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POST-FIRE RECOVERY OF ARBOREAL MAMMALS AT WOMBEYAN AND JENOLAN

2023 Report

Pale phase Greater Glider, Transect 12, May 2023

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Summary

We have been engaged by the Kanangra-Boyd to Wyangala (K2W) Conservation Partnership to monitor the post-fire recovery of gliders and other arboreal mammals in conservation reserves at Wombeyan and Jenolan that were impacted by the unprecedented 2019-20 Black Summer bushfires and the extreme drought of 2019 that led up to the fires. We have been monitoring seven 500 m long transects for which we have pre-fire, pre-drought data on arboreal mammals. Post-fire surveys have been carried out in 2020, 2021, 2022 and now 2023. Following the breaking of the drought, there has been good rainfall and good plant growth, which is likely to have favoured post-fire recovery of arboreal mammals.

Seven and possibly eight species of arboreal mammals have been recorded on the transects, including four threatened species – the Southern Greater Glider (*Petauroides volans*), Yellow-bellied Glider (*Petaurus australis*), Squirrel Glider (*Petaurus norfolcensis*, unconfirmed pre-fire record) and Spotted-tailed Quoll (*Dasyurus maculatus*) – and four non-threatened species – the 'Feathertail Glider' (Broad-toed and/or Narrow-toed Feathertail Glider *Acrobates frontalis/A. pygmaeus sensu stricto*; both species could be present but they cannot be distinguished without close inspection), Krefft's Glider (*Petaurus notatus*), Common Brushtail Possum (*Trichosurus vulpecula*) and Common Ringtail Possum (*Pseudocheirus peregrinus)*. Two of these species have not been recorded in any post-fire surveys: the Common Ringtail Possum and the unconfirmed Squirrel Glider. Common Ringtail Possums were rare in the pre-fire surveys but the absence of any post-fire records, despite a large number of searches over four years, is concerning.

The species for which we have the most data is the Southern Greater Glider. The drought and fires had a massive impact on Southern Greater Gliders in the Greater Blue Mountains World Heritage Area, burning 84% of their known locations and resulting in an estimated 60% reduction of their population. Fire severity was a critical factor. The species was eliminated from our transects burnt at high to extreme severity but survived, although its numbers were reduced, in the transects burnt at low to moderate severity. In the more severely burnt transects, even if the gliders were able to survive the fires in their hollows, there was no live eucalypt foliage for them to feed on when they emerged after the fires.

Post-fire recovery of Southern Greater Gliders on the study transects has also depended on fire severity. There has been no recovery in the more severely burnt transects but a good recovery in unburnt and less severely burnt transects. Glider numbers in these transects now exceed their pre-fire numbers. The first post-fire breeding season in 2020 was unsuccessful and did not result in any increase in numbers but the population increased following the 2021 breeding season and has now increased again following the 2022 breeding season.

The steepest rate of increase has been on the unburnt/low severity transects, where glider numbers in 2023 were 89% higher than the first post-fire counts in 2020, and 64% higher than the pre-fire, pre-drought counts in 2016. By comparison, the numbers of Southern Greater Gliders on the moderate severity transects in 2023 were 63% higher than the first post-fire counts in 2020, and 26% higher than the pre-fire, pre-drought counts in 2016-18.

The unburnt/low severity transects also happen to be the tallest forests and best glider habitat sampled. Before the fires, they supported much higher densities of Southern Greater Gliders than the other transects. Their glider densities were very high compared with other studies in the region and have increased since the fire to exceptional levels. These tall forests on fertile soils at higher elevations are critically important habitat for Southern Greater Gliders, not only for post-drought, post-fire recovery, but also in relation to the worrying retreat since the 1990s of this heat-sensitive species from lower elevations in the Blue Mountains as a consequence of temperature increase from climate change.

The Black Summer fires in the Greater Blue Mountains World Heritage Area burnt an unprecedented 79% of the World Heritage Area, which is more than three times greater than the area burnt in any of the previous 48 fire seasons. The fires were not proportionally more severe than previous large fires (i.e. the ratio of severely burnt to lightly burnt vegetation was similar to previous fires) but their huge scale meant that an unprecedented 29% of the World Heritage Area was burnt at high to extreme severity. This is a particular concern for the Southern Greater Glider in view of the loss of the species from the more severely burnt study transects and the lack of any post-fire recovery.

Tall, moist, fertile forests (wet sclerophyll forests) are the favoured habitat of Southern Greater Gliders in the World Heritage Area. Wet sclerophyll forests occur in sheltered fertile gullies at scattered locations throughout the World Heritage Area and as plateau forests on richer soils at higher elevations such as at Wombeyan and Jenolan. These forests usually remain unburnt or only lightly burnt in major wildfires and play an important role as natural firebreaks and as fauna refuges. In the Black Summer fires, however, the wet sclerophyll forests were as badly burnt as the normally much more fire-prone dry sclerophyll forests, which seriously compromised their role as fauna refuges. Before 2019, most of the plateau forests in the south-western corner of the World Heritage Area, including the Wombeyan and Jenolan areas, had not been burnt for at least 48 years or had only been burnt by a single fire. They were the least fire-prone part of the World Heritage Area but in the Black Summer fires they were one of the most severely burnt parts, probably because of the exceptionally dry conditions of the 2019 drought.

The survival and good post-fire recovery of Southern Greater Gliders in the Wombeyan transects burnt at low to moderate severity or unburnt are very encouraging, especially considering the slow post-fire recovery of Southern Greater Gliders reported in previous studies. The Jenolan transects burnt at high to extreme severity are a different story and the species is likely to be absent from these transects for years to come, judging by previous long-term studies that have reported long-lasting impacts in severely burnt sites 10-18 years post-fire. Nevertheless, recovery will eventually occur even in the most severely burnt parts of the Greater Blue Mountains World Heritage Area as long as the Black Summer fires prove to be a very rare event that will not recur for many decades. However, a change in the fire regime to more frequent, more extensive, more severe wildfires as a result of climate change has long been predicted. This would make suppression and containment of future wildfires increasingly difficult. If the Black Summer fires are a harbinger of this change, the long-term impact on Southern Greater Gliders, and on the other animals and plants of the Greater Blue Mountains World Heritage Area, would be catastrophic.

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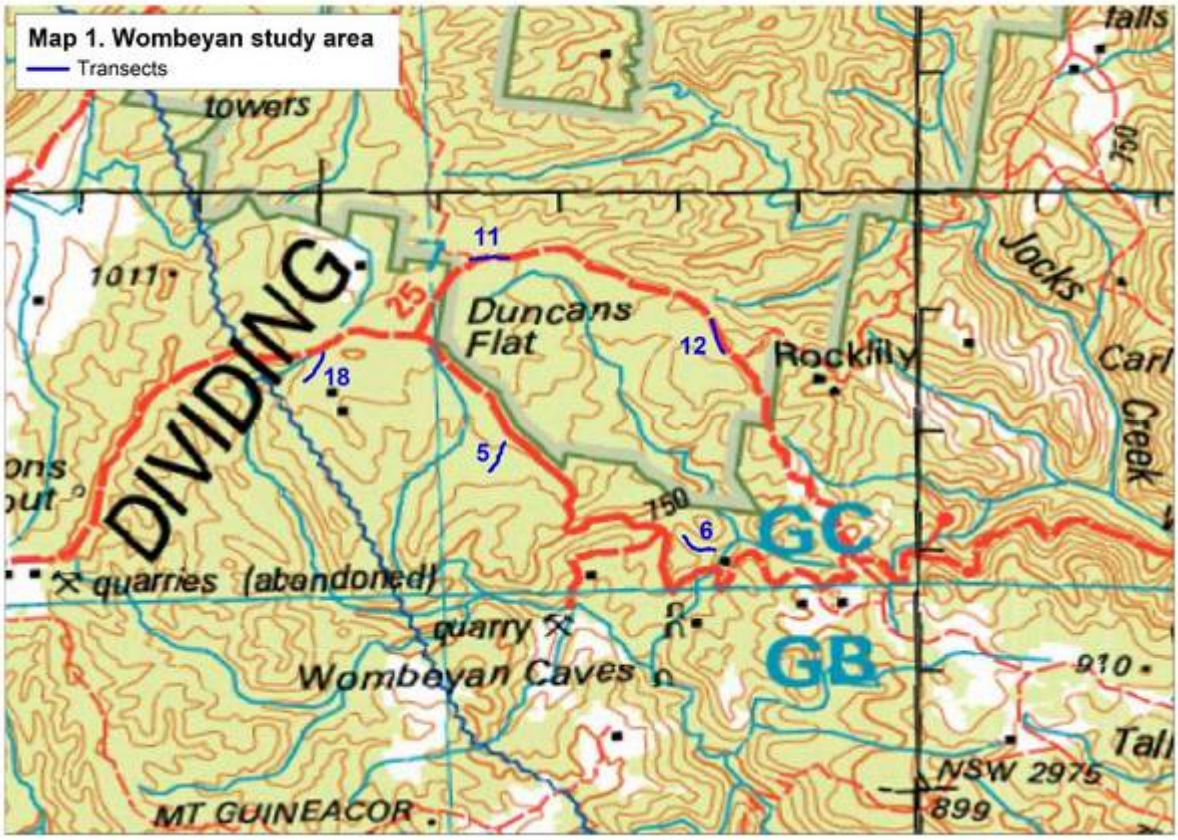
1. Introduction

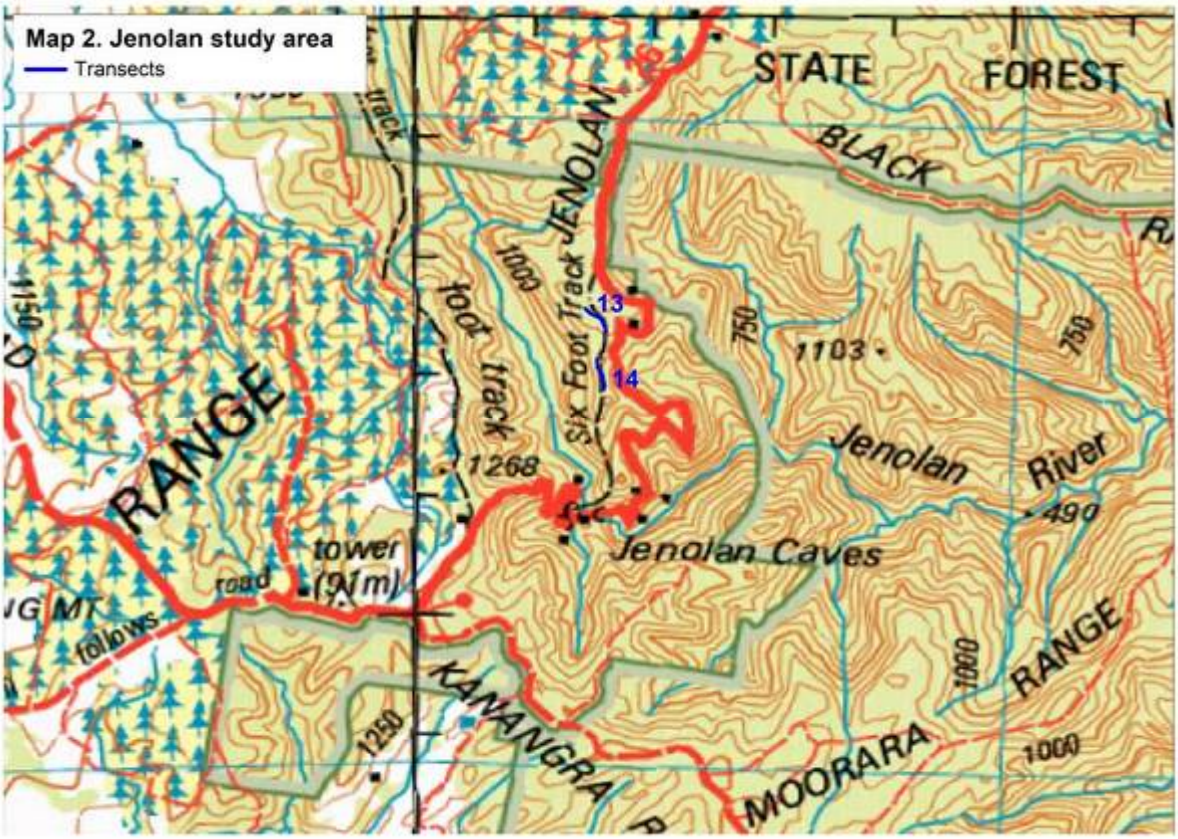
As part of the 'Cores, Corridors and Koalas: Jenolan to Wombeyan Post-fire Assessment' project, we have been engaged by the Kanangra-Boyd to Wyangala (K2W) Conservation Partnership to monitor the post-fire recovery of gliders and other arboreal mammals in conservation reserves at Wombeyan and Jenolan that were impacted by the 2019-20 Black Summer bushfires and the extreme drought and heatwave conditions that led up to the fires. After an initial fire impact study in 2020-21 (Smith and Smith 2021, 2022a), annual surveys to monitor recovery were carried out in 2022 (Smith and Smith 2022b) and 2023 (this report). The post-fire recovery surveys have been funded by WWF Australia and the Great Eastern Ranges Initiative.

Australia was subject to a drought of increasing severity over the three years 2017 to 2019. The peak year of the drought was 2019, which was the hottest and driest year on record in Australia (Bureau of Meteorology 2020, Abram *et al*. 2021) and culminated in the Black Summer bushfires of spring and summer 2019-20. More than 23% of the temperate forests of south-eastern Australia were burnt in this one fire season, making the scale of the fires unprecedented both for Australia and globally (Boer *et al.* 2020).

After the Black Summer fires, we resurveyed arboreal mammals in six burnt 500 m long transects for which we had pre-2019 survey data. Four transects are at Wombeyan (Map 1), including one in Wombeyan Karst Conservation Reserve (Transect 6), one in Mares Forest National Park (Transect 5) and two in Blue Mountains National Park (Transects 11 and 12). These four transects had been variously surveyed in December 2016 (Smith and Smith 2017a) and May 2018 (Smith and Smith 2018b). They were burnt at low to moderate severity in 2019-20. The other two transects (Transects 13 and 14) are in Jenolan Karst Conservation Reserve (Map 2). The Jenolan transects had been variously surveyed in January 2003 (DECC 2007), February 2011 (OEH 2012) and November 2018 (P. and J. Smith, K2W Jenolan Caves Bioblitz). They were burnt at high to extreme severity in 2019-20.

Our initial post-fire surveys in 2020 and 2021 identified the Greater Glider (*Petauroides volans*) as a species heavily impacted by the events of 2019-20, with an estimated loss of about 60% of its total population in the Greater Blue Mountains World Heritage Area (Smith and Smith 2021, 2022a). We resurveyed five of the six transects in May-June 2022 (Smith and Smith 2022b) and May 2023 (this report) to monitor recovery. Transect 6 could not be accessed in either year. To compensate, we resurveyed an additional transect in Mares Forest NP (Transect 18, Map 1) in an unburnt area. This transect had been previously surveyed in December 2016 (Smith and Smith 2017a). The May-June timing of our 2022 and 2023 surveys has allowed us to assess Greater Glider breeding success as young from the previous year's breeding season had grown up and were out at night feeding, not sheltering in tree hollows.


Map 1. Wombeyan study area
Transects
towers
falls
11
1011
DIVIDING
25
Duncans
Flat
12
Rocklily
Jocks
Carl
Creek
18
5
750
6
GC
quarries (abandoned)
quarry
Wombeyan Caves
GB
910
NSW 2975
899
MT GUINEACOR


Map 2. Jenolan study area
Transects
STATE
FOREST
BLACK
JENOLAN
1000
Six Foot Track
13
14
750
1103
Jenolan
River
490
RANGE
foot track
1268
tower
(914m)
road
Jenolan Caves
KANANGRA
1250
MOORARA
1000

2. Methods

Spotlight Surveys

Each monitoring site was a 500 m transect located along a track through eucalypt forest. Five points spaced at 125 m intervals along the transect, including the two end points and the centre point, were marked with numbered blue plastic tags attached to the trunks of adjacent trees. The coordinates of each point were recorded with a GPS receiver.

Each transect was searched for arboreal mammals for one hour on three different nights. The entire length of the transect was walked and if this could not be done in an hour (because of a high density of animals), the search time was extended until completion. The two Jenolan transects (Transects 13 and 14) were surveyed between 5 and 19 May 2023, and the four Wombeyan transects (Transects 5, 11, 12 and 18) were surveyed between 9 and 12 May 2023. The three searches per transect were carried out at different times of night, with at least one search commencing at dusk. Each search involved both of us walking together along the track, each systematically searching the vegetation on their side with a spotlight and, when needed, binoculars. For every arboreal mammal detected, we recorded the species, the number of animals if in a group, their location (GPS coordinates of the corresponding point along the transect centreline, the estimated perpendicular distance from the centreline, and which side of the track), details of the tree or shrub in which they were seen (species, condition) and any observations of feeding behaviour, use of tree hollows, etc. Some animals were detected by call without being sighted. It was usually not possible to determine the exact locations of these animals. Tree condition was recorded as live or dead and the type of live foliage (foliage sparse / all or mostly epicormic foliage / both canopy and epicormic foliage / all or mostly canopy foliage).

All arboreal mammals detected were recorded, whatever their distance from the transect centreline. None were detected beyond a distance of about 60 m. Other nocturnal mammals, birds, reptiles and frogs seen or heard along the transects during the searches were recorded. We also recorded any additional nocturnal species detected on or near the transects outside the search times, including records based on indirect evidence such as droppings and feeding signs.

We recorded the weather conditions during each survey, including cloud cover, wind, precipitation, fog and temperature. Cloud cover was recorded as clear (starry sky with few if any clouds), cloudy (partly clear, partly cloudy) or overcast (no stars visible). Wind was recorded as still, light (leaves moving), moderate (branches moving) or strong (whole trees moving). We also noted whether or not the moon was visible and the moon phase.

Wildlife Cameras

To complement the spotlight searches, we intended to put out two wildlife cameras along each transect during the survey period. However, we were unable to borrow additional cameras. No cameras were put out in the four Wombeyan transects and only a single camera was put out in each of the Jenolan transects. The cameras were put out on 7 May and collected on 19 May (12 nights). Each camera was aimed at a bait container attached to a tree trunk 1 to 2 m above ground. The bait was a mixture of peanut butter, oats, honey, tuna, olive oil and vanilla essence. This bait, with its various scents, is attractive to a variety of mammals. A ball of bait was placed inside a container with holes, allowing the animals to smell the bait but not remove it. Sugar water was sprayed on the trunk around the bait container. Unfortunately, the camera in Transect 14 malfunctioned. Photos were obtained only from the camera in Transect 13.

