



Wombat Forest

A Greater Refuge for Gliders

Significance of
Wombat Forest
Greater Gliders
2020



Victorian National Parks Association

An independent, non-profit, membership-based group, VNPA exists to protect Victoria's unique natural environment and biodiversity through the establishment and effective management of national parks, including marine national parks, conservation reserves and other measures. VNPA works by facilitating strategic campaigns and education programs, developing policies, conducting hands-on conservation work, and by running bushwalking and outdoor activity programs which promote the care and enjoyment of Victoria's natural heritage.



Wombat Forestcare Inc

Wombat Forestcare Inc.

Wombat Forestcare Inc. is dedicated to preserving the biodiversity and amenity of the Wombat State Forest, Central Victoria, Australia, by utilising the skills and resources of the community. Wombat Forestcare engages in a range of activities. These have a strong focus on community involvement and education, and include undertaking flora and fauna surveys. We also enjoy the social aspect of a forest group, with picnics and bushwalks for people who love being in the bush.

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Traditional Owners

The Victorian National Parks Association acknowledges the many Traditional Owners of Victoria's natural areas.

Aboriginal people occupied Victoria for tens of thousands of years before their communities were decimated by European occupation.

This report acknowledges the long history of Indigenous occupation, and respects the ongoing roles and responsibilities of Victoria's Traditional Owners in caring for country.

Photos & Maps

Photos Josh Bowell and Gayle Osborne

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List of abbreviations and acronyms:

CFM - Community Forest Management
Cth - Commonwealth
DELWP - Department of Environment, Land, Water and Planning
DEPI - Department of Environment and Primary Industries
DJPR - Department of Jobs, Precincts and Regions
DSE - Department of Sustainability and Environment
EPBC - Environment Protection and Biodiversity Conservation
EVC - Ecological Vegetation Classes
FFG - Flora and Fauna Guarantee
FFMV - Forest Fire Management Victoria

Glider - Greater Glider (*Petauroides volans*)
HBT - Hollow-bearing Trees
QGIS - Quantum Geographic Information Systems
SAC - Scientific Advisory Committee
TSSC - Threatened Species Scientific Committee
TUP - Timber Utilisation Plan (VicForests)
VBA - Victorian Biodiversity Atlas
VEAC - Victorian Environmental Assessment Council
Vic - Victoria
WFC - Wombat Forest Care
WSF - Wombat State Forest



Wombat Forest Greater Glider. Photo: Gayle Osborne

Key points:

- Greater Gliders have seen significant declines in key areas across the state over the last 20 years, and much of the suitable habitat within Victoria has been impacted by the current 2019 -2020 fires.
- Wombat State Forest (WSF) is the only population of Greater Gliders west of Melbourne, and a range-edge population of Greater Gliders in Australia. The nearest population is in the Central Highlands, which are approximately 80km away.
- This report provides an analysis of recent Greater Glider records from Wombat Forestcare surveys, a local community group which has documented 278 individual Gliders in 212 records since 2010.
- Over 2 Greater Gliders per hectare (10+ Gliders per 1km) were found for 83% of analysed surveys, density estimates matching those found in the Strathbogie Ranges and exceeding the threshold used in East Gippsland to protect significant populations.
- Results from this report highlight that the Greater Glider population in Wombat State Forest (WSF) is large and regionally significant with estimated densities similar to those in East Gippsland and the Strathbogie Ranges, where the significance of Greater Glider populations has been acknowledged and protections have been implemented.
- VEAC's proposed changes to make Wombat State Forest a mix of national and regional parks would protect all 278 Gliders through the establishment of a Wombat-Lerderderg National Park and additional areas of Hepburn Regional Park, preventing the timber harvesting in 62 coupes (4115 ha) scheduled under VicForests' current Timber Utilisation Plan TUP and preventing any future sawlog harvesting in the area.

1. Executive Summary

Context

Greater Glider (*Petauroides volans*) distribution and abundance has significantly declined over the last three decades. The Greater Glider is susceptible to disturbance given its highly specialised diet, low reproductive output, specific habitat requirements and low dispersibility. Key threats to the species include fire, logging, climate change, and habitat loss and fragmentation, with other threats such as drought and hyper-predation from forest owls adding pressure. With the current 2019–2020 fires having already impacted 26% of the species range in Victoria (projected to rise to 47%), it is a species at considerable risk of extinction.

