kangaroo population	8	
2.3	Revision of harvest quotas	9	
3	Results	9	
3.1	Direct impacts of bushfires on the kangaroo population	9	
3.2	Indirect impacts of bushfires on the kangaroo population	12	
3.3	Revision of harvest quotas	12	
4	Discussion	13	
4.1	Recommendations	13	
5	References	14	

Tables

Table 1. Estimates of abundance for Eastern Grey kangaroos for each LGA in the Gippsland Harvest Zone,
the percentage of the survey area that was burnt (% Burnt) and the corresponding number of
potentially impacted kangaroos (Impacted). Dispersal gives the mean expected flux in the kangaroo
population due to bushfire related movements
Table 2. Estimates of abundance for Eastern Grey kangaroos for each LGA in the North East Harvest Zone,
the percentage of the survey area that was burnt (% Burnt) and the corresponding number of
potentially impacted kangaroos (Impacted). Dispersal gives the mean expected flux in the kangaroo
population due to bushfire related movements
Table 3. Recommended revised commercial harvest quota and total allowable offtake for Eastern Grey

Figures

Figure 1. Extent of the 2019/20 bushfires within the North East and Gippsland kangaroo harvest zones 7
Figure 2. Kangaroo survey areas within the North East and Gippsland harvest zones (blue and green shading) and the area within the kangaroo survey areas that were affected by the 2019/20 bushfires (red shading). Polygons show the boundaries of Local Government Areas (LGA) within each zone. 8
Figure 3. Numbers of kangaroos harvested in the North East and Gippsland harvest zones during the period 1 st October – 31 st December 2019
Figure 4. Number of kangaroos authorised for control (expressed as a proportion of the estimated kangaroo abundance) under the ATCW permit process in the North East and Gippsland harvest zones during 2019
Figure 5. Predicted relative flux in kangaroo abundance expected into unburnt regions of the kangaroo survey area due to bushfire related movements. The pale red region indicates the extent of the
2019/20 Victorian bushfires



Context:

Victoria's commercial kangaroo harvesting program commenced on 1st October 2019 with the commercial take limited by quotas set across seven harvest zones. Following the recent bushfires during the 2019/20 summer season, quota allocation was suspended in the North East and Gippsland harvest zones due to the severity of the fires in these regions.

Aims:

To assess the extent of the probable impacts of the bushfires on the kangaroo populations in the North East and Gippsland harvest zones to determine whether commercial harvesting can recommence in these zones and if so, whether revision of the quota allocation is required.

Methods:

The extent of the overlap between the areas burnt by the bushfires and the areas where commercial harvest is undertaken (i.e. kangaroo survey area) was used as a proxy for direct impacts. Indirect impacts were assessed by examining the likely flux of kangaroos from burnt to unburnt areas of the kangaroo survey area due to bushfire related movements. Impacts (both direct and indirect) were then assessed for individual local government areas (LGA) within each zone. Recommendations were then made about risks of recommencing harvest in individual LGAs. Allowable offtake for the affected zones was revised on a pro rata basis, under an assumption that harvesting would not recommence where impacts were likely to be significant.

Results:

The bushfires had the greatest impacts in the Towong, East Gippsland and Alpine LGAs burning an estimated 31%, 11% and 5%, of their respective kangaroo survey areas. The likely flux of kangaroos into the kangaroo survey areas due to the bushfires were also highest for these LGAs. Direct and indirect impacts in other LGAs were trivial by comparison.

Conclusions and implications:

Based on these analyses, allowing commercial harvesting to recommence in the Towong, Alpine and East Gippsland LGAs for the remainder of 2020 may impede the recovery of these local populations from the bushfires. If commercial harvesting in these LGAs is accordingly not permitted for the remainder of 2020, the maximum allowable offtake of kangaroos in the North East and Gippsland harvest zones would be reduced by 10% and 23%, respectively.