Habitat Measurements

Arboreal mammal habitat measurements have been made at the five marked points along each transect centreline. The 10 nearest trees at each point (five nearest trees on each side of the track) were identified to species (a sample of 50 trees per transect). Trees less than a third the height of the tallest trees were not included. Both live and dead trees were included but since dead trees could not always be identified to species, all dead trees were lumped as one category. For each tree, we recorded whether it was a canopy tree (>2/3 the height of the tallest trees) or an understorey tree (1/3 – 2/3 the height of the tallest trees). We estimated how much of the tree's canopy consisted of dead or defoliated branches (to the nearest 10%); whether or not it had live mistletoes; and whether or not it contained hollows that were apparently suitable as den sites for gliders. Hollows were classified as small (suitable for Sugar and Squirrel Gliders) or large (suitable for Greater and Yellow-bellied Gliders).

The Wombeyan and Jenolan areas were both burnt by the Black Summer bushfires in late December 2019/early January 2020. Habitat measurements were made in the burnt transects at Wombeyan (Transects 5, 6, 11 and 12) in mid-November 2020 (about 10.5 months post-fire); in the burnt transects at Jenolan in early December 2020 (about 11 months post-fire); and in the unburnt transect at Wombeyan (Transect 18) in June 2022. Each of the sample of 50 trees was scored for post-fire epicormic regrowth as 0 (none), 1 (some), 2 (moderate amount) or 3 (large amount). Epicormic growth was also present in the unburnt transect and was scored in the same way (epicormic growth occurs in response to various factors, not just fire). In the burnt transects, when assessing how much of a tree's canopy was dead or defoliated, we ignored the epicormic regrowth in order to make an assessment of the condition of the tree immediately after the fire, before any regrowth occurred. We used the mean percentage of dead/defoliated canopy in our sample of 50 trees immediately after the fire as a measure of fire severity. Note that this is not strictly the proportion of the tree canopy burnt since it does not take into account how much of the tree canopy was dead/defoliated before the fire.

Acacia sap and banksia flowers are important food sources for several species of gliders. At each of the five points per transect, we identified any acacia or banksia species present within 10 m of the point. The abundance of each species at each point was scored as 0, 1 (<10 plants within 10 m) or 2 (10 or more plants within 10 m). The scores were then summed to provide an index of abundance for each species along the transect, with a maximum value of 10. We also noted if there were any additional acacia or banksia species present along the transect but not within 10 m of any point.

We measured the height of the tallest tree at each point with a clinometer. This was the tallest tree in the vicinity and not necessarily one of the 10 trees identified to species. We also estimated the overall tree foliage cover around each point. This is the percentage of the ground shaded by a vertical projection of the leaves and branches of the trees, including both canopy and understorey trees, but not trees less than a third the height of the tallest trees. Tree foliage cover was estimated to the nearest 10%. This measurement includes both remnant pre-fire foliage and epicormic post-fire regrowth. Other features that we noted at each point included any evidence of recent tree felling, any plant species in flower that were likely to provide food sources for gliders (eucalypts, acacias, mistletoes and banksias), and any nest boxes. We took two reference photos at each point using an 18 mm lens setting, one photo on each side of the track perpendicular to the transect centreline. The photos were taken during the 2020 survey and taken again during the 2022 and 2023 surveys. Photos had also been taken at each point in Transects 5 and 6 in 2018, before the 2019-20 fires.

From the tree species composition and other habitat features, we classified the vegetation along each transect in terms of Keith's (2004) NSW vegetation classes. We determined the

geology of the Wombeyan transects from a GIS layer based on the Goulburn 1:250,000 geological map (Thomas *et al*. 2013), and the geology of the Jenolan transects from mapping by Branagan *et al*. (2014). We also used GIS layers to determine the elevation range along the transect centreline, the distance from human habitation, and the distance from the Greater Blue Mountains World Heritage Area. A fire history GIS layer from NSW National Parks and Wildlife Service, current to December 2020, was used to determine how many fires there have been at each site since 1980, whether they were wildfires or prescribed burns, and the date of the last fire of each type. There have been no fires on any of the transects since the 2019-20 fires. To assess the landscape context of each transect, we mapped and calculated the extent of native forest and woodland within 1 km of the transect using Google Earth satellite imagery from October 2019 (Wombeyan) and December 2019 (Jenolan). The satellite imagery was taken before the sites were burnt by the Black Summer bushfires.

3. Results

Arboreal Mammal Species Diversity

Seven and possibly eight species of arboreal mammals have been recorded on the seven survey transects (Table 1, Appendix 1). These include four, possibly five, gliders, two possums and a quoll. Two of the gliders are threatened species. The Southern Greater Glider is listed as an endangered species and the Yellow-bellied Glider as a vulnerable species in both Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*) and NSW legislation (*Biodiversity Conservation Act 2016*). The Spotted-tailed Quoll is also a threatened species, listed as endangered at Commonwealth level and vulnerable in NSW. There was a tentative, unconfirmed record of another threatened glider, the Squirrel Glider, near Transect 6 before the fire (Smith and Smith 2018b). The Squirrel Glider is listed as a vulnerable species in NSW but is not listed at Commonwealth level.

Before the Black Summer fires, the Southern Greater Glider had been listed as a vulnerable species at Commonwealth level and was not listed at all in NSW. Its recent uplisting at both levels reflects the huge impact of the fires and the likelihood of other increasing impacts in future from climate change. The Yellow-bellied Glider has been similarly uplisted. Before the fires, it had been listed as a vulnerable species but was not listed at Commonwealth level.

Two species of Feathertail Glider could potentially be present on the transects: the Broad-toed Feathertail Glider (*Acrobates frontalis*) and the Narrow-toed Feathertail Glider (*Acrobates pygmaeus sensu stricto*) (Van Dyck *et al.* 2013). However, these can only be distinguished by close inspection and we have not been able to determine the identity of any of the Feathertail Gliders seen during our spotlighting surveys.

Similarly, two species of Sugar Glider could potentially be present on the transects: Krefft's Glider (*Petaurus notatus*) and the now more narrowly defined Sugar Glider (*Petaurus breviceps sensu stricto*) (Cremona *et al.* 2020). Krefft's Gliders have been identified in five of the seven transects, but the 'Sugar Glider' records in Transects 5 and 14 have not been identified to species (Appendix 1). No Sugar Gliders in the strict sense have been identified. Accordingly, we have assumed in Table 1 that all records were Krefft's Gliders.

There has also been a recent study indicating that the Greater Glider is actually three separate species (McGregor *et al.* 2020). Only one of these, the Southern Greater Glider

(*Petauroides volans sensu stricto*), occurs in the study area (and in southern NSW and Victoria generally).

Most of the arboreal mammal species recorded before the extreme drought of 2019 and the 2019-20 Black Summer bushfires are still present or have recolonized the study transects since the fires (Table 1). It is noteworthy that the Krefft's Glider, Feathertail Glider and Common Brushtail Possum were all recorded in the transect burnt at high severity (Transect 13) in both 2022 and 2023 and are recovering more rapidly in that transect than the Southern Greater Glider, which has not yet reappeared (Appendix 1). The threatened Yellow-bellied Glider is still being recorded in the moderate severity burnt transect where it was recorded pre-fire (Transect 12). This is particularly encouraging because a stand of Ribbon Gum (*Eucalyptus viminalis*) trees that was an important pre-fire food source for Yellow-bellied Gliders in this transect was badly burnt and is still in very poor condition (Appendix 2).

Two arboreal mammal species that were recorded pre-fire have not yet been recorded in any post-fire surveys: the Common Ringtail Possum and the unconfirmed Squirrel Glider. Common Ringtail Possums were rare in the pre-fire surveys but the absence of any post-fire records, despite a large number of searches over four years, is concerning.

Table 1. Summary of arboreal mammal survey results

Note that the year to year changes in Southern Greater Glider mean counts shown below should be interpreted with caution since a transect with low counts surveyed in 2020 and 2021 (Transect 6) was replaced in 2022 and 2023 with a transect with high counts (Transect 18). The difference had been evident when both transects were surveyed before the fire. [T] = threatened species, x = recorded elsewhere in Jenolan Karst Conservation Reserve in 2018 but not near the transects, d = droppings, ? = tentative identification of one animal.

	Mean count (no. animals per 500 m)				
	Before drought and fire (2003-18)	1st year after (2020)	2nd year after (2021	3rd year after (2022)	4th year after (2023)
No. transects	7	6	6	6	6
No. counts	15	18	18	18	18
[T]Southern Greater Glider *Petauroides volans*	9.2	4.9	4.7	9.4	11.6
[T]Yellow-bellied Glider *Petaurus australis*	0.2	0	0.1	0.1	0.1
Krefft's Glider *Petaurus notatus*	0.5	0.1	0.2	0.5	0.2
Feathertail Glider *Acrobates frontalis/pygmaeus*	0.2	0	0	0.1	0.1
Common Brushtail Possum *Trichosurus vulpecula*	0.1	0.5	0.2	0.1	0.2
Common Ringtail Possum *Pseudocheirus peregrinus*	0.2	0	0	0	0
[T]Spotted-tailed Quoll *Dasyurus maculatus*	x	0	d	0	0
[T]Squirrel Glider *Petaurus norfolcensis*?	?	0	0	0	0

Post-fire recovery of the Southern Greater Glider

The species for which we have the most data is the Southern Greater Glider, which was present in all seven Wombeyan and Jenolan transects before the fire. We have been able to track its post-fire recovery through our annual surveys. In 2020, we surveyed the six burnt transects in November, when the young from that year's breeding season were small and mostly stayed in their hollows at night. By excluding any young that we saw (we only saw one), we obtained a measure of the adult population that had survived the fire. Our subsequent surveys in 2021, 2022 and 2023 were carried out in May-June, when the young from the previous year's breeding season were independent and both adults and young were out at night feeding (Harris and Maloney 2010). These surveys allowed us to assess

breeding success in the 2020, 2021 and 2022 breeding seasons. In 2021, we surveyed all six burnt transects but in 2022 and 2023 we were unable to access and survey one of the moderate severity transects (Transect 6). Instead, we surveyed an unburnt transect (Transect 18) that had not been surveyed in 2020 and 2021, but for which we had a pre-fire count.

Figure 1. Impact of the 2019-20 drought and fires on Southern Greater Gliders at Wombeyan and Jenolan, and subsequent recovery, in relation to fire severity.
Compares results from two unburnt/low severity transects, three moderate severity transects and two high/extreme severity transects. Not all transects were surveyed every year: the one unburnt transect was not surveyed in 2020 or 2021 and one of the moderate severity transects was not surveyed in 2022 or 2023. Error bars are standard errors.

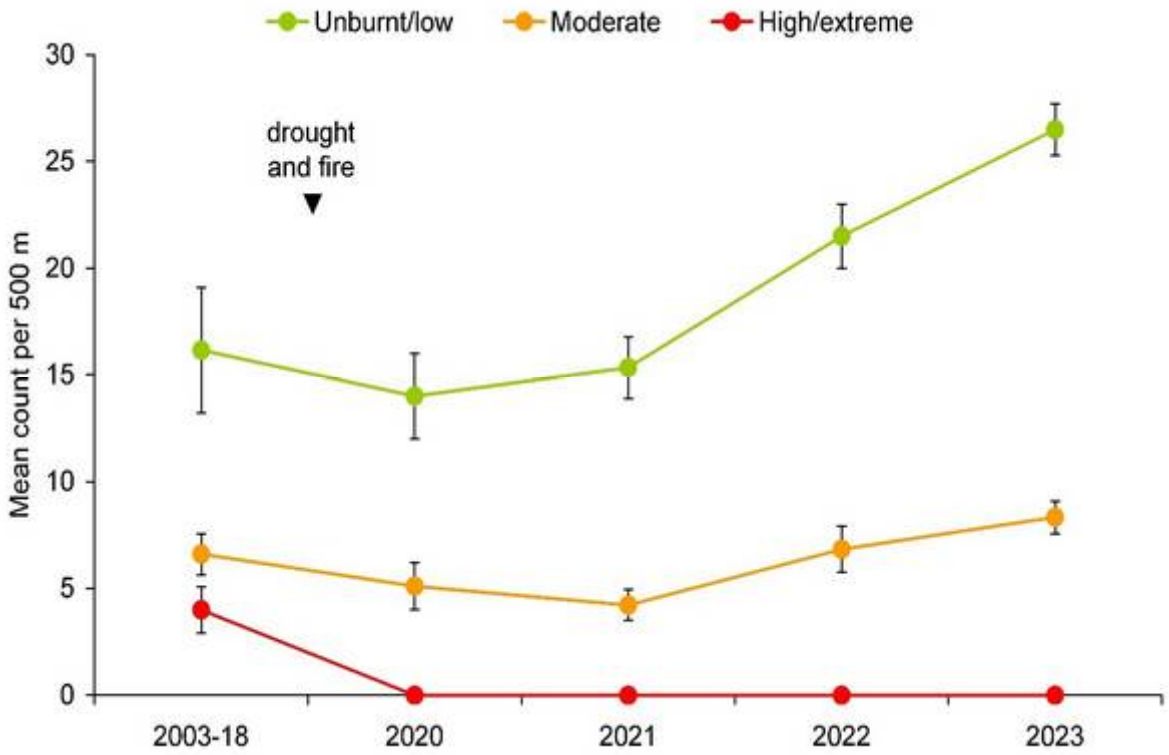


Table 2. Fire severity categories.
Canopy scorch is when the leaves are killed by the heat of the fire but not consumed.

Severity class	Description
Unburnt	Both understorey and tree canopy unburnt
Low	Understorey burnt but tree canopy unburnt
Moderate	Understorey burnt, tree canopy partly burnt/scorched, partly unburnt
High	Understorey burnt, tree canopy completely scorched and may be partly burnt
Extreme	Understorey burnt, tree canopy completely burnt (i.e. a crown fire)

The impact of the 2019-20 extreme drought and mega-fires on Southern Greater Gliders at Wombeyan and Jenolan, and their subsequent recovery, is summarised in Figure 1, which compares transects burnt at low severity or unburnt (Transects 11 and 18) with those burnt

at moderate severity (Transects 5, 6 and 12) and those burnt at high or extreme severity (Transects 13 and 14). Fire severity categories are explained in Table 2. Results for the individual transects are shown in Figures 2-8.

There has been no recovery of Southern Greater Gliders in the two high/extreme severity transects. The fire eliminated Southern Greater Gliders from these two transects and almost four years after the fire, there is still no sign of any recolonisation (Figure 1). Southern Greater Gliders feed almost exclusively on eucalypt leaves and even if some gliders had survived the fires in their hollows, they could not survive on these transects in the immediate aftermath of the fires, when all the eucalypt foliage had been killed and there was nothing for the gliders to feed on until epicormic regrowth foliage began to appear.

By contrast, Southern Greater Gliders were still present after the fires on all of the transects burnt at low to moderate severity, where there was live eucalypt foliage for them to feed on. Their numbers had been reduced but part of the population had survived the drought and the fires. There has since been a good recovery in these transects and glider numbers in 2023 were higher than in the pre-fire, pre-drought counts (Figure 1). This is probably a result of the wet La Niňa conditions and good plant growth in 2020-22, meaning that there has been lots of young eucalypt foliage for the gliders to feed on. Southern Greater Gliders feed predominantly on young foliage, which is softer and more nutritious than old foliage (Kavanagh and Lambert 1990, Harris and Maloney 2010). How much young foliage is available is an important factor influencing how many Southern Greater Gliders a forest can support.

The first post-fire breeding season in 2020 was an unsuccessful one that did not result in any increase in the Southern Greater Glider population on the study transects (Smith and Smith 2021). However, there was an increase in the population following the 2021 breeding season (Smith and Smith 2022b) and there has now been a further increase following the 2022 breeding season (this survey).

The rate of recovery has been particularly steep in the two unburnt/low severity burnt transects. In 2023, the numbers of Southern Greater Gliders recorded on these transects were 89% higher than the first post-fire counts in 2020, and 64% higher than the pre-fire, pre-drought counts in 2016 (Figure 1). By comparison, the numbers of Southern Greater Gliders on the three moderate severity transects in 2023 were 63% higher than the first post-fire counts in 2020, and 26% higher than the pre-fire, pre-drought counts in 2016-18 (Figure 1).

The two unburnt/low severity transects also happen to be the tallest forests (mean height of the tallest trees 36-39 m; Appendix 2) and supported high densities of Southern Greater Gliders before the drought and fires. The moderate/high/extreme severity transects are lower forests (mean height of the tallest trees 20-33 m) and supported fewer Southern Greater Gliders: a mean pre-drought, pre-fire count of 6.5 gliders per 500 m compared with 16.2 in the unburnt/low severity transects. Tall forests are an indicator of higher soil fertility, which means better habitat for Southern Greater Gliders because the eucalypt foliage has higher nutrient levels (Kavanagh and Lambert 1990) and because taller forests have more eucalypt foliage per unit area.

The numbers of Southern Greater Gliders recorded in the unburnt/low severity transects in 2016 were very high compared with other studies in the region. The highest mean count per 500 m in a study in Blue Mountains Local Government Area in 2015-16 was only 5.4 (Smith and Smith 2018b). Apart from the Wombeyan area, the highest mean counts per 500 m in various studies in the Kanangra-Boyd National Park to Lake Wyangala vegetation corridor in 2016-18 were 9.5 in the Abercrombie River-Mount Werong area (Smith and Smith 2017b), 4.9 in the Wyangala-Gillindich area (Smith and Smith 2017c, 2018), 4.7 in the Kempfield

area (Smith and Smith 2016) and 2.1 in Wiarborough Nature Reserve (Smith and Smith 2017a).

The Southern Greater Glider population in the unburnt/low severity transects has recovered well and increased since the fire to exceptional levels, with a mean count of 26.5 gliders per 500 m in 2023. These tall forests on fertile soils at higher elevations are critically important habitat for Southern Greater Gliders, not only for post-drought, post-fire recovery, but also in relation to the worrying retreat of this heat-sensitive species from lower elevations in the Blue Mountains since the 1990s as a consequence of temperature increase from climate change (Smith and Smith 2018a, 2020).

Table 3. Analysis of variance (ANOVA) for differences in Southern Greater Glider counts between years (2020, 2021, 2022 and 2023) in Transects 5, 11 and 12

The analysis shows a highly significant difference between years (Southern Greater Gliders increased in numbers between 2020 and 2023), a highly significant difference between transects (Southern Greater Gliders were more numerous in Transect 11 than in Transects 5 and 12) and a highly significant interaction between transect and year (the rate of post-fire increase varied between transects and was particularly high in Transect 11).