Recommendations:

- Recommencing commercial harvest in the North East and Gippsland harvest zones is considered to be low risk, except for areas within the Towong, Alpine and East Gippsland LGAs.
- Due to high predicted impacts from the bushfires, recommencing commercial harvest within the Towong, Alpine and East Gippsland LGAs for the remainder of 2020 is considered to have a high risk of impeding the recovery of these local populations.
- If these LGAs are excluded from harvesting, commercial harvest quotas in the North East and Gippsland harvest zone should be revised accordingly to 11,300 and 3,100 kangaroos respectively and harvesting can be undertaken in the remaining LGAs in each zone for the 2020 calendar year.
- Management of Authorities to Control Wildlife (ATCWs) should also be considered carefully in the three most significantly impacted LGAs (Towong, Alpine and East Gippsland). A total revised allocation of 25,900 and 7,000 kangaroos are recommended as the maximum sustainable offtake for the North East and Gippsland harvest zones, respectively, which can be undertaken in the remaining LGAs in each zone for the 2020 calendar year. This includes kangaroos taken by both commercial harvest and the ATCW permit process.
- Careful management of ATCW permit applications is required for the North East harvest zone in particular, to ensure that numbers do not exceed the maximum allowable offtake.

1 Introduction

Victoria's commercial kangaroo harvesting program commenced on 1 October 2019 with the regulatory guidelines underpinning the program detailed in the "Victorian Kangaroo Harvest Management Plan" (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 harvest zones, which were set using ecologically sustainable criteria (Scroggie and Ramsey 2019). The total allowable offtake of kangaroos in each harvest zone includes both the commercial harvest quota as well as kangaroos taken under Authority to Control Wildlife (ATCW) permits.

In response to the severity and extent of the recent bushfires across much of eastern and north east Victoria in late 2019 and early 2020, quota allocation was suspended across all seven harvest zones. However, in early February 2020 harvesting resumed in all but the two worst-affected harvest zones – the North East and Gippsland zones – as continued suspension of the entire commercial harvesting program was considered a disproportionate response in relation to the areas impacted by the fires. This approach was also consistent with the intent behind the creation of commercial harvesting zones to manage quota allocation, which enables the treatment of each zone individually in response to local conditions and circumstances. An additional consideration was the fact that commercial harvest or other offtake of kangaroos occurs predominantly on private land, which may not have been affected by the fires to the same extent as more heavily forested areas of public land.

By February 2020, the bushfires in eastern and north east Victoria were largely contained. Hence, an assessment of the extent of the Victorian bushfires is now required to assess whether the commercial kangaroo harvest can recommence in the North East and Gippsland harvest zones without posing an unacceptable risk to kangaroo populations in those zones. In addition, if recommencement of commercial harvest was recommended, then an assessment of whether commercial quotas should be revised is required to ensure ecological sustainability of the harvest for the remainder of the 2020 calendar year. Hence, this report details the assessment of the potential impacts of the bushfires on the kangaroo populations in the North East and Gippsland harvest zones in order to make recommendations on the recommencement of the harvest and/or revision of the commercial quota.

1.1 Aims

- Using existing aerial survey data and fire extent maps, assess the impact of the 2019/20 bushfires in the North East and Gippsland harvest zones on kangaroo populations in those areas.
- Using 2019 kangaroo harvesting data from the Kangaroo Harvesting Program and Authority to Control Wildlife (ATCW) data, assess the extent to which harvesting activity and ATCW control overlaps with fire-affected areas.
- Using known information about kangaroo dispersal, consider how far and where kangaroos may have dispersed from fire-affected areas.
- Using existing aerial survey data and the outcomes from the first three aims, analyse risks to kangaroo populations of recommencing harvest in the North East and Gippsland zones, or parts thereof.
- Recommend any qualifying conditions that may need to be imposed if harvest recommences in the North East and Gippsland harvest zones, for example, considering the need for reduced harvest areas, adjustments to quotas or timing considerations.

2 Methods

2.1 Direct impacts of bushfires on the kangaroo population

A similar method to that detailed in Heard and Ramsey (2020) was used for estimating the potential direct impacts of the bushfires on the kangaroo population. This method examines the extent of the overlap between the fire regions and the region of interest as a simple proxy of the direct impacts of the bushfires. Hence, polygons of the extent of the 2019/20 bushfires in the North East and Gippsland kangaroo harvest zones were obtained from Biodiversity Division (version dated 11th February 2020). These bushfires occurred predominantly in heavily forested areas of public land in East Gippsland and the Alpine National Park (Figure 1). However, current aerial survey estimates of kangaroo abundance only consider habitat that is outside the densely forested parts of the state (Scroggie *et al.* 2017) and it is this portion of the population that is subject to commercial harvest (kangaroo survey area). Thus, the fire extent map was intersected with the map of the kangaroo survey area to estimate the proportion of the kangaroo survey area affected by the bushfires. This was undertaken separately for each LGA in the North East and Gippsland harvest zones (Figure 2).