Source	Sum of squares	Degrees of freedom	Mean square	F value	P value
Year	174.75	3	58.25	9.24	0.0003
Transect	1191.17	2	595.58	94.45	<0.0001
Year x transect	149.50	6	24.92	3.95	0.0069
Within	151.33	24	6.31		
Total	1666.75	35			

The statistical significance of the post-fire increase in Southern Greater Glider numbers on transects burnt at low to moderate severity was tested by an analysis of variance for the three Wombeyan transects that have been surveyed every year from 2020 to 2023 (Table 3). This showed that:

- there has been a highly significant increase in Southern Greater Glider numbers between 2020 and 2023,
- there are highly significant differences in glider numbers between transects - Transect 11, which is the tallest forest and best glider habitat and was only burnt at low severity, supports more Southern Greater Gliders than Transects 5 and 12, which were burnt at moderate severity and had fewer gliders that Transect 11 before the drought and fires, and
- there are highly significant differences between transects in their rate of post-fire recovery – Southern Greater Glider numbers on Transect 11 increased by 88% between 2020 and 2023, whereas the increase on Transect 5 was 38% and the increase on Transect 12 was only 7%.

Figure 2. Impact of the 2019-20 drought and fires on Southern Greater Gliders in extreme severity burnt Transect 14 at Jenolan, and lack of subsequent recovery.
Figures in parentheses are the number of counts.

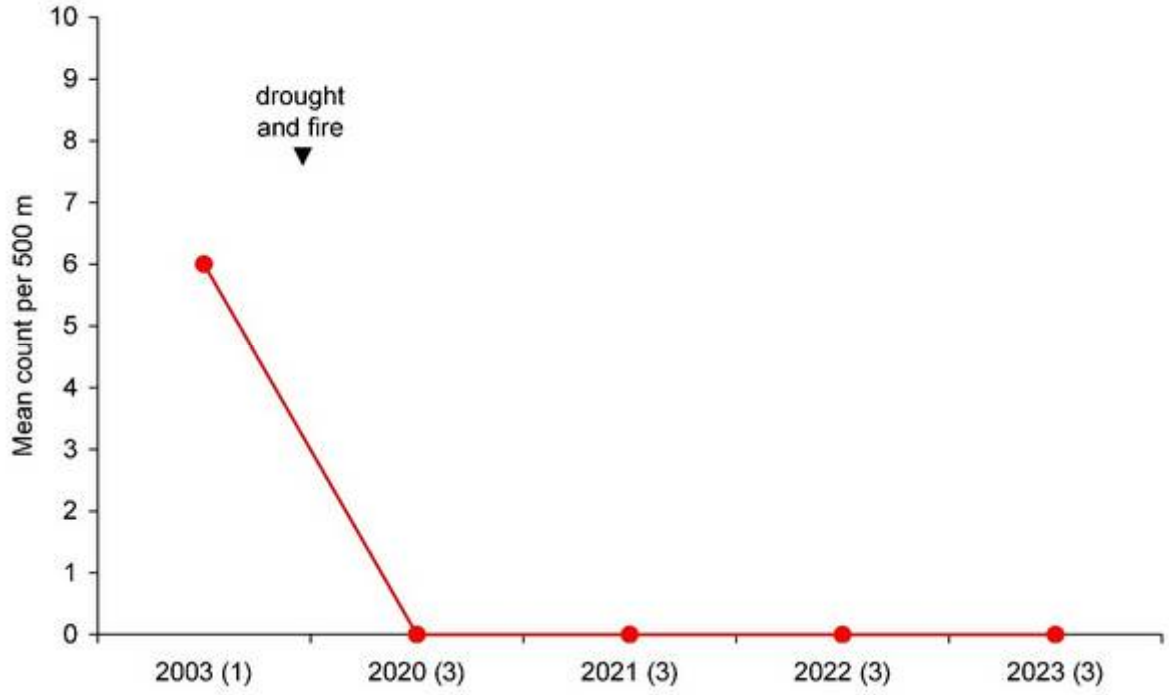


Figure 3. Impact of the 2019-20 drought and fires on Southern Greater Gliders in high severity burnt Transect 13 at Jenolan, and lack of subsequent recovery.
Figures in parentheses are the number of counts. Error bars are standard errors.

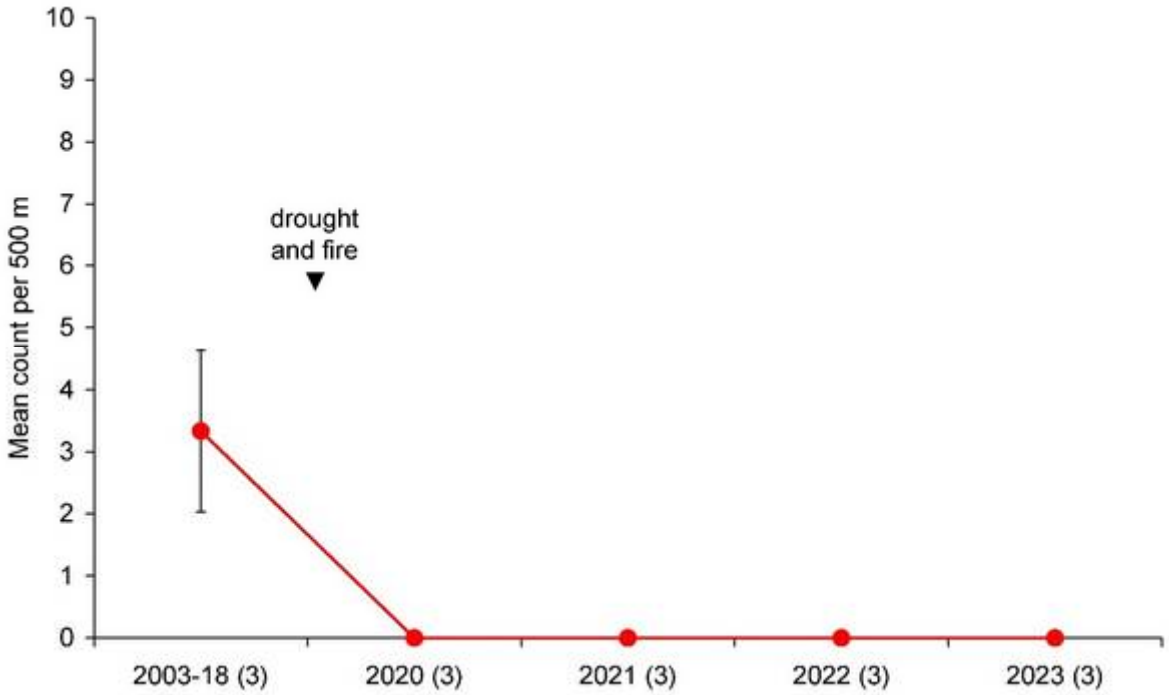


Figure 4. Impact of the 2019-20 drought and fires on Southern Greater Gliders in moderate severity burnt Transect 5 at Wombeyan, and subsequent recovery.
Figures in parentheses are the number of counts. Error bars are standard errors.

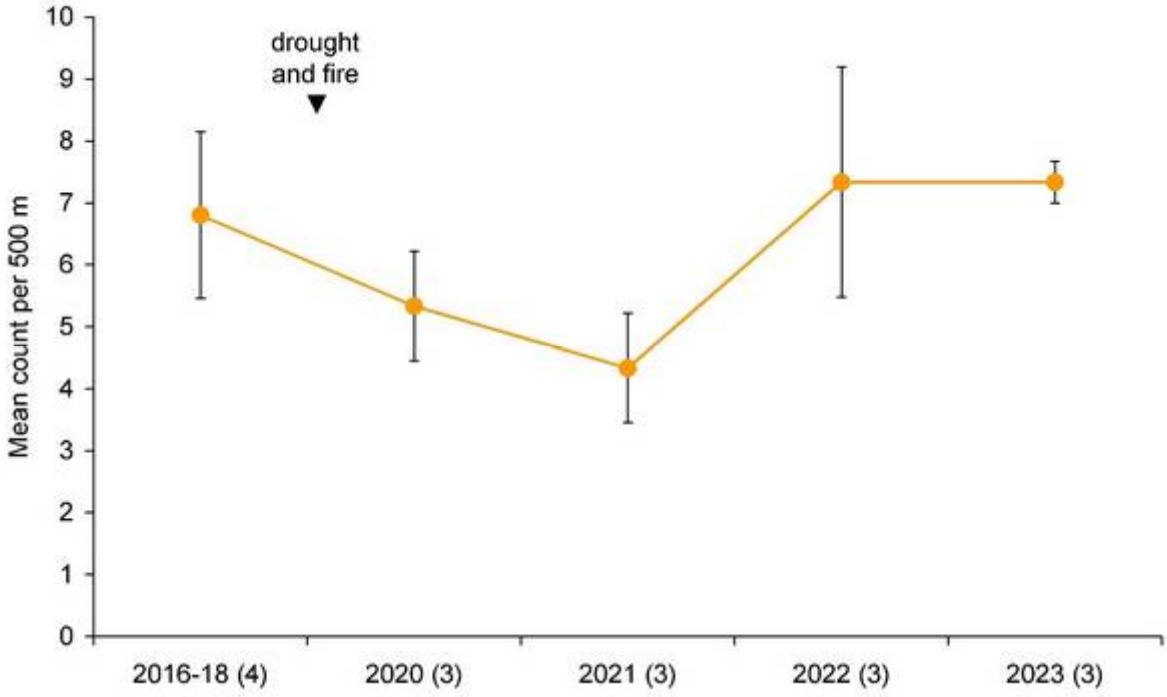


Figure 5. Impact of the 2019-20 drought and fires on Southern Greater Gliders in moderate severity burnt Transect 6 at Wombeyan.
Figures in parentheses are the number of counts. Error bars are standard errors.

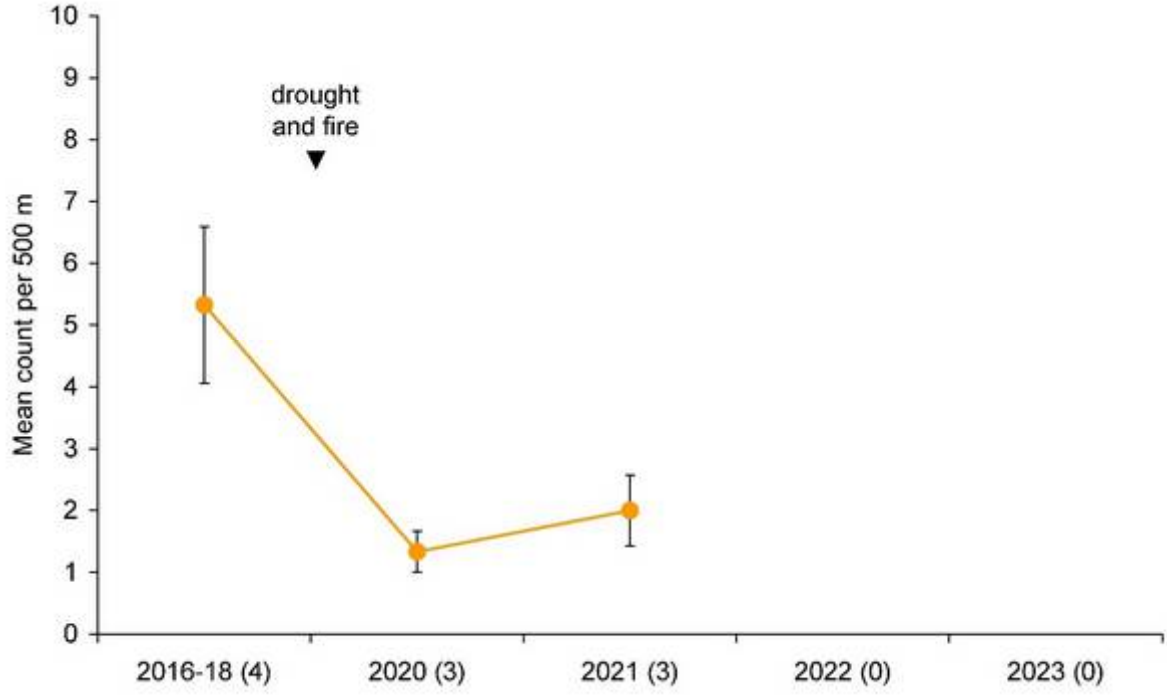


Figure 6. Impact of the 2019-20 drought and fires on Southern Greater Gliders in moderate severity burnt Transect 12 at Wombeyan, and subsequent recovery.
Figures in parentheses are the number of counts. Error bars are standard errors.

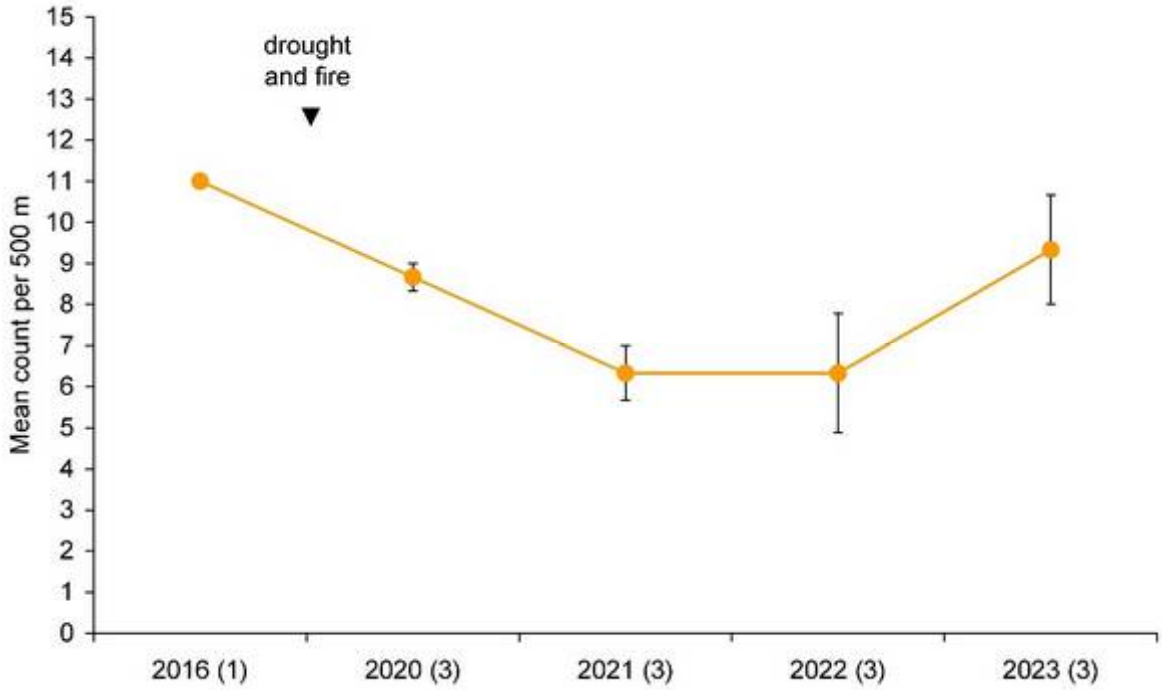


Figure 7. Impact of the 2019-20 drought and fires on Southern Greater Gliders in low severity burnt Transect 11 at Wombeyan.
Figures in parentheses are the number of counts. Error bars are standard errors.

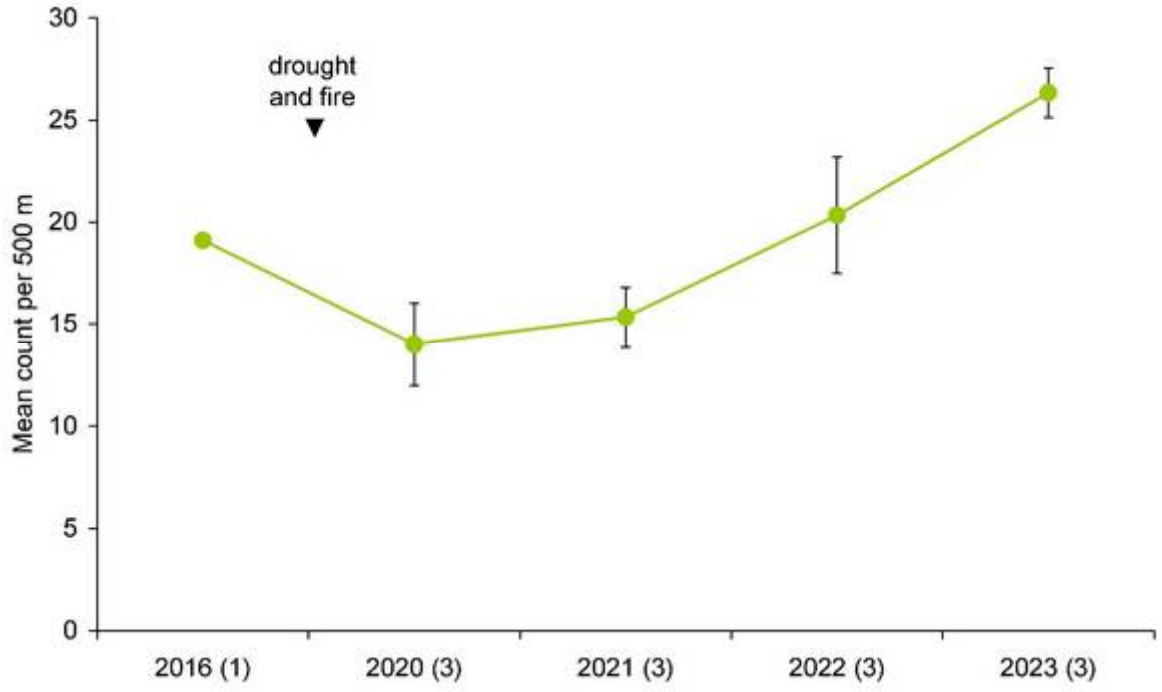
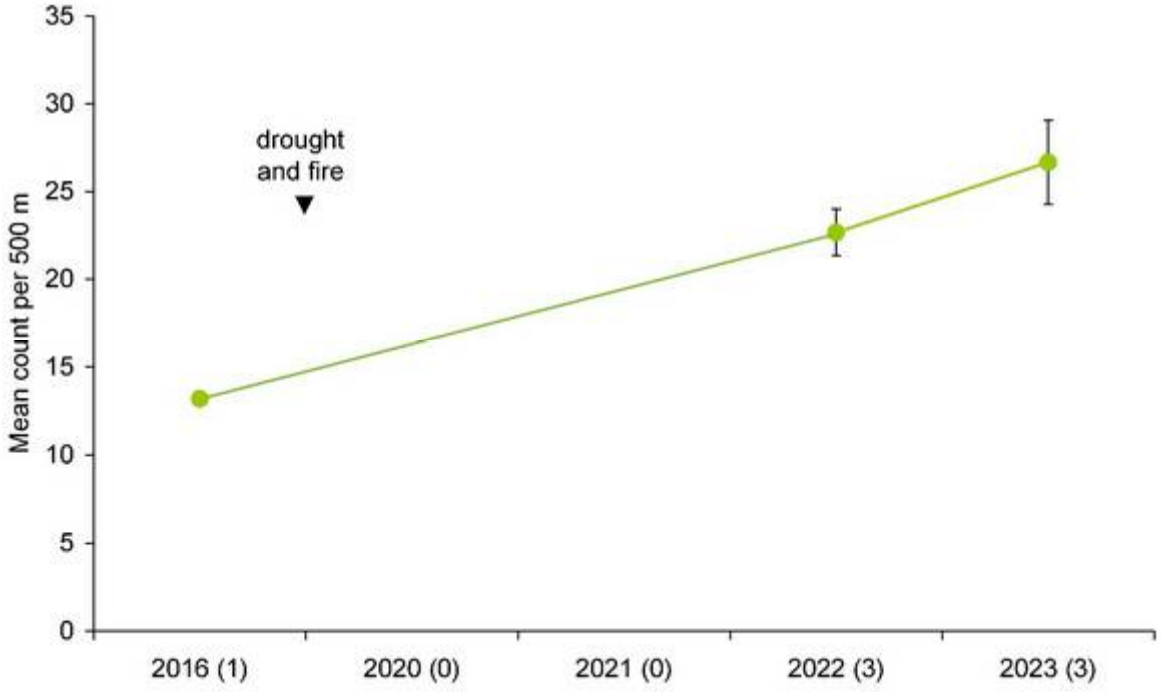


Figure 8. Impact of the 2019-20 drought and fires on Southern Greater Gliders in unburnt Transect 18 at Wombeyan.

Figures in parentheses are the number of counts. Error bars are standard errors.



Southern Greater Glider Tree Preferences

Southern Greater Glider tree preferences were assessed by comparing the trees available with the trees in which gliders were seen. Southern Greater Gliders were seen in seven eucalypt species in Wombeyan Transects 5, 11, 12 and 18 in 2022 and 2023 but favoured *Eucalyptus fastigata* (Brown Barrel) and *E. viminalis* (Ribbon Gum). These two species made up 44% of the trees available on the transects but 66% of the trees in which Southern Greater Gliders were seen (Figure 9). The difference between trees available and trees utilised was highly statistically significant (chi-square test for association, $\chi^2(5) = 29.94$, $p < 0.0001$), indicating that *E. fastigata* and *E. viminalis* are favoured food trees.

Southern Greater Gliders were seen at 23 hollows in Wombeyan Transects 5, 11, 12 and 18 in 2022 and 2023. They were using hollows in both live and dead trees (Figure 10) but the sample size was too small for any other conclusions about tree species preferences.

Southern Greater Gliders show a marked preference for canopy trees over understorey trees (trees 1/3 to 2/3 the height of the tallest trees): 95% of the trees in which Southern Greater Gliders were seen in Wombeyan Transects 5, 11, 12 and 18 in 2022 and 2023 were canopy trees but only 64% of the trees in the transects were canopy trees. The difference was highly statistically significant (chi-square test for association, $\chi^2(1) = 84.66$, $p << 0.0001$).

Figure 9. Tree species in which Southern Greater Gliders were seen in Wombeyan Transects 5, 11, 12 and 18 in 2022-23.

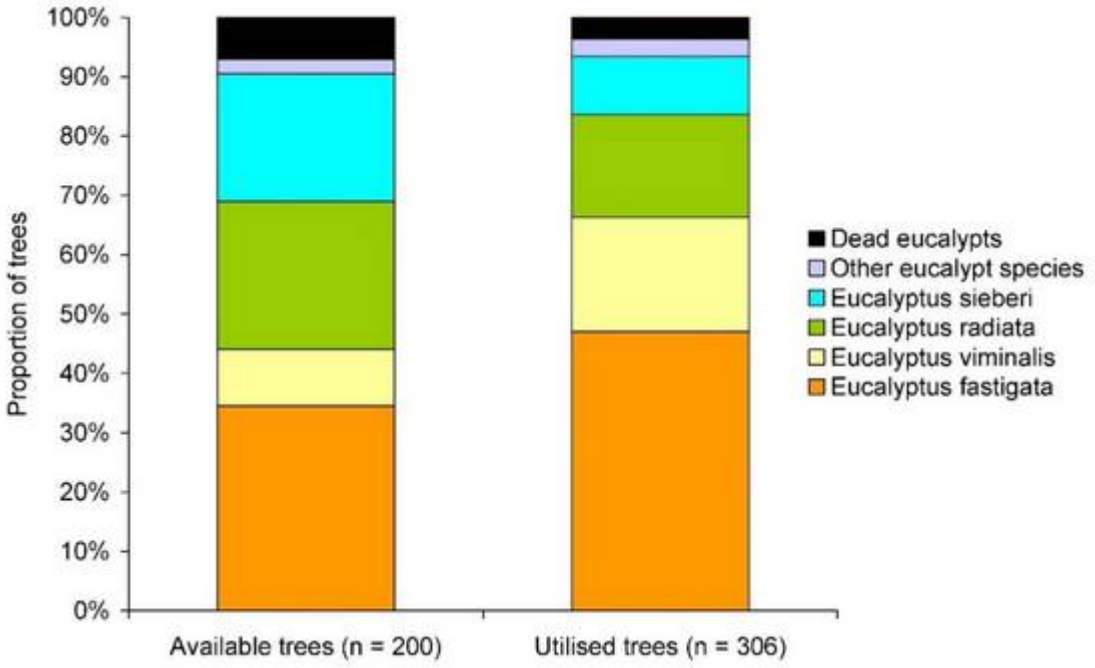


Figure 10. Tree species in which Southern Greater Gliders were seen at hollows in Wombeyan Transects 5, 11, 12 and 18 in 2022-23.

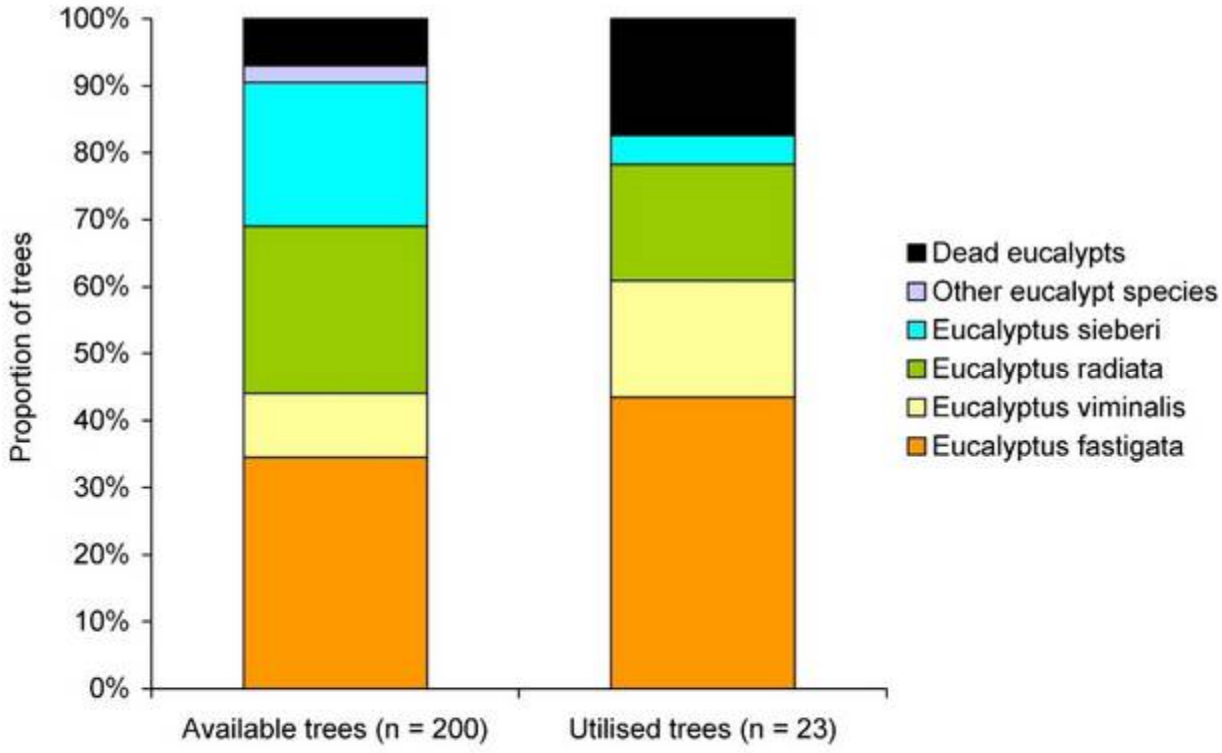
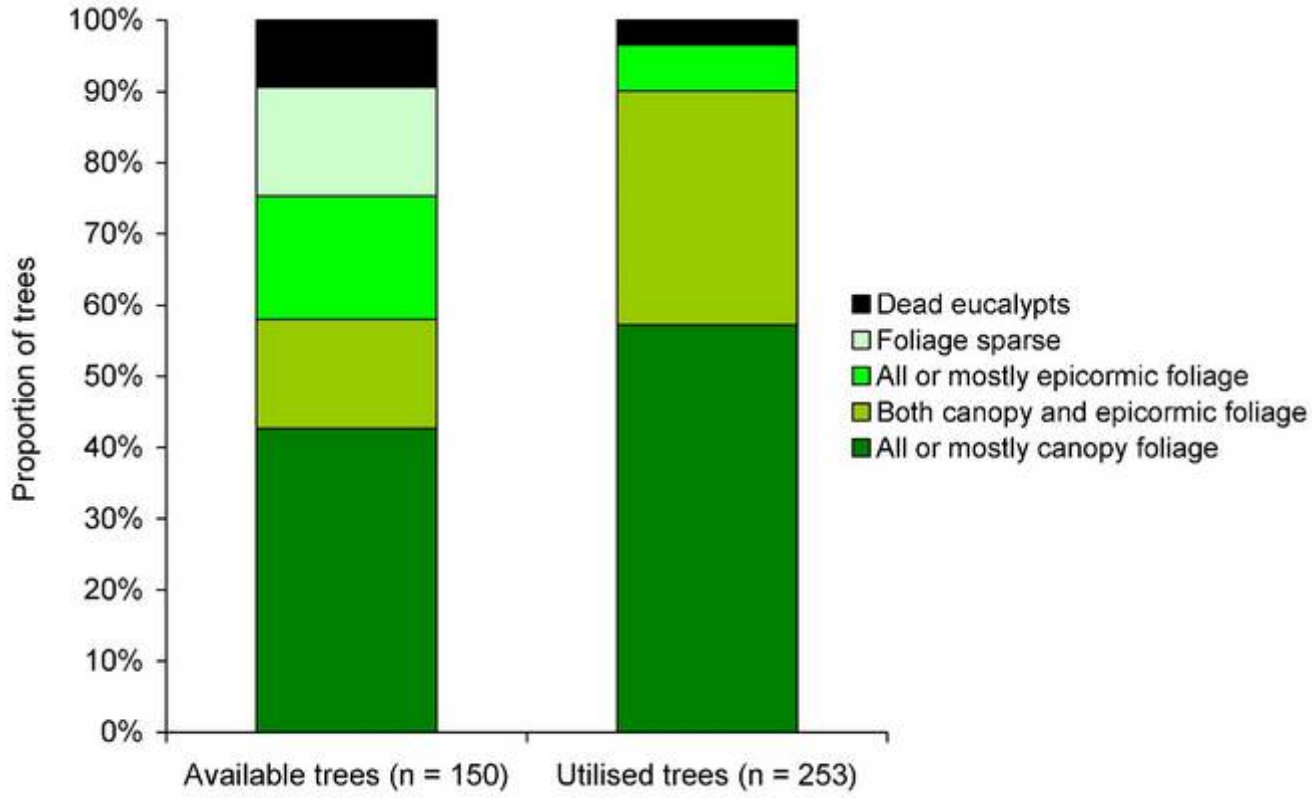


Figure 11. Types of trees in which Southern Greater Gliders were seen in the burnt Wombeyan Transects 5, 11 and 12 in 2021-23.



In the burnt Wombeyan Transects 5, 11 and 12 in 2021-23, Southern Greater Gliders were predominantly (90%) seen in trees with mainly canopy foliage or with both canopy and epicormic foliage (Figure 11). The latter trees were particularly favoured, making up 15% of available trees but 33% of trees used. Gliders were rarely seen in trees with mainly epicormic foliage, nor in trees with sparse foliage or in dead trees (sightings in dead trees were mostly at hollows). The difference between the types of trees available and the trees utilised was highly statistically significant (chi-square test for association, $\chi^2(4) = 71.80$, $p << 0.0001$).

During the post-fire surveys, Southern Greater Gliders were seen feeding on both canopy foliage and epicormic foliage but there were too few observations to establish whether they preferred one type of foliage over the other. A possible reason why they avoid trees with dense epicormic foliage but no canopy foliage (trees such as those in Photo 32 in Appendix 2), despite them being a potential food source, may be that they are more exposed to predators in such trees. Another possible explanation, which may also account for the gliders' preference for canopy trees over understorey trees, is that they prefer to be high up in trees because it is a better launching site for gliding, especially since they are the largest and heaviest of the Australian gliders.

4. Discussion

The extreme drought conditions of 2019, culminating in the mega-fires of the 2019-20 Black Summer fire season, had a massive impact on Southern Greater Gliders in the Greater Blue Mountains World Heritage Area. The fires burnt 84% of the known locations for this species in the World Heritage Area and, combined with the effects of the preceding drought, resulted in an estimated 60% reduction of the population (Smith and Smith 2022a). The impact depended on fire severity. Southern Greater Gliders survived, although their numbers were reduced, at the study sites burnt at low to moderate severity, but the species was eliminated at study sites burnt at high to extreme severity. At the latter sites, even if the gliders had survived the fires in their hollows, there was no live eucalypt foliage for them to feed on in the immediate aftermath of the fires.

Recovery of Southern Greater Gliders in the study sites at Wombeyan and Jenolan in the four years since the fires has also depended on fire severity. There has been no recovery in the Jenolan transects burnt at high to extreme severity but a good recovery in the Wombeyan transects burnt at low to moderate severity or unburnt. No Southern Greater Gliders have been seen on the high/extreme severity transects in any of the post-fire surveys. However, on the other transects, glider numbers have increased and now exceed their pre-fire numbers. The first post-fire breeding season in 2020 was an unsuccessful one that did not result in any increase in Southern Greater Glider numbers on the study transects. However, there was an increase in the population following the 2021 breeding season and there has now been a further increase following the 2022 breeding season.

The steepest rate of increase has been on the unburnt/low severity transects, where glider numbers in 2023 were 89% higher than the first post-fire counts in 2020, and 64% higher than the pre-fire, pre-drought counts in 2016. By comparison, the numbers of Southern Greater Gliders on the moderate severity transects in 2023 were 63% higher than the first post-fire counts in 2020, and 26% higher than the pre-fire, pre-drought counts in 2016-18.

The unburnt/low severity transects also happen to be the tallest forests and best glider habitat sampled. Before the fires, they supported much higher densities of Southern Greater Gliders than the other transects. Their glider densities were very high compared with other studies in the region and have increased since the fire to exceptional levels. These tall forests on fertile soils at higher elevations are critically important habitat for Southern Greater Gliders, not only for post-drought, post-fire recovery, but also in relation to the worrying retreat since the 1990s of this heat-sensitive species from lower elevations in the Blue Mountains as a consequence of temperature increase from climate change (Smith and Smith 2018a, 2020).

The Black Summer fires in the Greater Blue Mountains World Heritage Area had a number of exceptional features (Smith and Smith 2022c). They burnt an unprecedented 79% of the World Heritage Area, which is more than three times greater than the area burnt in any of the previous 48 fire seasons. The fires were not proportionally more severe than previous large fires (i.e. the ratio of severely burnt to lightly burnt vegetation was similar to previous fires) but their huge scale meant that an unprecedented 29% of the World Heritage Area was burnt at high to extreme severity. This is a particular concern for the Southern Greater Glider in view of the loss of the species from the more severely burnt study transects and the lack of any post-fire recovery.

Tall, moist, fertile forests (wet sclerophyll forests) are the favoured habitat of Southern Greater Gliders in the World Heritage Area (Smith *et al.* 2019). Wet sclerophyll forests occur in sheltered fertile gullies at scattered locations throughout the World Heritage Area and as plateau forests on richer soils at higher elevations such as at Wombeyan and Jenolan. These forests usually remain unburnt or only lightly burnt in major wildfires and play an important

role as natural firebreaks and as fauna refuges (Hammill and Tasker 2010, Smith *et al.* 2019). In the Black Summer fires, however, the wet sclerophyll forests were as badly burnt as the normally much more fire-prone dry sclerophyll forests (Smith and Smith 2022c), which seriously compromised their role as fauna refuges. Before 2019, most of the plateau forests in the south-western corner of the World Heritage Area, including the Wombeyan and Jenolan areas, had not been burnt for at least 48 years or had only been burnt by a single fire. They were the least fire-prone part of the World Heritage Area but in the Black Summer fires they were one of the most severely burnt parts (Smith and Smith 2022c), probably because of the exceptionally dry conditions of the 2019 drought.

A study of Southern Greater Gliders following the Black Saturday bushfires in central Victoria in 2009 has reported similar impacts to the present study at Wombeyan and Jenolan (Campbell-Jones *et al*. 2022). Three years after the 2009 fires, Southern Greater Gliders were absent from severely burnt sites and were restricted to unburnt or lightly burnt sites. They were still absent from severely burnt sites when the sites were resurveyed 10 years after the fires, showing that not only is fire severity a critical factor in the impact of fires on Southern Greater Gliders but also that it has long-lasting effects in severely burnt sites. In 1994, Southern Greater Gliders disappeared from Royal National Park, south of Sydney, after a wildfire burnt 90% of the reserve; they were not recorded again until 18 years later (Andrew *et al*. 2014). These reports of long-lasting effects do not bode well for the recovery of the species in the severely burnt sites at Jenolan.

The survival and good post-fire recovery of Southern Greater Gliders in the Wombeyan transects burnt at low to moderate severity or unburnt are very encouraging, especially considering the slow post-fire recovery of Southern Greater Gliders reported in previous studies. The Jenolan transects burnt at high to extreme severity are a different story and the species is likely to be absent from these transects for years to come, judging by the findings from previous long-term studies. Nevertheless, recovery will eventually occur even in the most severely burnt parts of the Greater Blue Mountains World Heritage Area as long as the Black Summer fires prove to be a very rare event that will not recur for many decades. However, a change in the fire regime to more frequent, more extensive, more severe wildfires as a result of climate change has long been predicted (Cary and Banks 2000, Bradstock 2010, Hammill and Tasker 2010, Clarke and Evans 2019). This would make suppression and containment of future wildfires increasingly difficult. If the Black Summer fires are a harbinger of this change, the long-term impact on Southern Greater Gliders, and on the other animals and plants of the Greater Blue Mountains World Heritage Area, would be catastrophic.