Figure 1. Extent of the 2019/20 bushfires (red shading) within the North East and Gippsland kangaroo harvest zones.

This proportion was then simply multiplied by the kangaroo abundance within each LGA, estimated from the last aerial survey in November 2018 (Moloney *et al.* 2019), to estimate the proportion of the kangaroo population that was potentially impacted by fires. This assumes that kangaroos are uniformly distributed within the kangaroo survey region within each LGA. Overall impacts for each harvest zone were estimated by summing the impacts for each individual LGA.

Potential impacts within each LGA were also assessed by examining previous records of the locations of harvested kangaroos as well as kangaroos authorised for control under ATCW permits. Harvest data from 2019 (1st October – 31st December) as well as the number of kangaroos approved for control under ATCW permits during 2019 were obtained from Biodiversity Division and collated. A large proportion of the harvest locations were available only to the nearest street address, so the midpoint of the street location was used as the harvest location. Locations of kangaroos culled under ATCW permits were only resolved to the level of the LGA. Locations of these activities were then mapped and compared with the predicted fire impacts.



Figure 2. Kangaroo survey areas within the North East and Gippsland harvest zones (blue and green shading) and the amount of this area affected by the 2019/20 bushfires (red shading). The remaining areas represent densely forested areas of public land, which are not considered during kangaroo aerial surveys. Polygons show the boundaries of Local Government Areas (LGA) within each zone.

2.2 Indirect impacts of bushfires on the kangaroo population

Indirect impacts of the bushfires on the kangaroo population were also assessed by examining the likely movements of kangaroos dispersing from fire affected areas. The rationale for examining dispersal from the bushfire zone was that areas considered to have a relatively high level of flux due to immigration of kangaroos may need consideration in respect of additional disturbances from harvest or control. For example, recolonization of the bushfire regions is likely to be dependent on those areas that received high levels of kangaroo immigration due to the fires. Hence, allowances might need to be made for this recolonization to occur without disturbance due to harvest or control activities.

Although observations of Eastern Grey Kangaroos fleeing bushfires are relatively common, no information exists about how far individuals might travel from the bushfire front. In addition, limited published information exists on patterns of dispersal in Eastern Grey Kangaroos and what information does exist, depends heavily on the methods used for measuring dispersal. Studies using radiotracking of kangaroos have suggested that limited (breeding) dispersal occurs in established populations with evidence of some mature individuals dispersing up to 20 km from their breeding sites (Jarman and Taylor 1983; Johnson 1989). In contrast, studies measuring the amount of genetic differentiation (a measure of geneflow) occurring among populations separated by various distances have shown that (generational) dispersal occurred over much

larger distances, up to 230 km (Zenger *et al.* 2003). Unfortunately, these studies shed little light on the potential movements of kangaroos responding to bushfires. Indeed, the pattern of bushfire related movements are likely to be highly context specific, dependent on the proximity of nearby suitable unburnt habitat and other sources of shelter (Nimmo *et al.* 2019).

In the absence of any information on the expected pattern of movements of kangaroos in relation to bushfires, an *ad hoc* approach was adopted to gauge the likelihood of unburnt regions of the kangaroo survey area receiving dispersing kangaroos. Hence, it was assumed that kangaroos dispersed directly away from an active bushfire front with dispersal distances drawn from a half-normal distribution with a standard deviation of 20 km. Hence, the majority of movements (66%) were within 20 km of the bushfire region with 95% of the movements within 39 km. No assumptions were made about the directions of movements so that any direction was equally likely. The probability of bushfire related movement of kangaroos into the kangaroo survey area within each LGA was then calculated using the dispersal kernel defined above emanating from the edge of each of the bushfire polygons and calculated over a 1 km grid of the kangaroo survey area. The net effect of these movements was then estimated by calculating the proportion of these 1 km cells in the kangaroo survey area with a probability of movement greater than 0.20, separately for each LGA. The proportion of cells meeting this criterion thus represents the proportion of the survey area within each LGA potentially subject to bushfire related kangaroo movement.