Acknowledgements

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References

Abram, N.J., Henley, B.J., Sen Gupta, A., Lippmann, T.J.R., Clarke, H., Dowdy, A.J., Sharples, J.J., Nolan, R.H., Zhang, T., Wooster, M.J., Wurtzel, J.B., Meissner, K.J., Pitman, A.J., Ukkola, A.M., Murphy, B.P., Tapper, N.J. and Boer, M.M. (2021). Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth and Environment* https://doi.org/10.1038/s43247-020-00065-8

Andrew, D., Koffel, D., Harvey, G., Griffiths, K. and Fleming, M. (2014). Rediscovery of the Greater Glider *Petauroides volans* (Marsupialia: Petauroidea) in the Royal National Park, NSW. *Australian Zoologist* **37,** 23-28.

Boer, M. M., Resco de Dios, V. and Bradstock, R. A, (2020). Unprecedented burn area of Australian mega forest fires. *Nature Climate Change* **10,** 171-172.

Bradstock, R. A. (2010). A biogeographic model of fire regimes in Australia: current and future implications. *Global Ecology and Biogeography* **19,** 145-158.

Branagan, D.F., Pickett, J. and Percival, I.G. (2014). Geology and geomorphology of Jenolan Caves and the surrounding region. *Proceedings of the Linnean Society of NSW* **136,** 99-130.

Bureau of Meteorology (2020). *Special Climate Statement 70 Update – Drought Conditions in Australia and Impact on Water Resources in the Murray-Darling Basin*. Version 3.0, 13 August 2020. Bureau of Meteorology, Australian Government, Melbourne.

Campbell-Jones, M. M., Bassett, M., Bennett, A. F., Chia, E. K., Leonard, S. and Collins, L. (2022). Fire severity has lasting effects on the distribution of arboreal mammals in a resprouting forest. *Austral Ecology* **47,** 1456-1469.

Cary, G. J. and Banks, J. C. G. (2000). Fire regime sensitivity to global climate change: an Australian perspective. Pp. 233-246 in *Biomass Burning and its Inter-relationships with the Climate System*, eds J. L. Innes, M. Beniston and M. M. Verstraete. Springer, Dordrecht.

Clarke, H. and Evans, J. P. (2019). Exploring the future change space for fire weather in southeast Australia. *Theoretical and Applied Climatology* **136,** 513-527.

Cremona, T., Baker, A.M., Cooper, S.J.B., Montague-Drake, R., Stobo-Wilson, A.M. and Carthew, S.M. (2020). Integrative taxonomic investigation of *Petaurus breviceps* (Marsupialia: Petauridae) reveals three distinct species. *Zoological Journal of the Linnean Society* **20,** 1-25.

DECC (2007). *Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region*. *Volume 1. Background Report*. NSW Department of Environment and Climate Change, Sydney.

Harris, J. M. and Maloney, K. S. (2010). *Petauroides volans* (Diprotodontia: Pseudocheiridae). *Mammalian Species* **42,** 207-219.

Kavanagh, R. P. and Lambert, M. J. (1990). Food selection by the greater glider, *Petauroides volans*: is foliar nitrogen a determinant of habitat quality. *Australian Wildlife Research* **17,** 285-299.

Keith, D. (2004). *Ocean Shores to Desert Dunes: The Native Vegetation of New South Wales and the ACT*. NSW Department of Environment and Conservation, Hurstville.

McGregor, D. C., Padovan, A., Georges, A., Krockenberger, A., Yoon, H.-J. and Youngentob, K. N. (2020). Genetic evidence supports three previously described

species of greater glider, *Petauroides volans*, *P. minor* and *P. armillatus*. *Scientific Reports* **10,** Article 19284. https://doi.org/10.1038/s41598-020-76364-z
Smith, J., Smith, P. and Smith, K. (2019). *Native Fauna of the Greater Blue Mountains World Heritage Area*. P. & J. Smith Ecological Consultants, Blaxland.
OEH (2012). *The Vertebrate Fauna of the Jenolan Karst Conservation Reserve*. NSW Office
Smith, P. and Smith, J. (2016). A proposal for monitoring arboreal mammal populations in the Abercrombie-Copperhannia corridor. Report to NSW Office of Environment and Heritage, July 2016. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.21329.48485
Smith, P. and Smith, J. (2017a). Reconnaissance survey of arboreal mammal populations in the Wombeyan-Wiarborough area. Report to NSW Office of Environment and Heritage, January 2017. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.33073.53606
Smith, P. and Smith, J. (2017b). Reconnaissance survey of arboreal mammal populations in the Abercombie River-Mount Werong area. Report to NSW Office of Environment and Heritage, June 2017. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.25051.92967
Smith, P. and Smith, J. (2017c). Reconnaissance survey of arboreal mammal populations in the Wyangala-Gillindich area. Report to NSW Office of Environment and Heritage, September 2017. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.31762.81602/1
Smith, P. and Smith, J. (2018a). Decline of the greater glider (*Petauroides volans*) in the lower Blue Mountains, New South Wales. *Australian Journal of Zoology* **66,** 103-114.
Smith, P. and Smith, J. (2018b). Monitoring of arboreal mammals in the Kanangra to Wyangala corridor: baseline surveys of six transects in May 2018. Report to K2W Glideways Partnership, July 2018. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.12521.44647
Smith, P. and Smith, J. (2020). Future of the Greater Glider (*Petauroides volans*) in the Blue Mountains, New South Wales. *Proceedings of the Linnean Society of NSW* **142,** 55-66.
Smith, P. and Smith, J. (2021). Post-fire survey of arboreal mammals at Wombeyan and Jenolan: final report. Report to Kanangra-Boyd to Wyangala Conservation Partnership, August 2021. P. and J. Smith Ecological Consultants, Blaxland. https://doi.org/10.13140/RG.2.2.12894.56641
Smith, P. and Smith, J. (2022a). Impact of the 2019-20 drought, heatwaves and mega-fires on Greater Gliders (*Petauroides volans*) in the Greater Blue Mountains World Heritage Area, New South Wales. *Australian Zoologist* **42,** 164-181.
Smith, P. and Smith, J. (2022b). Post-fire recovery of arboreal mammals at Wombeyan and Jenolan: 2022 report. Report to Kanangra-Boyd to Wyangala Conservation Partnership, August 2021. P. and J. Smith Ecological Consultants, Blaxland https://doi.org/10.13140/RG.2.2.15112.08963
Smith, P. and Smith, J. (2022c). Impact of the 2019-20 mega-fires on the Greater Blue Mountains World Heritage Area, New South Wales. *Proceedings of the Linnean Society of NSW* **144,** 227-254.
Thomas, O.D, Pogson, D.J., Johnston, A.J., Scott, M.M., Warren, A.Y.E., Sherwin, L., Colquhoun, G.P., Watkins, J.J., Cameron, R.G., MacRae, G.P., Glen, R.A. and Vassallo, J.J. (2013). *Goulburn 1:250 000 Geological Sheet SI/55-12, Second Edition*. Geological Survey of New South Wales, Maitland.
Van Dyck, S., Gynther, I. and Baker, A. (eds) (2013). *Field Companion to the Mammals of Australia*. New Holland Publishers, Sydney.

Appendix 1. Survey results

Table 5. Survey results for Transect 5, Oak Range Trail, Mares Forest National Park

Burnt at moderate severity in 2019-20, with an estimated 63% of the eucalypt foliage killed. Figures in the table are the number of animals detected per 500 m. s = seen, h = heard, d = droppings, t = tracks, a = carcass, c = camera records, [T] = threatened species, * = introduced species, X = recorded on or near transect outside search times.

	2016-18 (pre-fire)					**2020 (10.5 mths post-fire)**				**2021 (17 mths post-fire)**				**2022 (29.5 mths post-fire)**				**2023 (40.5 mths post-fire)**			
Date	16/12/16	28/5/18	29/5/18	30/5/18	**Mean**	13/11/20	14/11/20	15/11/20	**Mean**	24/5/21	26/5/21	27/5/21	**Mean**	15/6/22	16/6/22	18/6/22	**Mean**	9/5/23	11/5/23	12/5/23	**Mean**
Start time (AEST)	2145	1743	2023	1800		2130	2020	1900		1919	2020	1735		2015	1910	1730		1750	2033	1910	
Duration (minutes)	55	60	60	60		60	60	60		60	60	60		60	60	60		60	60	60	
Transect length (m)	490	500	500	500		500	500	500		500	500	500		500	500	500		500	500	500	
Arboreal mammals																					
Feathertail Glider *Acrobates frontalis/pygmaeus*	1s				**0.3s**																
[T]Southern Greater Glider *Petauroides volans*	9.2s	8s	3s[+]	7s	**6.8s**	5s[+]	7s	4s	**5.3s**	4s	3s	6s	**4.3s**	6s	5s	11s	**7.3s**	7s	7s	8s	**7.3s**
Krefft's/Sugar Glider *Petaurus notatus/breviceps*										1h			**0.3h**			1s	**0.3s**				
Other mammals																					
Common Wombat *Vombatus ursinus*									**d**				**d**				**d**				**d**
Eastern Grey Kangaroo *Macropus giganteus*									**Xs**				**Xc**								
Red-necked Wallaby *Macropus rufogriseus*									**Xc**												
Swamp Wallaby *Wallabia bicolor*																s	**s**				**Xs**
Microbats	s		s		**s**	s	s	s	**s**	s			**s**			s	**s**			s	**s**
Dingo/*Dog *Canis lupus dingo/familiaris*																					**d**
*Red Fox *Vulpes vulpes*													**t**								
*Goat *Capra hircus*									**t**												
*Pig *Sus scrofa*					**a**																
*European Rabbit *Oryctolagus cuniculus*									**d**				**d**	s			**s**				
Nocturnal birds																					
Southern Boobook *Ninox novaeseelandiae*	h				**h**	h	h	h	**h**	h			**h**								
Frogs																					
Common Eastern Froglet *Crinia signifera*	h				**h**																

[+] Including one tentative identification

Table 6. Survey results for Transect 6, quarry track, Wombeyan Karst Conservation Reserve

Burnt at moderate severity in 2019-20, with an estimated 77% of the eucalypt foliage killed. Figures in the table are the number of animals detected per 500 m. s = seen, h = heard, d = droppings, c = camera records, [T] = threatened species, X = recorded on or near transect outside search times, ? = tentative identification. Unfortunately, we have been unable to access this transect to carry out surveys in either 2022 or 2023.

	2016-18 (pre-fire)					2020 (10.5 mths post-fire)				2021 (17 mths post-fire)			
Date	13/12/16	28/5/18	29/5/18	30/5/18	**Mean**	14/11/20	15/11/20	17/11/20	**Mean**	24/5/21	25/5/21	27/5/21	**Mean**
Start time (AEST)	1210	1915	1843	1938		2150	2200	1900		1745	2050	2042	
Duration (minutes)	55	60	60	60		60	60	60		60	60	60	
Transect length (m)	635	500	500	500		500	500	500		500	500	500	
Arboreal mammals													
[T]Southern Greater Glider *Petauroides volans*	6.3s	8s	2s	5s	**5.3s**	1s	2s	1s	**1.3s**	3s	2s[+]	1s	**2s**
Krefft's Glider *Petaurus notatus*		1s?			**0.3s?**			1s?	**0.3s?**	1s	1s		**0.7s**
[T]Squirrel Glider *Petaurus norfolcensis*?					**Xs?**								
Common Brushtail Possum *Trichosurus vulpecula*		1s		1s?	**0.5s**	1s	3s	3s	**2.3s**	3s			**1s**
Common Ringtail Possum *Pseudocheirus peregrinus*					**Xs**								
Other mammals													
Common Wombat *Vombatus ursinus*									**Xc**				**d**
Eastern Grey Kangaroo *Macropus giganteus*					**Xs**	s			**s**		s		**s**
Red-necked Wallaby *Macropus rufogriseus*									**Xs**				**Xs**
Swamp Wallaby *Wallabia bicolor*							s		**s**				**d**
Microbats			s		**s**			s	**s**	s			**s**
Nocturnal birds													
Tawny Frogmouth *Podargus strigoides*						h			**h**	s			**s**
White-throated Nightjar *Eurostopodus mystacalis*								h	**h**				
Southern Boobook *Ninox novaeseelandiae*						h	h	h	**h**				
Frogs													
Brown-striped Frog *Limnodynastes peronii*									**Xh**				
Spotted Grass Frog *Limnodynastes tasmaniensis*									**Xh**				
Common Eastern Froglet *Crinia signifera*									**Xh**	h	h	h	**h**
Brown Toadlet *Pseudophryne bibronii*										h			**h**
Bleating Tree Frog *Litoria dentata*						h	h		**h**				
Peron's Tree Frog *Litoria peronii*							h	h	**h**				

[+] Including one tentative identification

Table 7. Survey results for Transect 11, Langs Road at Range Trail junction, Blue Mountains National Park

Burnt at low severity in 2019-20, with an estimated 44% of the eucalypt foliage killed. Figures in the table are the number of animals detected per 500 m. s = seen, h = heard, d = droppings, t = tracks, c = camera records, [T] = threatened species, * = introduced species, X = recorded on or near transect outside search times, ? = tentative identification.

	2016 (pre-fire)	**2020 (10.5 mths post-fire)**				**2021 (17 mths post-fire)**				**2022 (29.5 mths post-fire)**				**2023 (40.5 mths post-fire)**			
Date	14/12/16	13/11/20	14/11/20	16/11/20	**Mean**	24/5/21	25/5/21	26/5/21	**Mean**	15/6/22	16/6/22	17/6/22	**Mean**	9/5/23	10/5/23	11/5/23	**Mean**
Start time (AEST)	2050	2015	1900	2045		2032	1900	1733		1850	2030	1730		2035	1910	1745	
Duration (minutes)	50	60	60	60		60	60	60		60	60	60		60	65	70	
Transect length (m)	340	500	500	500		500	500	500		500	500	500		500	500	500	
Arboreal mammals																	
[T]Southern Greater Glider *Petauroides volans*	**19.1s**	12s	12s	18s[++]	**14s**	15s	13s[+]	18s	**15.3s**	18s	17s	26s	**20.3s**	24s	28s	27s	**26.3s**
Krefft's Glider *Petaurus notatus*										1h?		2s[+]	**1s**			1s?	**0.3s**
Common Brushtail Possum *Trichosurus vulpecula*															1h		**0.3h**
Other mammals																	
Antechinus species												s?	**s?**				
Common Wombat *Vombatus ursinus*					**Xs**				**d**				**d**				**dt**
Eastern Grey Kangaroo *Macropus giganteus*													**Xs**				
Red-necked Wallaby *Macropus rufogriseus*													**Xs**				
Swamp Wallaby *Wallabia bicolor*													**d**				
Unidentified macropod									**t**								**d**
Microbats	**s**	s	s		**s**							s	**s**		s	s	**s**
Dingo/*Dog *Canis lupus dingo/familiaris*																	**t**
*Unidentified deer													**Xc**				**t**
Nocturnal birds																	
Southern Boobook *Ninox novaeseelandiae*		s	h	h	**s**							h	**h**				
[T]Powerful Owl *Ninox strenua*															h		**h**
[T]Australian Masked Owl *Tyto novaehollandiae*						h			**h**					h			**h**
Frogs																	
Brown-striped Frog *Limnodynastes peronii*				h	**h**												
Peron's Tree Frog *Litoria peronii*		h		h	**h**												

[+] Including one tentative identification [++] Including one joey

Table 8. Survey results for Transect 12, Langs Road at Rock Lily Road junction, Blue Mountains National Park

Burnt at moderate severity in 2019-20, with an estimated 72% of the eucalypt foliage killed. Figures in the table are the number of animals detected per 500 m. s = seen, h = heard, d = droppings, t = tracks, a = carcass, f = feeding signs, (f) = old pre-fire feeding signs, T = threatened species, * = introduced species, X = recorded on or near transect outside search times, ? = tentative identification.

	2016 (pre-fire)	2020 (10.5 mths post-fire)				2021 (17 mths post-fire)				2022 (29.5 mths post-fire)				2023 (40.5 mths post-fire)			
Date	14/12/16	13/11/20	15/11/20	16/11/20	**Mean**	25/5/21	26/5/21	27/5/21	**Mean**	15/6/22	17/6/22	18/6/22	**Mean**	10/5/23	11/5/23	12/5/23	**Mean**
Start time (AEST)	1935	1900	2020	1930		1743	1900	1856		1730	1855	2020		2035	1905	1745	
Duration (minutes)	60	60	60	60		60	60	60		60	60	60		60	60	60	
Transect length (m)	455	500	500	500		500	500	500		500	500	500		500	500	500	
Arboreal mammals																	
TSouthern Greater Glider *Petauroides volans*	**11s**	9s	9s	8s	**8.7s**	5s	7s	7s	**6.3s**	4s	9s	6s	**6.3s**	12s	8s	8s	**9.3s**
TYellow-bellied Glider *Petaurus australis*	**1.1h**				**(f)**	1h			**0.3h**	2s			**0.7s**		1h		**0.3h**
Krefft's Glider *Petaurus notatus*			1h?		**0.3h?**					1s1h?			**0.7s?**			1s	**0.3s**
Other mammals																	
Common Wombat *Vombatus ursinus*					**d**				**d**				**d**				
Eastern Grey Kangaroo *Macropus giganteus*					**Xs**				**Xs**								**Xs**
Swamp Wallaby *Wallabia bicolor*													**d**				**Xs**
Microbats	**s**	s	s	s	**s**	s			**s**	s	s	s	**s**	s	s	s	**s**
*Black Rat *Rattus rattus*													**a**				
*Cat *Felis catus*		s			**s**					s			**s**				
*Unidentified deer																	**t**
*Pig *Sus scrofa*													**f**				**t**
*European Rabbit *Oryctolagus cuniculus*																	**d**
Nocturnal birds																	
Tawny Frogmouth *Podargus strigoides*	**s**		s		**s**												
White-throated Nightjar *Eurostopodus mystacalis*					**Xs**												
Southern Boobook *Ninox novaeseelandiae*	**s**	h	h		**h**												
TPowerful Owl *Ninox strenua*																h	**h**
Frogs																	
Eastern Banjo Frog *Limnodynastes dumerilii*			s		**s**												
Brown-striped Frog *Limnodynastes peronii*	**h**																
Common Eastern Froglet *Crinia signifera*						h	h		**h**		h		**h**				
Brown Toadlet *Pseudophryne bibronii*									**Xh**								
Smooth Toadlet *Uperoleia laevigata*		h	h	h	**h**												
Bleating Tree Frog *Litoria dentata*		h	h	h	**h**												
Lesueur's Frog *Litoria lesueuri ss*					**Xh**												
Peron's Tree Frog *Litoria peronii*		h	s	s	**s**												
Verreaux's Tree Frog *Litoria verreauxii*													**Xh**				

Table 9. Survey results for Transect 13, Six Foot Track, Jenolan Karst Conservation Reserve

Burnt at high severity in 2019-20, with an estimated 100% of the eucalypt foliage killed (scorched). Figures in the table are the number of animals detected per 500 m. Results for 2003 and 2011 only list arboreal mammals; other pre-fire species records are all from November 2018. s = seen, h = heard, d = droppings, c = camera records, e = trapped (Elliott traps), [T] = threatened species, * = introduced species, X = recorded on or near transect outside search times, ? = tentative identification.

	2003-18 (pre-fire)				**2020 (11 mths post-fire)**				**2021 (17 mths post-fire)**				**2022 (29 mths post-fire)**				**2023 (40.5 mths post-fire)**			
Date	20/01/03	21/02/11	24/11/18	**Mean**	4/12/20	6/12/20	11/12/20	**Mean**	1/6/21	2/6/21	5/6/21	**Mean**	27/5/22	2/6/22	4/6/22	**Mean**	5/5/23	18/5/23	19/5/23	**Mean**
Start time (AEST)			1945		2030	1930	2040		1745	1843	1730		1740	1840	1843		1900	1740	1855	
Duration (minutes)		30	90		60	60	60		60	60	60		60	60	60		60	60	60	
Transect length (m)	500	200	500		500	500	500		500	500	500		500	500	500		500	500	500	
Arboreal mammals																				
Feathertail Glider *Acrobates frontalis/pygmaeus*														1s		**0.3s**			1s	**0.3s**
[T]Southern Greater Glider *Petauroides volans*	4s	5s	1s	**3.3s**																
Krefft's Glider *Petaurus notatus*													1s	1s		**0.7s**			1s?	**0.3s?**
Common Brushtail Possum *Trichosurus vulpecula*						1s	1s	**0.7s**	1s			**0.3s**		1s		**0.3s**	2s	1s		**1s**
[T]Spotted-tailed Quoll *Dasyurus maculatus*												**d**								
Other mammals																				
Agile Antechinus *Antechinus agilis*				**Xe**								**Xc?**				**Xc?**				
Common Dunnart *Sminthopsis murina*												**Xc**								
Common Wombat *Vombatus ursinus*				**d**				**d**				**d**				**d**				**d**
Eastern Grey Kangaroo *Macropus giganteus*			s	**s**	s			**s**				**Xs**	s	s		**s**	s			**s**
Red-necked Wallaby *Macropus rufogriseus*			s	**s**		s		**s**							s	**s**				**Xs**
Swamp Wallaby *Wallabia bicolor*				**Xs**				**Xs**				**Xs**				**d**				**Xs**
Microbats			s	**s**	s	s		**s**		s		**s**	s			**s**	s	s		**s**
*Pig *Sus scrofa*																				**Xc**
*European Rabbit *Oryctolagus cuniculus*				**Xd**				**Xs**				**Xd**				**d**				**Xd**
Nocturnal birds																				
Tawny Frogmouth *Podargus strigoides*					h			**h**												
Southern Boobook *Ninox novaeseelandiae*					h			**h**		s		**s**				**Xh**				
Frogs																				
Common Eastern Froglet *Crinia signifera*				**Xh**																
Verreaux's Tree Frog *Litoria verreauxii*													h			**h**				**Xh**

Table 10. Survey results for Transect 14, Six Foot Track, Jenolan Karst Conservation Reserve

Burnt at extreme severity in 2019-20, with an estimated 100% of the eucalypt foliage killed (consumed). Figures in the table are the number of animals detected per 500 m. Results for 2003 only list arboreal mammals. s = seen, h = heard, d = droppings, f = feeding signs, c = camera records, [T] = threatened species, * = introduced species, X = recorded on or near transect outside search times.

	2003 (pre-fire)	**2020 (11 mths post-fire)**				**2021 (17 mths post-fire)**				**2022 (29 mths post-fire)**				**2023 (40.5 mths post-fire)**			
Date	20/1/03	4/12/20	6/12/20	11/12/20	**Mean**	1/6/21	2/6/21	5/6/21	**Mean**	27/5/22	2/6/22	4/6/22	**Mean**	5/5/23	18/5/23	19/5/22	**Mean**
Start time (AEST)		1930	2035	1930		1854	1735	1835		1845	1735	1735		1750	1845	1745	
Duration (minutes)		60	60	60		60	60	60		60	60	60		60	60	60	
Transect length (m)	500	500	500	500		500	500	500		500	500	500		500	500	500	
Arboreal mammals																	
Feathertail Glider *Acrobates frontalis/pygmaeus*	**1s**																
[T]Southern Greater Glider *Petauroides volans*	**6s**																
Krefft's/Sugar Glider *Petaurus notatus/breviceps*	**2s**																
Common Brushtail Possum *Trichosurus vulpecula*										1h			**0.3h**				
Common Ringtail Possum *Pseudocheirus peregrinus*	**1s**																
[T]Spotted-tailed Quoll *Dasyurus maculatus*									**Xd**								
Other mammals																	
Common Dunnart *Sminthopsis murina*									**Xc**								
Common Wombat *Vombatus ursinus*					**d**				**d**				**d**				
Eastern Grey Kangaroo *Macropus giganteus*					**Xs**								**Xc**				
Swamp Wallaby *Wallabia bicolor*					**Xs**				**d**				**d**	s			**s**
Microbats						s	s		**s**	s	s		**s**	s	s	s	**s**
*Red Fox *Vulpes vulpes*												s	**s**				
*Cat *Felis catus*														s			**s**
*Pig *Sus scrofa*																	**f**
*European Rabbit *Oryctolagus cuniculus*					**Xs**				**d**				**d**				**Xd**
Nocturnal birds																	
Tawny Frogmouth *Podargus strigoides*		h			**h**												
Southern Boobook *Ninox novaeseelandiae*		h			**h**		h		**h**	h			**h**	h			**h**

Table 11. Survey results for Transect 18, Queens Gap Trail, Mares Forest National Park

Not burnt in 2019-20. Figures in the table are the number of animals detected per 500 m. s = seen, h = heard, d = droppings, t = tracks, [T] = threatened species, * = introduced species, ? = tentative identification.

	2016 (pre-fire)	**2922 (29 months post-fire)**				**2023 (40.5 months post-fire)**			
Date	16/12/16	16/6/22	17/6/22	18/6/22	**Mean**	9/5/23	10/5/23	12/5/23	**Mean**
Start time (AEST)	2150	1730	2020	1900		1900	1745	2025	
Duration (minutes)	60	60	60	60		70	70	65	
Transect length (m)	455	500	500	500		500	500	500	
Arboreal mammals									
[T]Southern Greater Glider *Petauroides volans*	**13.2s**	24s[+]	24s	20s	**22.7s**	28s	22s	30s	**26.7s**
Krefft's Glider *Petaurus notatus*	**1.1s?**					1s			**0.3s**
Other mammals									
Common Wombat *Vombatus ursinus*					**d**				**d**
Eastern Grey Kangaroo *Macropus giganteus*									**d**
Swamp Wallaby *Wallabia bicolor*									**d**
Microbats	**s**	s			**s**				
Bush Rat *Rattus fuscipes*						s			**s**
*Unidentified deer									**t**
Nocturnal birds									
Tawny Frogmouth *Podargus strigoides*									**Xs**
Australian Owlet-nightjar *Aegotheles cristatus*									**Xs**
Southern Boobook *Ninox novaeseelandiae*							h		**h**
[T]Powerful Owl *Ninox strenua*			h		**h**			h	**h**

[+] Including one tentative identification

Table 12. Weather conditions during Transect 5 searches

Date	Weather conditions
16/12/16	Cloudy, still, some fog, lot of rain earlier, 16°C, moon not visible
28/5/18	Cloudy, still to light wind, 10°C, full moon
29/5/18	Overcast, moderate wind, light rain, 9°C, full moon visible through cloud
30/5/18	Clear, moderate to strong wind, 4°C, full moon
13/11/20	Clear, still to light wind, raining earlier today, 12°C, no moon
14/11/20	Clear, still, 13°C, no moon
15/11/20	Clear, still, 18°C, no moon
24/5/21	Overcast, still, 11°C, occasional glimpse of full moon
26/5/21	Overcast becoming clear, light to moderate wind, 6°C, faint misting rain first half of search, full moon undergoing eclipse
27/5/21	Cloudy becoming clear, moderate to strong wind, 5°C, full moon
15/6/22	Clear, moderate to strong wind, 6°C, full moon
16/6/22	Cloudy, moderate to strong wind, 6°C, occasional faint misting rain, full moon
18/6/22	Clear, still, 5°C, no moon
9/5/23	Clear, light wind, 5°C, no moon
11/5/23	Clear, still to light wind, 7°C, no moon
12/5/23	Clear, still, 8°C, no moon

Table 13. Weather conditions during Transect 6 searches

Date	Weather conditions
13/12/16	Clear, still, 18°C, full moon
28/5/18	Cloudy becoming clear, still, 10°C, full moon
29/5/18	Overcast, still, some light rain, 9°C, moon not visible
30/5/18	Clear, light to strong wind, 5°C, full moon
14/11/20	Clear, still,12°C, no moon
15/11/20	Clear, still, 16°C, no moon
17/11/20	Overcast, light wind, mist forming, no moon
24/5/21	Overcast, still to light wind, 11°C, occasional glimpse of full moon
25/5/21	Cloudy, still, 7°C, full moon
27/5/21	Clear, light to moderate wind, 6°C, full moon

Table 14. Weather conditions during Transect 11 searches

Date	Weather conditions
14/12/16	Overcast, still, spots of rain, 18°C, moon not visible
13/11/20	Clear, still, raining earlier today, 12°C, no moon
14/11/20	Clear, still, 13°C, no moon
16/11/20	Overcast, light to moderate wind, 16°C, no moon
24/5/21	Cloudy, light wind, 11°C, full moon
25/5/21	Clear becoming cloudy, still, 9°C, full moon
26/5/21	Overcast becoming cloudy, moderate to strong wind, 6°C, full moon
15/6/22	Clear, moderate wind, 5°C, full moon
16/6/22	Overcast, moderate wind, 6°C, some faint misting rain, occasional glimpse of full moon
17/6/22	Cloudy, still, 7°C, no moon
9/5/23	Clear, still to light wind, 4°C, waning gibbous moon rising
10/5/23	Clear, still, 6°C, no moon
11/5/23	Clear, still, 8°C, no moon

Table 15. Weather conditions during Transect 12 searches

Date	Weather conditions
14/12/16	Overcast, light wind, 18°C, moon not visible
13/11/20	Clear, still to light wind, raining earlier today, 12°C, no moon
15/11/20	Clear, still, 18°C, no moon
16/11/20	Overcast becoming cloudy, moderate to strong wind, 16°C, no moon
25/5/21	Clear, still to moderate wind, 9°C, full moon
26/5/21	Cloudy becoming overcast, moderate wind, 6°C, full moon
27/5/21	Clear, moderate to strong wind, 5°C, full moon
15/6/22	Clear, moderate wind, 5°C, full moon rising
16/6/22	Cloudy to overcast, light to moderate wind, 6°C, no moon
18/6/22	Clear to overcast (high mist), still to moderate wind, 4°C, no moon
10/5/23	Clear, still, 5°C, no moon
11/5/23	Clear, still, 7°C, no moon
12/5/23	Clear, still, 8°C, no moon

Table 16. Weather conditions during Transect 13 searches

Date	Weather conditions
4/12/20	Clear, still to moderate wind, 18°C, no moon
6/12/20	Clear, moderate to strong wind, cold, no moon
11/12/20	Overcast, moderate to strong wind, 7°C, moon not visible
1/6/21	Cloudy, moderate wind, 6°C, no moon
2/6/21	Cloudy becoming clear, still, 9°C, no moon
5/6/21	Clear, moderate to strong wind, 2°C, no moon
27/5/22	Cloudy, still, 10°C, no moon
2/6/22	Cloudy, still, 3°C, no moon
4/6/22	Cloudy, strong wind, 4°C, occasional faint misting rain, new moon
5/5/23	Clear, light wind, 5°C, full moon
18/5/23	Overcast becoming cloudy, still to light wind, 5°C, no moon
19/5/23	Clear, moderate wind, 3°C, no moon

Table 17. Weather conditions during Transect 14 searches

Date	Weather conditions
4/12/20	Clear, light wind, 18°C, no moon
6/12/20	Clear, moderate to strong wind, cold, no moon
11/12/20	Overcast, moderate to strong wind, 11°C, moon not visible
1/6/21	Cloudy, light to moderate wind, 6°C, no moon
2/6/21	Overcast becoming cloudy, still to light wind, 9°C, no moon
5/6/21	Clear, moderate to strong wind, 2°C, no moon
27/5/22	Cloudy to overcast, still to light wind, 10°C, no moon
2/6/22	Cloudy, still, 3°C, no moon
4/6/22	Cloudy to overcast, strong wind, 4°C, occasional faint misting rain, new moon
5/5/23	Clear, still to light wind, 5°C, full moon
18/5/23	Cloudy becoming overcast, light to moderate wind, 5°C, no moon
19/5/23	Clear, moderate wind, 3°C, no moon

Table 18. Weather conditions during Transect 18 searches

Date	Weather conditions
16/12/16	Clear, still to moderate wind, 16°C, lot of rain earlier, waning gibbous moon rising
16/6/22	Overcast, moderate to strong wind, 6°C, no moon
17/6/22	Clear, still, 6°C, waning gibbous moon rising
18/6/22	Clear, still, 4°C, no moon
9/5/23	Clear, still, 5°C, no moon
10/5/23	Clear, still, 7°C, no moon
12/5/23	Clear, still, 8°C, no moon

Appendix 2. Transect descriptions

Table 19. Tree measurements

Tree height and foliage cover are means for the five sample points per transect. Other values are means or counts for the 50 trees sampled per transect (10 trees per sample point). Tree foliage cover is the % of the ground vertically shaded by tree leaves and branches, including both canopy and understorey trees but not ones less than 1/3 the height of the tallest trees. Tree condition is the % of each tree that was dead or defoliated. For the burnt transects, tree condition ignores post-fire epicormic regrowth in order to assess the condition of the trees immediately after the fire. Live epicormic regrowth was scored for each tree as 0, 1 (some), 2 (moderate) or 3 (abundant), including regrowth at the base of the tree. Large hollows are ones potentially suitable for Greater Gliders and Yellow-bellied Gliders, whereas small hollows are ones potentially suitable for Squirrel Gliders and Sugar Gliders. Some trees had both types of hollows. The assessment was made from the ground and probably overestimates the number of trees with suitable hollows (since we could only see the entrance of the potential hollow, not the interior). Understorey trees are 1/3 to 2/3 the height of the tallest trees; canopy trees are >2/3 the height of the tallest trees. + = additional species present along transect.

Tree measurement	**Transect**						
	5	**6**	**11**	**12**	**13**	**14**	**18**
2019-20 fires	burnt	burnt	burnt	burnt	burnt	burnt	unburnt
Height (m) of tallest trees (mean and range)	20 (17-22)	27 (23-34)	39 (30-47)	33 (27-36)	27 (26-29)	24 (22-27)	36 (33-41)
Tree foliage cover % (mean and range)	22 (20-30)	16 (10-20)	34 (20-40)	24 (10-30)	16 (10-20)	10 (10-10)	32 (30-40)
Tree condition % (mean and range)	63 (0-100)	77(10-100)	44(10-100)	72(10-100)	100 (90-100)	100 (100-100)	29 (0-70)
Epicormic regrowth score (mean and range)	1.8 (0-3)	1.8 (0-3)	1.7 (0-3)	1.8 (0-3)	2.4 (0-3)	2.2 (0-3)	1.1 (0-3)
Ratio of canopy to understorey trees	25:25	26:24	34:16	37:13	37:13	39:11	32:18
No. of trees with large hollows	8	1	6	9	4	3	5
No. of trees with small hollows	9	6	19	20	7	7	13
No. of trees with live mistletoes	0	0	0	0	0	0	0
No. of dead trees	6	6	3	5	5	2	0
No. of live *Acacia falciformis* trees		5					
No. of live *Allocasuarina littoralis* trees		1					
No. of live *Casuarina cunninghamiana* trees		3					
No. of live *Eucalyptus agglomerata* trees		4					
No. of live *Eucalyptus blaxlandii* trees						+	
No. of live *Eucalyptus bridgesiana* trees		12					
No. of live *Eucalyptus dalrympleana* trees				1	18	9	4
No. of live *Eucalyptus elata* trees		4					
No. of live *Eucalyptus eugenioides* trees		1					
No. of live *Eucalyptus fastigata* trees			27	23	22	38	19
No. of live *Eucalyptus mannifera* trees	+						
No. of live *Eucalyptus radiata* trees	12		5	15	5	1	18
No. of live *Eucalyptus sieberi* trees	32	14		2			9
No. of live *Eucalyptus viminalis* trees			15	4			

Table 20. Acacia and banksia abundance

Abundance of each species scored at each point as 0 (none within 10 m of point), 1 (<10 plants within 10 m) or 2 (10 or more plants within 10 m) then summed for the five points per transect, giving an abundance index with a maximum value of 10. + = present along transect but not within 10 m of any point.

Species	Transect						
	5	6	11	12	13	14	18
Acacia dealbata							3
Acacia falciformis		10	3	1	1	1	6
Acacia longifolia	+						
Acacia melanoxylon				+	6	4	
Acacia parramattensis		+		+			
Acacia terminalis	9			+			
Banksia spinulosa	3						

Table 21. Reserve, vegetation, elevation, landscape context and fire history

Reserve: BMN = Blue Mountains National Park; MFN = Mares Forest National Park; JKR = Jenolan Karst Conservation Reserve; WKR = Wombeyan Karst Conservation Reserve. Vegetation class (Keith 2004): ERF = Eastern Riverine Forest; SEW = Southern Escarpment Wet Sclerophyll Forest; SMD = Sydney Montane Dry Sclerophyll Forest; STW = Southern Tableland Wet Sclerophyll Forest. Fire history obtained from NSW National Parks and Wildlife Service records. The forest and woodland % is the proportion of land within 1 km of the transect centreline that is native forest and woodland based on satellite imagery taken in October 2019 for Transects 5, 6, 11, 12 and 18, and December 2019 for Transects 13 and 14, before the 2019-20 fires.