2.3 Revision of harvest quotas

Based on above analyses, recommendations were made as to whether a revision of the harvest quotas for the North East and Gippsland harvest zones may be required. This was undertaken by considering the impacts of the bushfires on the kangaroo survey areas within individual LGAs, either directly due to loss of habitat from burning, or indirectly due to dispersal from fire affected areas. If impacts were considered high (i.e. >25% of an LGA area subject to either direct or indirect impacts), then it was assumed a decision may be made to close that LGA to further harvest for the duration of the 2020 calendar year. An expected decision to close an LGA from any offtake then reduced the estimated number of kangaroos potentially available for harvest in that harvest zone on a pro rata basis, and the corresponding harvest quota was revised in proportion to this new abundance estimate.

3 Results

3.1 Direct impacts of bushfires on the kangaroo population

The 2019/20 bushfires had the greatest impacts in the Towong, East Gippsland and Alpine LGAs burning an estimated 31%, 11% and 5%, of their respective kangaroo survey areas (Tables 1 & 2). Bushfire impacts on the remaining LGAs were all trivial (<1%) (Tables 1 & 2). Overall, the bushfires burnt 2.7% and 2.5% of the kangaroo survey area in the Gippsland and North East harvest zones, potentially impacting a predicted 2414 and 7328 individual kangaroos in those two harvest zones respectively (Tables 1 & 2).

Commercial harvesting activity was highest in the North East harvest zone, occurring predominantly in the Greater Bendigo, Strathbogie, Benalla and Mansfield LGAs while harvesting activity in the Gippsland region occurred primarily in the South Gippsland LGA (Figure 3). Overall 1730 and 157 kangaroos were harvested between 1st October and 31st December 2019 in the North East and Gippsland harvest zones, respectively. Very little harvesting activity (< 15 kangaroos) occurred in those LGAs most impacted by the bushfires (Figure 3).

The number of kangaroos authorised for control under ATCW permits during 2019 was also higher in the North East compared with the Gippsland harvest zone (Figure 4). In the North East the highest number of authorisations occurred in the Strathbogie, Mansfield, Benalla, Wangaratta and Greater Bendigo LGAs (> 4000 kangaroos authorised in total in each of these LGAs) while the highest number of authorisations in the Gippsland harvest zone occurred in the East Gippsland LGA (2507 kangaroos authorised), which was the LGA most affected by the bushfires in this harvest zone (Figure 4).

Overall, the number of kangaroos authorised for ATCW control in the North East harvest zone during 2019 (37,633) was higher than the maximum recommended offtake for 2020 (28,800) (Scroggie and Ramsey 2019). Hence, ATCW numbers for the North East harvest zone should be closely managed during 2020 to ensure the total take does not exceed the recommended maximum.

Table 1. Estimates of abundance for Eastern Grey kangaroos for each LGA in the Gippsland Harvest Zone, the percentage of the survey area that was burnt (% Burnt), the number of potentially impacted kangaroos (Impacted), and the percentage of the survey area potentially subject to bushfire related kangaroo movements (% Dispersal).

LGA	Abundance	Area	% Burnt	Impacted	% Dispersal
Bass Coast	4845	846	0	0	0.0
Baw Baw	8763	1530	0	0	0.0
Cardinia	5538	967	0	0	0.0
Casey	2239	391	0	0	0.0
East Gippsland	20716	3617	11.3	2341	79.4
Latrobe	5040	880	0	0	0.0
Mornington Peninsula	3688	644	0	0	0.0
South Gippsland	15384	2686	0	0	0.0
Wellington	24496	4277	0.3	73	2.3
Total	90711	15838	2.7	2414	18.7

Table 2. Estimates of abundance for Eastern Grey kangaroos for each LGA in the North East Harvest Zone, the percentage of the survey area that was burnt (% Burnt), the number of potentially impacted kangaroos (Impacted), and the percentage of the survey area potentially subject to bushfire related kangaroo movements (% Dispersal).

LGA	Abundance	Area	% Burnt	Impacted	% Dispersal
Alpine	7079	607	5	354	96.3
Benalla	20140	1727	0.1	20	0.1
Campaspe	49761	4267	0.2	100	0.2
Greater Bendigo	26449	2268	0.1	26	0.1
Greater Shepparton	27021	2317	0	0	0.0
Indigo	16572	1421	0	0	2.8
Mansfield	14053	1205	0	0	0.0
Moira	42578	3651	0	0	0.0
Strathbogie	33831	2901	0.1	34	0.1
Towong	21819	1871	30.9	6742	65.3
Wangaratta	24012	2059	0.1	24	8.9
Wodonga	4700	403	0.6	28	0.8
Total	288,014	24697	2.5	7328	8.2



Figure 3. Numbers of kangaroos harvested in the North East and Gippsland harvest zones during the period 1st October – 31st December 2019.



Figure 4. Number of kangaroos authorised for control (expressed as a proportion of the estimated kangaroo abundance) under the ATCW permit process in the North East and Gippsland harvest zones during 2019.

3.2 Indirect impacts of bushfires on the kangaroo population

Based on the assumed dispersal kernel, the Alpine, East Gippsland and Towong LGAs, were relatively more likely to have a high flux of kangaroos with 96%, 79% and 65% of their respective survey areas potentially subject to bushfire related kangaroo movements (i.e. relative flux > 0.2) (Figure 5). For the remaining LGAs, the proportion of the survey area potentially subject to bushfire related kangaroo movements were predicted to be low (< 10%) (Tables 1 & 2) (Figure 5). Overall, 19% and 8% of the kangaroo survey areas in the Gippsland and North East harvest zones, respectively, were potentially subject to bushfire related kangaroo movements (Tables 1 & 2).



Figure 5. Potential relative flux in kangaroo abundance expected into unburnt regions of the kangaroo survey area due to bushfire related movements. The pale grey region indicates the extent of the 2019/20 Victorian bushfires.

3.3 Revision of harvest quotas

Impacts of the 2019/20 bushfires in Victoria in three local government areas, the Alpine and Towong LGAs in the North East harvest zone and the East Gippsland LGA in the Gippsland harvest zone, were considered to be high enough to warrant a management response. Each of these LGAs were either extensively burned and/or were relatively more likely to have a high flux of kangaroos due to bushfire related movements. If these LGAs are closed from further commercial harvest of kangaroos for the remainder of the calendar year, the total revised offtake for 2020 in the North East and Gippsland harvest zones should be reduced by 10% and 23%, respectively, representing the pro rata contribution of these LGAs to kangaroo abundance in the two harvest zones. Hence, commercial harvest could continue in the remaining LGAs in both zones, using the revised allocations provided in Table 3.

Table 3. Recommended revised commercial harvest quota and total allowable offtake for Eastern Grey Kangaroos (rounded to the nearest 100) for the Gippsland and North East harvest zones for the period 1 January to 31 December 2020.

Harvest zone	Current commercial quota	Current total offtake	Revised commercial quota	Revised total offtake
Gippsland	4,000	9,100	3,100	7,000
North East	12,550	28,800	11,300	25,900

4 Discussion

The extensive bushfires across Victoria during the 2019-20 summer season were predicted to directly impact only a small proportion (< 3%) of the overall kangaroo survey area in the Gippsland and North East harvest zones. Nevertheless, impacts were predicted to be high enough to warrant intervention for three local government areas, Towong, Alpine and East Gippsland with over 30% of the kangaroo population within the Towong LGA predicted to be impacted.

Both direct and indirect impacts were modelled with indirect impacts predicted to occur due to dispersal of kangaroos from the burnt areas into adjacent unburnt areas. Since the scale and extent of these movements is unknown, our simple model of movements from the bushfire regions can only provide an indication of the relative expected flux in kangaroos occurring in areas adjacent to the bushfires. As the densities (pre-fire) within the forested areas within the burnt zones are also unknown, we have little basis for estimating how many kangaroos in total may have been impacted by the bushfires, or how many are likely to have dispersed out of burnt habitat into adjacent unburnt habitat. These analyses suggest that dispersal into unburnt regions of the kangaroo survey areas were likely to be highest in the East Gippsland, Alpine and Towong LGAs. Clearly, these analyses would benefit from future research into the movements of wildlife in response to bushfires (Nimmo *et al.* 2019).

The predicted impacts of the bushfires on kangaroos remain speculative. While kangaroos almost certainly either fled the bushfire regions or were killed, their fate remains unknown. There is some evidence that Eastern Grey Kangaroos rapidly recolonise burnt habitat to take advantage of new regrowth (Southwell and Jarman 1987) so any movement of kangaroos out of burnt habitat may rapidly reverse. Despite this, it seems prudent to take a precautionary approach and allow this natural reorganisation and/or recovery of the kangaroo populations in the impacted areas to proceed without additional pressures due to kangaroo harvest activities. These predicted impacts should also be re-assessed in light of future kangaroo aerial surveys, which are scheduled for late 2020.