	Transect						
	5	6	11	12	13	14	18
Reserve	MFN	WKR	BMN	BMN	JKR	JKR	MFN
Vegetation class	SMD	SMD/STW/ERF	SEW	SEW	STW	STW	SEW/SMD
Elevation (m)	890-905	605-640	960-970	890-900	1150-1170	1100-1120	965-975
Forest and woodland within 1 km (%)	94	82	99	99	97	98	97
Distance from human habitation (km)	0.8	0.2	0.9	1.4	0.1	0.8	0.4
Distance from World Heritage Area (km)	0.1	0.5	0	0	0	0	1.4
Wildfires since 1980	1	1	1	1	1	1	0
Prescribed burns since 1980	1	0	0	0	0	0	0
Date of last wildfire	Dec 2019 - Jan 2020	Dec 2019 - Jan 2020	Dec 2019 - Jan 2020	Dec 2019 - Jan 2020	Dec 2019 - Jan 2020	Dec 2019 - Jan 2020	Before 1980
Date of last prescribed burn	May 2019						

Table 22. Coordinates of transect points (GDA94)

Point	Latitude	Longitude
5A	-34.284911	149.942520
5B	-34.285998	149.942020
5C	-34.287022	149.941627
5D	-34.288005	149.941134
5E	-34.288863	149.940394
6A	-34.299827	149.971857
6B	-34.299716	149.970771
6C	-34.299722	149.969277
6D	-34.299025	149.968258
6E	-34.297979	149.967518
11A	-34.259371	149.937730
11B	-34.259219	149.939083
11C	-34.259088	149.940209
11D	-34.259089	149.941565
11E	-34.259134	149.943042
12A	-34.272332	149.973095
12B	-34.271305	149.972501
12C	-34.270258	149.972077
12D	-34.269170	149.971827
12E	-34.267873	149.971390
13A	-33.790690	150.024017
13B	-33.791447	150.024878
13C	-33.791907	150.026009
13D	-33.792803	150.026574
13E	-33.793859	150.026915
14A	-33.797695	150.025675
14B	-33.798751	150.025712
14C	-33.799742	150.026279
14D	-33.800852	150.026595
14E	-33.801936	150.026601
18A	-34.272421	149.917193
18B	-34.273513	149.916892
18C	-34.274624	149.916140
18D	-34.275581	149.915510
18E	-34.276285	149.914524

Transect 5, Oak Range Trail, Mares Forest National Park

Transect 5 runs along an unsealed vehicle track, Oak Range Trail, from near its junction with Wombeyan Caves Road. The site is a plateau on Siluro-Devonian Mares Forest Volcanics geology at an elevation of 890-905 m. The vegetation class is Sydney Montane Dry Sclerophyll Forest about 20 m tall in which the main tree species are *Eucalyptus sieberi* (Silvertop Ash) and *E. radiata* (Narrow-leaved Peppermint). Originally a state forest, the area was dedicated as a national park in 2010. Impacts of past logging are evident at the southern end of the transect, where larger trees are sparse and there are many young trees and saplings. The north-western side of the track was burnt in a hazard reduction burn in May 2019. Prior to that, there had been no recorded fires at the site since before 1980, either wildfires or hazard reduction burns. The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire. The impacts of that fire were most severe on the south-eastern side of the track (Photos 2 and 3). Overall, the transect was burnt at moderate severity, with an estimated 63% of the eucalypt foliage along the transect killed in the fire. A number of trees fell either during or soon after the fire. Plant species in flower during the 2020, 2021, 2022 and 2023 post-fire surveys that were potential food sources for arboreal mammals were some *Xanthorrhoea australis* (Austral Grass-tree) in November 2020 and numerous *Banksia spinulosa* (Hairpin Banksia) in June 2022 and May 2023.

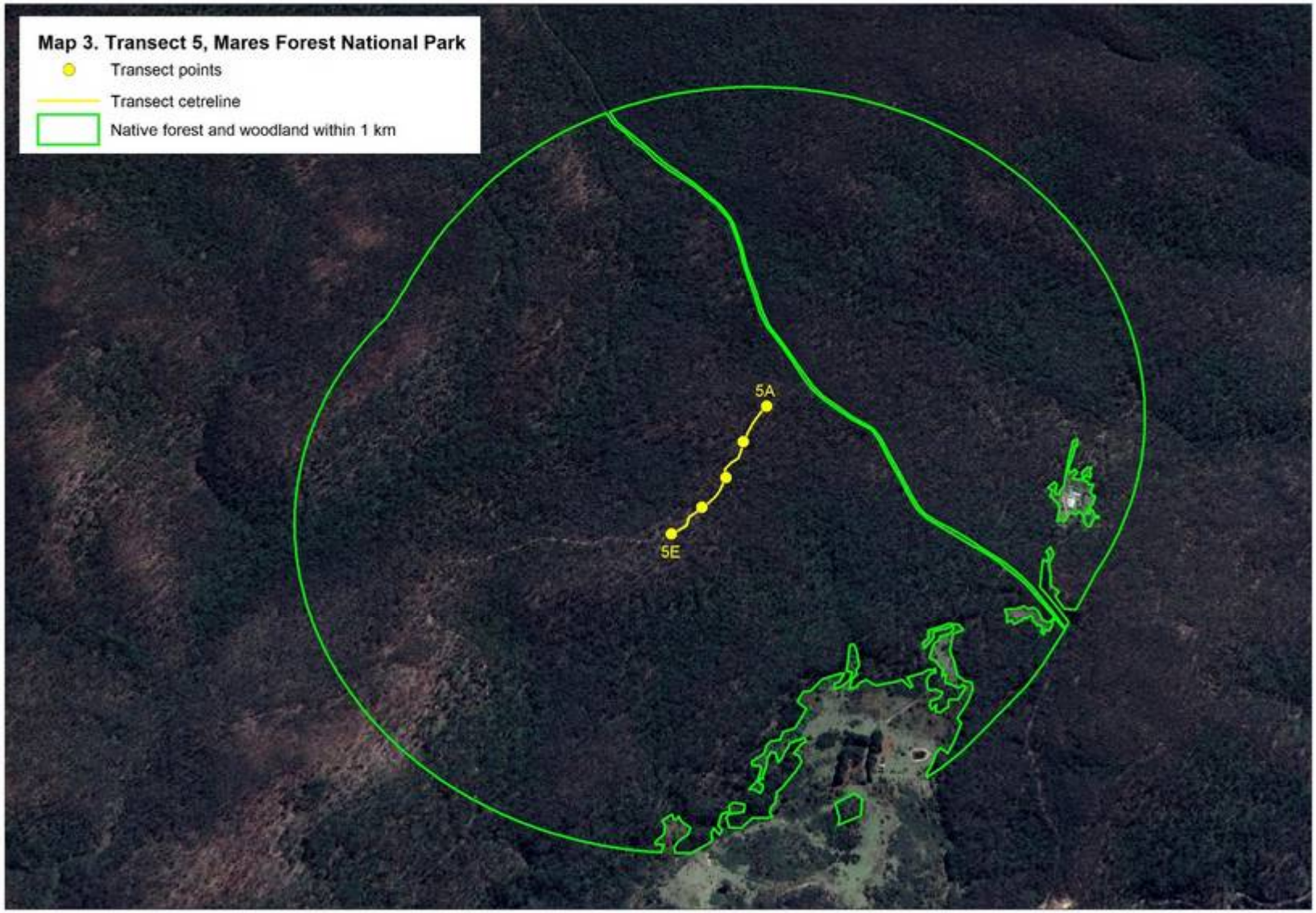
Photo 1. Sydney Montane Dry Sclerophyll Forest south-east of Point 5A in May 2018, before the May 2019 hazard reduction burn and the December 2019-January 2020 wildfire.

Photo 2. Sydney Montane Dry Sclerophyll Forest south-east of Point 5A in November 2020, 10.5 months after being severely burnt in the December 2019-January 2020 wildfire, which was a crown fire in this part of the transcect. Not burnt in the May 2019 hazard reduction burn.

Photo 3. Sydney Montane Dry Sclerophyll Forest south-east of Point 5A in May 2023, 40.5 months post-fire, showing dense shrub layer regeneration (mainly *Acacia terminalis*), good eucalypt seedling regeneration (mainly *Eucalyptus sieberi*, now 1-4 m tall) and some increase in epicormic foliage since November 2020, but little recovery of canopy foliage.

Photo 4. Sydney Montane Dry Sclerophyll Forest north-west of Point 5A in November 2020, 10.5 months post-fire. Lightly burnt in the May 2019 hazard reduction burn, which appears to have had a marked effect in reducing the impact of the December 2019-January 2020 wildfire compared with the other side of the road, especially the impact on the tree layer.

Photo 5. Sydney Montane Dry Sclerophyll Forest north-west of Point 5A in May 2023, 40.5 months post-fire, showing dense *Acacia terminalis* shrub layer regeneration about 1.5 m tall, which is present all along the transect.


Map 3. Transect 5, Mares Forest National Park
Transect points
Transect cetreline
Native forest and woodland within 1 km
5A
5E

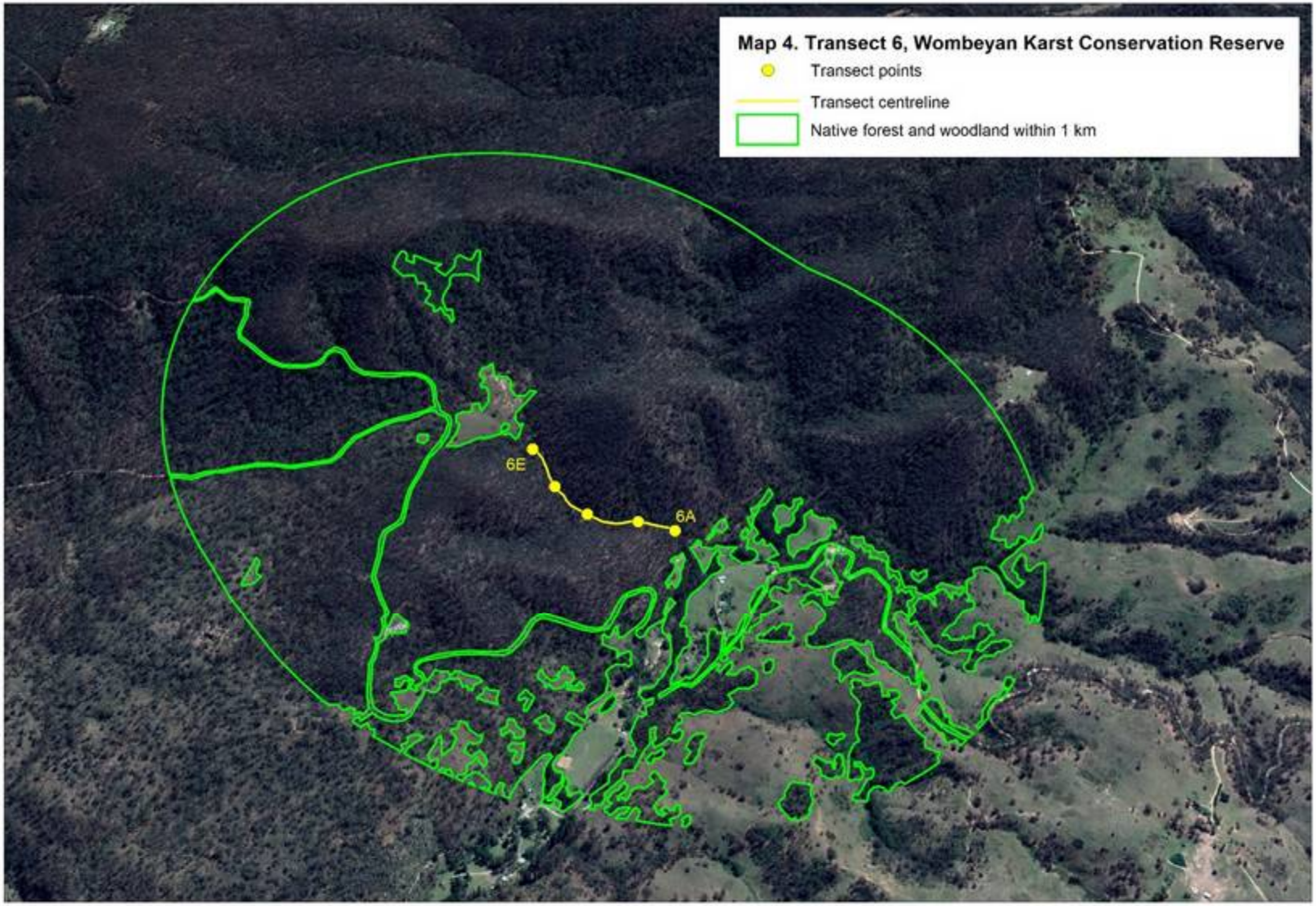
Transect 6, Quarry track, Wombeyan Karst Conservation Reserve

Transect 6 runs along an unsealed vehicle track up a gully beside an ephemeral creek that is a tributary of Wombeyan Creek. The elevation is 605-640 m. The track was badly eroded in the flooding rains of February 2020 and became impassable to vehicles and barely passable on foot. The track runs between the Wombeyan Caves campground and a long-abandoned marble quarry. The geology is Siluro-Devonian Mares Forest Volcanics. The vegetation is eucalypt forest about 27 m tall consisting of a mixture of three vegetation classes. The main class is the vegetation of the hillsides, Sydney Montane Dry Sclerophyll Forest, in which the main tree species are *Eucalyptus sieberi* (Silvertop Ash) and *E. agglomerata* (Blue-leaved Stringybark). Along the creek is a narrow band of Southern Tableland Wet Sclerophyll Forest characterised by *E. bridgesiana* (Apple Box), which changes downstream, at the eastern end of the transect, to Eastern Riverine Forest characterised by *Casuarina cunninghamiana* (River Oak) and *E. elata* (River Peppermint). The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire, which was the first recorded fire at the site, either wildfire or hazard reduction burn, since before 1980. Fire severity varied along the transect. Overall, the transect was burnt at moderate severity, with an estimated 77% of the eucalypt foliage along the transect killed in the fire. A number of trees fell either during or soon after the fire. A few *Acacia falciformis* trees that survived the fire were flowering in November 2020, otherwise no plant species were in flower during the 2020 and 2021 post-fire surveys that were potential food sources for arboreal mammals. A number of nest boxes of various types had been erected along the transect in 2017, some of which survived the fire.

Photo 6. Sydney Montane Dry Sclerophyll Forest in Transect 6 in May 2018, south-west of Point 6D.

Photo 7. Severely burnt Sydney Montane Dry Sclerophyll Forest in Transect 6, south-west of Point 6D, in November 2020, 10.5 months after the December 2019-January 2020 wildfire.

Photo 8. One of only a few patches of lightly burnt Sydney Montane Dry Sclerophyll Forest in Transect 6, north-east of Point 6C, in November 2020, 10.5 months post-fire.


Map 4. Transect 6, Wombeyan Karst Conservation Reserve
Transect points
Transect centreline
Native forest and woodland within 1 km
6E
6A

Transect 11, Langs Road at Range Trail junction, Blue Mountains National Park

Transect 11 runs along an unsealed road, Langs Road, east from its junction with the Range Trail. The site is a plateau on Siluro-Devonian Mares Forest Volcanics geology at an elevation of 960-970 m. The vegetation class is Southern Escarpment Wet Sclerophyll Forest about 39 m tall in which the main tree species are *Eucalyptus fastigata* (Brown Barrel) and *E. viminalis* (Ribbon Gum). The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire, which was the first recorded fire at the site, either wildfire or hazard reduction burn, since before 1980. The transect was burnt at low severity, with an estimated 44% of the eucalypt foliage along the transect killed in the fire, chiefly understorey foliage; most of the canopy foliage survived the fire. There was some felling of trees along Langs Road for safety reasons. No plant species were in flower during the post-fire surveys in 2020, 2021, 2022 and 2023 that were potential food sources for arboreal mammals.

Photo 9. Southern Escarpment Wet Sclerophyll Forest in Transect 11 in December 2016, before the 2019-20 fires.

Photo 10. Lightly burnt Southern Escarpment Wet Sclerophyll Forest in Transect 11, south of Point 11E, in November 2020, 10.5 months after the December 2019-January 2020 wildfire, showing intact tree canopies and epicormic regrowth on trunks.

Photo 11. Lightly burnt Southern Escarpment Wet Sclerophyll Forest in Transect 11, south of Point 11E, in May 2023, 40.5 months post-fire, showing abundant *Eucalyptus fastigata* seedling regeneration, now up to about 4 m tall.

Photo 12. One of only a few patches of moderately burnt Southern Escarpment Wet Sclerophyll Forest in Transect 11, south of Point 11D, in November 2020, 10.5 months after the December 2019-January 2020 wildfire.

Photo 13. Moderately burnt Southern Escarpment Wet Sclerophyll Forest in Transect 11, south of Point 11D, in May 2023, 40.5 months post-fire, showing dense *Eucalyptus fastigata* seedling regeneration but not much change in canopy and epicormic foliage since November 2020.


11A
11E
Map 5. Transect 11, Blue Mountains National Park
Transect points
Transect centreline
Native forest and woodland within 1 km

Transect 12, Langs Road at Rock Lily Road junction, Blue Mountains National Park

Transect 12 runs along an unsealed road, Langs Road, at its junction with Rock Lily Road. The site is a plateau on Siluro-Devonian Mares Forest Volcanics geology at an elevation of 890-900 m The vegetation class is Southern Escarpment Wet Sclerophyll Forest about 33 m tall in which the main tree species are *Eucalyptus fastigata* (Brown Barrel) and *E. radiata* (Narrow-leaved Peppermint), although *E. viminalis* (Ribbon Gum) is the dominant species in a broad, swampy depression adjacent to a small dam on the western side of Langs Road at the southern end of the transect (Photo 15). The extent of this stand is shown by its light-coloured understorey in the Map 7 satellite image. The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire, which was the first recorded fire at the site, either wildfire or hazard reduction burn, since before 1980. Fire severity varied along the transect. Overall, the transect was burnt at moderate severity, with an estimated 72% of the eucalypt foliage along the transect killed in the fire. The *E. viminalis* stand, which was an important pre-fire feeding site for Yellow-bellied Gliders, was severely burnt (Photos 16 and 17). Some parts of the *E. fastigata-E. radiata* forest were also severely burnt (Photos 18 and 19) but other parts were only lightly burnt (Photos 20 and 21). There was some felling of trees along Langs Road for safety reasons. No plant species were in flower during the 2020, 2021, 2022 and 2023 post-fire surveys that were potential food sources for arboreal mammals.

Photo 14. *Eucalyptus fastigata-E. radiata* forest in Transect 12 in December 2016.

Photo 15. *Eucalyptus viminalis* forest in Transect 12 in December 2016, pre-fire.

Photo 16. Severely burnt *Eucalyptus viminalis* forest in Transect 12, west of Point 12A, in November 2020, 10.5 months after the December 2019-January 2020 wildfire.

Photo 17. Severely burnt *Eucalyptus viminalis* forest in Transect 12, west of Point 12A, in May 2023, 40.5 months post-fire, showing very little recovery of eucalypt canopy foliage and some loss of epicormic foliage since November 2020.

Photo 18. Severely burnt *Eucalyptus fastigata-E. radiata* forest in Transect 12, east of Point 12C, in November 2020, 10.5 months after the December 2019-January 2020 wildfire.

Photo 19. Severely burnt *Eucalyptus fastigata-E. radiata* forest in Transect 12, east of Point 12C, in May 2023, 40.5 months post-fire, showing an increase in eucalypt canopy and epicormic foliage since November 2020.

Photo 20. Lightly burnt *Eucalyptus fastigata-E. radiata* forest in Transect 12, west of Point 12C, in November 2020, 10.5 months after the December 2019-January 2020 wildfire.

Photo 21. Lightly burnt *Eucalyptus fastigata-E. radiata* forest in Transect 12, west of Point 12C, in May 2023, 40.5 months post-fire, showing an increase in increase in epicormic foliage since November 2020.


12E
12A
Map 6, Transect 12, Blue Mountains National Park
Transect points
Transect centreline
Native forest and woodland within 1 km

Transect 13, Six Foot Track, Jenolan Karst Conservation Reserve

Transect 13 runs along a walking track, the Six Foot Track, on a broad ridgetop at an elevation of 1150-1170 m. The geology is Silurian Inspiration Point Formation (interbedded siltstone and sandstone). The vegetation class is Southern Tableland Wet Sclerophyll Forest about 27 m tall in which the main tree species are *Eucalyptus fastigata* (Brown Barrel) and *E. dalrympleana* (Mountain Gum). The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire, which was the first recorded fire at the site, either wildfire or hazard reduction burn, since before 1980. The transect was burnt at high severity, with an estimated 99.8% of the eucalypt foliage along the transect killed in the fire. The transect begins about 100 m from a cluster of holiday cottages (Jenolan Caves Cottages) and an adjacent clearing. The forest in the immediate vicinity of the cottages was not burnt. A number of trees fell either during or soon after the fire, and others beside the Six Foot Track were felled for safety reasons, some of them large trees with hollows. No plant species were in flower during the 2020, 2021, 2022 and 2023 post-fire surveys that were potential food sources for arboreal mammals. Canopy foliage has regrown on many (but by no means all) of the eucalypt trees along the transect, which was first noticeable in the 2022 survey and more so in the 2023 survey (Photos 23-26). There has also been an abundant growth of *Eucalyptus fastigata* seedlings, now 1-4 m tall.

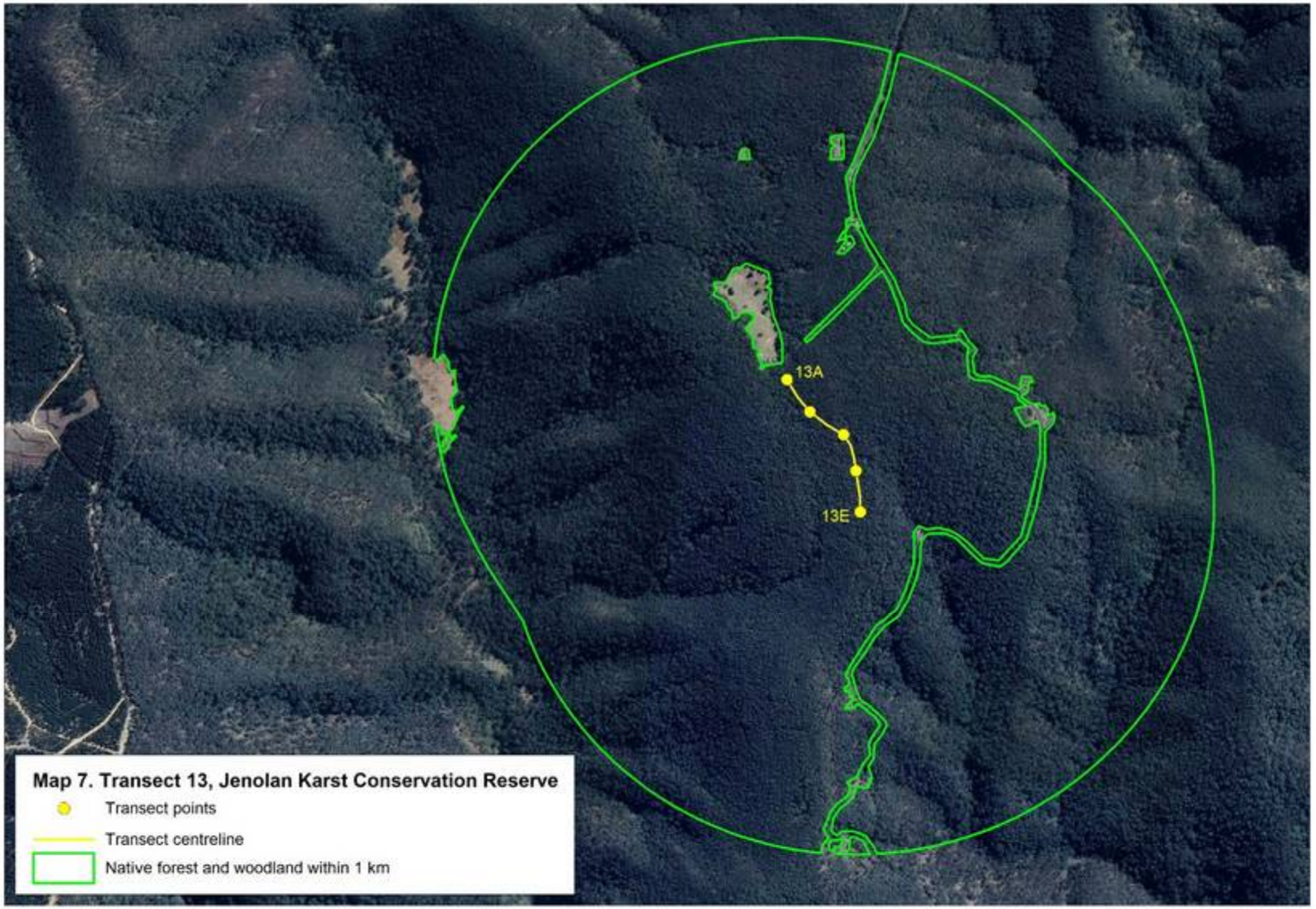
Photo 22. Southern Tableland Wet Sclerophyll Forest in Transect 13 in September 2018, before the 2019-20 fires.

Photo 23. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 13, west of Point 13B, in December 2020, 11 months after the December 2019-January 2020 wildfire, showing abundant epicormic regrowth.

Photo 24. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 13, west of Point 13B, in May 2023, 40.5 months post-fire, showing good eucalypt canopy foliage recovery.

Photo 25. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 13, east of Point 13E, in December 2020, 11 months after the December 2019-January 2020 wildfire.

Photo 26. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 13, east of Point 13E, in May 2023, 40.5 months post-fire, showing an increase in eucalypt canopy and epicormic foliage since December 2020 and abundant *Eucalyptus fastigata* seedling regeneration, now 1-4 m tall.


13A
13E
Map 7. Transect 13, Jenolan Karst Conservation Reserve
Transect points
Transect centreline
Native forest and woodland within 1 km

Transect 14, Six Foot Track, Jenolan Karst Conservation Reserve

Transect 14 runs along a walking track, the Six Foot Track, on a narrow ridgetop at an elevation of 1100-1120 m. The geology is Silurian Inspiration Point Formation (interbedded siltstone and sandstone). The vegetation class is Southern Tableland Wet Sclerophyll Forest about 24 m tall in which the main tree species are *Eucalyptus fastigata* (Brown Barrel) and *E. dalrympleana* (Mountain Gum). The entire transect was burnt around New Year December 2019-January 2020 by the Green Wattle Creek wildfire, which was the first recorded fire at the site, either wildfire or hazard reduction burn, since before 1980. The transect was burnt at extreme severity, with an estimated 100% of the eucalypt foliage along the transect killed in the fire. A number of trees fell either during or soon after the fire, and others beside the Six Foot Track were felled for safety reasons, some of them large trees with hollows. No plant species were in flower during the 2020, 2021, 2022 and 2023 post-fire surveys that were potential food sources for arboreal mammals. There has been abundant regeneration of epicormic foliage in Transect 14 but, unlike Transect 13, there has been virtually no recovery of eucalypt canopy foliage. We believe that this is because Transect 14 was subject to an extreme severity fire (a crown fire) that consumed the canopy foliage and killed the smaller canopy branches, whereas Transect 13 was subject to a high severity fire that killed the canopy foliage by scorching but did not kill the canopy branches, which have since been able to regenerate their foliage. There has been abundant *Eucalyptus fastigata* seedling regeneration in Transect 14, resulting in dense stands of young eucalypts 3-4 m tall all along the transect in May 2023. There has also been abundant *Eucalyptus fastigata* seedling regeneration in Transect 13 but the stands of young eucalypts in Transect 13 are much more open than in Transect 14.

Photo 27. Example of a hollow-bearing tree, an important potential denning and breeding site for arboreal mammals, which fell as a result of fire damage.

Photo 28. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 14, west of Point 14B, in December 2020, 11 months after the December 2019-January 2020 wildfire.

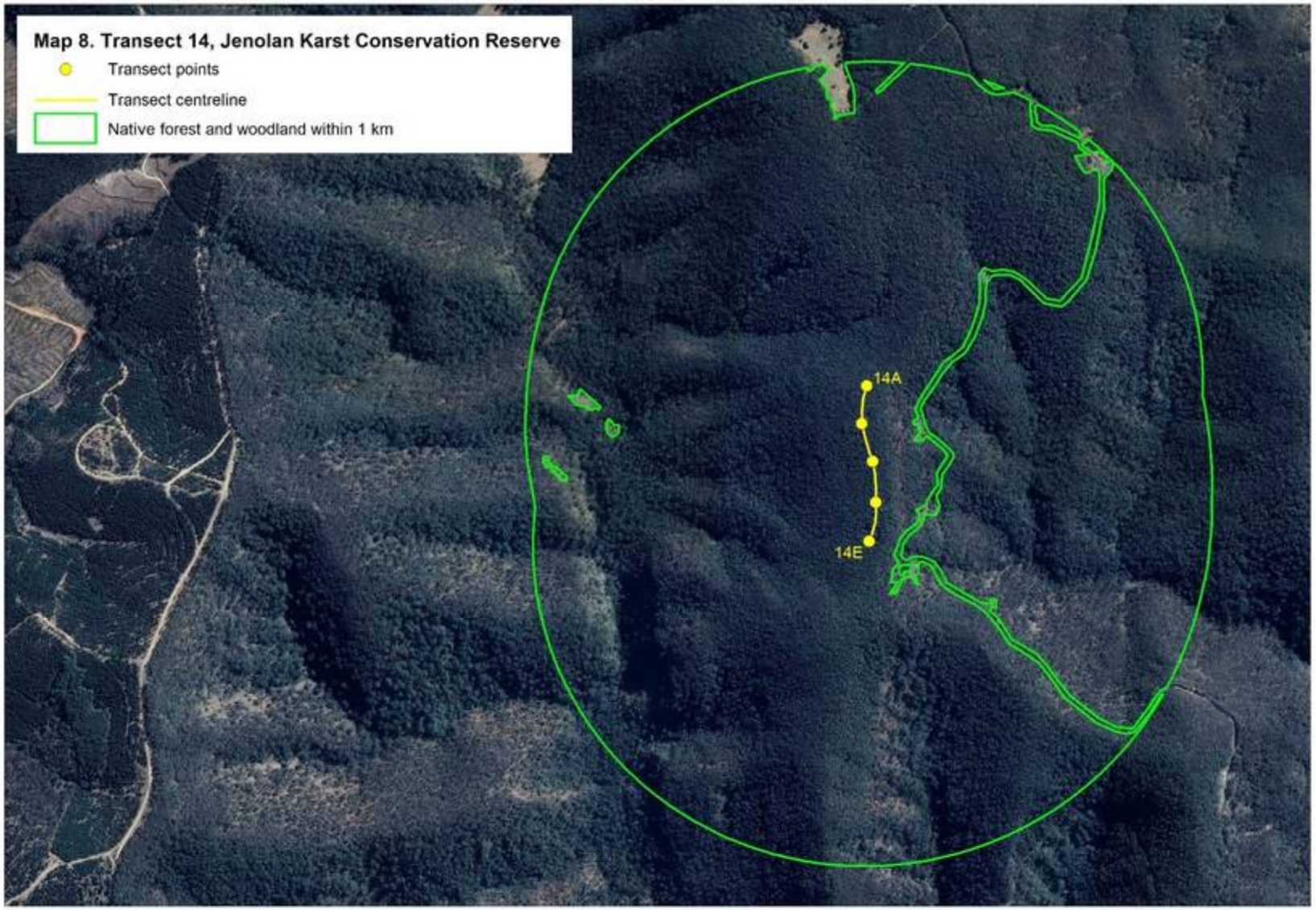
Photo 29. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 14, west of Point 14B, in May2023, 40.5 months post-fire, showing a marked increase in epicormic foliage and dense *Eucalyptus fastigata* seedling regeneration since December 2020 but no canopy foliage recovery.

Photo 30. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 14, east of Point 14B, in December 2020, 11 months after the December 2019-January 2020 wildfire.

Photo 31. Severely burnt Southern Tableland Wet Sclerophyll Forest in Transect 14, east of Point 14B, in May 2023, showing a marked increase in epicormic foliage and dense *Eucalyptus fastigata* seedling regeneration since December 2020 but no canopy foliage recovery.

Photo 32. Typical eucalypt trees in Transect 14 in June 2022, 29 months after the fire. Leafless after the fire, these trees had abundant epicormic foliage on the trunks and major branches in June 2022 but no recovery of canopy foliage on the smaller branches, which had apparently been killed by the extreme severity (crown) fire to which they had been subjected.

Photo 33. Typical eucalypt trees in Transect 13 in June 2022. Leafless after the fire, these trees had good canopy foliage regeneration in June 2022. They had apparently been subjected to a high severity fire which had killed all the leaves by scorching but left many of the smaller branches alive and capable of regenerating canopy foliage.


Map 8. Transect 14, Jenolan Karst Conservation Reserve
Transect points
Transect centreline
Native forest and woodland within 1 km
14A
14E

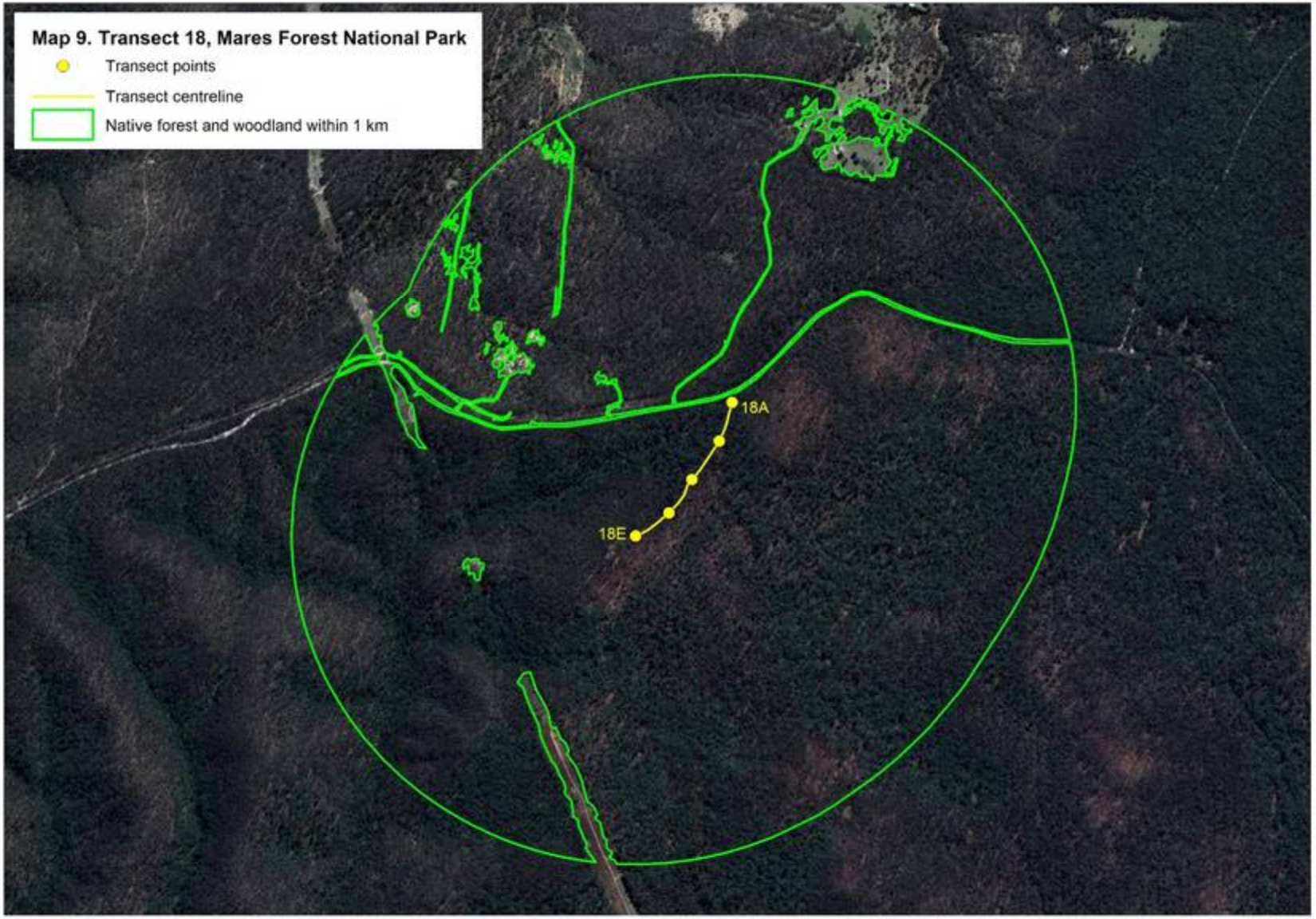
Transect 18, Queens Gap Trail, Mares Forest National Park

Transect 18 runs along an unsealed vehicle track, Queens Gap Trail, from near its junction with Wombeyan Caves Road. The site is a plateau on Siluro-Devonian Mares Forest Volcanics geology at an elevation of 965-975 m. The main vegetation class is Southern Escarpment Wet Sclerophyll Forest about 36 m tall in which the main tree species are *Eucalyptus fastigata* (Brown Barrel) and *E. radiata* (Narrow-leaved Peppermint). At the southern end of the transect (Point 18E), the vegetation class is Sydney Montane Dry Sclerophyll Forest in which the main tree species is *Eucalyptus sieberi* (Silvertop Ash). Originally a state forest, the area was dedicated as a national park in 2010. There have been no recorded fires at the site since before 1980, either wildfires or hazard reduction burns, although a May 2019 hazard reduction burn to the east came close. The transect was not burnt in the Green Wattle Creek wildfire that burnt all the other transects around New Year December 2019-January 2020. No plant species were in flower during the 2022 and 2023 surveys that were potential food sources for arboreal mammals.

Photo 34. Southern Escarpment Wet Sclerophyll Forest in Transect 18 in December 2016.

Photo 35. Southern Escarpment Wet Sclerophyll Forest in Transect 18, south-east of Point 18B, in June 2022.

Photo 36. Sydney Montane Dry Sclerophyll Forest in Transect 18, south-east of Point 18E, in May 2023.


Map 9. Transect 18, Mares Forest National Park
Transect points
Transect centreline
Native forest and woodland within 1 km
18A
18E