If commercial harvest was accordingly withheld in those LGAs most impacted by the bushfires, harvest quotas should be reduced by 23% and 10% in the Gippsland and North East harvest zones, respectively. Close management of numbers of kangaroos authorised for control under ATCW permits will also be required in light of the revised offtake, especially for the North East harvest zone where ATCW authorisations were already higher than the recommended sustainable offtake.

4.1 Recommendations

- Recommencing commercial harvest in the North East and Gippsland harvest zones is considered to be low risk, except for areas within the Towong, Alpine and East Gippsland LGAs.
- Due to high predicted impacts from the bushfires, recommencing commercial harvest within the Towong, Alpine and East Gippsland LGAs for the remainder of 2020 is considered to have a high risk of impeding the recovery of these local populations.

- If these LGAs are excluded from harvesting, commercial harvest quotas in the North East and Gippsland harvest zone should be revised accordingly to 11,300 and 3,100 kangaroos respectively, which can be undertaken in the remaining LGAs in each zone for the 2020 calendar year.
- Management of ATCWs should also be considered carefully in the three most significantly impacted LGAs (Towong, Alpine and East Gippsland). A total revised allocation of 25,900 and 7,000 kangaroos are recommended as the maximum sustainable offtake for the North East and Gippsland harvest zones, respectively and harvesting can be undertaken in the remaining LGAs in each zone for the 2020 calendar year. This includes kangaroos taken by both commercial harvest and the ATCW permit process.
- Careful management of ATCW permit applications is required for the North East harvest zone in particular, to ensure that numbers do not exceed the maximum allowable offtake.

5 References

- DELWP (2020). Victorian Kangaroo Harvest Management Plan. Department of Environment, Land, Water and Planning, Victorian Government, Melbourne. Available at: http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/495029/Kangaroo-harvest-management-plan-2020.pdf?v=2
- Heard, G. W., and Ramsey, D. S. L. (2020). Modelling the abundance of the Common Wombat across Victoria. Unpublished Client Report for Biodiversity Division, Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Jarman, P. J., and Taylor, R. J. (1983). Ranging of eastern grey kangaroos and wallaroos on a new england pastoral property. *Wildlife Research* **10**, 33–38. doi:10.1071/WR9830033
- Johnson, C. N. (1989). Dispersal and philopatry in the Macropods. In 'Kangaroos, wallabies and ratkangaroos'. (Eds G. C. Grigg, P. Jarman, and I. D. Hume.) (Surrey Beatty & Sons: Chipping Norton, N.S.W.)
- Moloney, P. D., Ramsey, D. S. L., and Scroggie, M. P. (2019). State-wide abundance of kangaroos in Victoria: Results from the 2018 aerial survey. Arthur Rylah Institute for Environmental Research Technical Report Series No. 296, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.
- Nimmo, D. G., Avitabile, S., Banks, S. C., Bliege Bird, R., Callister, K., Clarke, M. F., Dickman, C. R., Doherty, T. S., Driscoll, D. A., Greenville, A. C., Haslem, A., Kelly, L. T., Kenny, S. A., Lahoz-Monfort, J. J., Lee, C., Leonard, S., Moore, H., Newsome, T. M., Parr, C. L., Ritchie, E. G., Schneider, K., Turner, J. M., Watson, S., Westbrooke, M., Wouters, M., White, M., and Bennett, A. F. (2019). Animal movements in fire-prone landscapes. *Biological Reviews* 94, 981–998. doi:10.1111/brv.12486
- 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., and Ramsey, D. 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.
- Southwell, C. J., and Jarman, P. J. (1987). Macropod studies at Wallaby Creek III. The effect of fire on pasture utilisation by macropodids and cattle. *Wildlife Research* **14**, 117–124. doi:10.1071/WR9870117
- Zenger, K. R., Eldridge, M. D. B., and Cooper, D. W. (2003). Intraspecific variation, sex-biased dispersal and phylogeography of the eastern grey kangaroo (Macropus giganteus). *Heredity* **91**, 153–162.

www.delwp.vic.gov.au www.ari.vic.gov.au