The Wombat State Forest is an area of biological, geological, hydrological and cultural significance, representing one of the last largely intact areas of native vegetation in the region. Wombat State Forest is the only population of Greater Gliders west of Melbourne, and a range-edge population of Greater Gliders in Australia. The next closest population is in the Central Highlands with nearest records approximately 80km away.

The full values of the Wombat State Forest are outlined in a recent Victorian Environmental Assessment Council (VEAC) report, which recommends the area be protected under the establishment of new national and regional parks. The region has a long history of land clearing, mining and logging. Intensive and extensive logging has degraded much of the Greater Glider's habitat within Wombat State Forest, and there is a large knowledge gap surrounding the extent and significance of the Greater Glider population within Wombat State Forest. Wombat Forestcare, a local community group has recently collected an abundance of Greater Glider records within the Wombat State Forest, which are subject to the analysis of this report.

Aims

This study uses data collected from Wombat Forestcare to analyse the significance of the Greater Glider population in Wombat State Forest. The analysis seeks to provide low end estimates for Greater Glider densities across Wombat State Forest and compare these densities to other significant populations across Victoria. This study aims to identify key habitats for the Greater Glider across Wombat State Forest and assess threats to remnant habitat and the overall viability of the population. Regarding future threats to the Wombat State Forest population, we aim to assess the impacts of proposed changes to public land use and provide recommendations to the government to ensure the viability of this population.

Methods

Greater Glider records from Wombat Forestcare surveys and the Victorian Biodiversity Atlas (VBA) were spatially mapped in QGIS to assess the isolation and geographic uniqueness of the Greater Glider population in Wombat State Forest. Greater Glider records from Wombat Forestcare were spatially analysed in relation to ecological vegetation classes (EVCs) and watercourses to identify key Greater Glider habitat in Wombat State Forest. Transect data from Wombat Forestcare spotlighting surveys was then analysed to predict Greater Glider densities in Wombat State Forest, with transects over 500m in length incorporated into the analysis. The number of Greater Gliders detected and the transect length of corresponding surveys were used to predict detection rates per 500m and 1km of spotlighting, thus providing low end density estimates of Greater Gliders per hectare across various

areas in Wombat State Forest. VEAC's proposed changes to public land use were also analysed in relation to Wombat Forestcare Greater Glider records and VicForests' current Timber Utilisation Plan (TUP), to assess the implications of proposed changes on Greater Gliders and the impacts which future timber harvesting would have on the Greater Glider population in Wombat State Forest.

Results

There are only 13 publicly available Greater Glider records in the Wombat State Forest listed in the VBA since 2010. The bulk of Greater Glider detections come from Wombat Forestcare surveys, which document 278 individual Greater Gliders in 212 records (Figure 1). Greater Glider detections from Wombat Forestcare occurred across 9 EVCs, with 49% of Greater Gliders located within 50m and 93% of Greater Gliders located within 100m of watercourses respectively. Henry Track had the highest detection number of Greater Gliders amongst Wombat Forestcare spotlighting surveys, with 13 Greater Gliders detected along a 473m transect (Figure 3).

There were 6 spotlighting transect surveys by Wombat Forestcare which covered over 500m in length (Table 1). The number of Greater Gliders detected on these surveys ranged between 4 and 8 individuals, and detection rates per km ranged from 7.9 to 12.8 (Table 1). Five of the 6 surveys (83%) resulted in an estimated detection rate >10 Greater Gliders per 1km, detection rates which equate to >2 Greater Gliders per ha searched (Table 1). These density estimates match those found in the Strathbogrie Ranges and exceed the threshold used in East Gippsland to protect significant populations. VEAC's proposed changes to public land use would protect all 278 Gliders through the establishment of a Wombat-Lerderderg National Park and additional areas of Hepburn Regional Park, preventing timber harvesting in 62 coupes (4115 ha) scheduled under VicForests' current TUP and preventing the re-introduction of sawlog harvesting by VicForests.

Conclusion and Recommendations

Our results support the contention that the Greater Glider population in Wombat State Forest is large and regionally significant, with estimated densities similar to those in East Gippsland and the Strathbogrie Ranges, where the significance of those populations was acknowledged and protections implemented. Greater Glider populations are predominantly isolated in gully refuges with limited suitable habitat undisturbed from past logging, and remnant populations are under further threats from future timber harvesting, mining, wildfire and prescribed burns. The fragmentation and loss of hollow-bearing trees in the landscape, in tandem with the poor dispersal capabilities of the Greater Glider, leaves isolated populations at great risk of extinction across Wombat State Forest. Future threats, particularly additional logging, must be prohibited to protect the Greater Glider population in Wombat State Forest and allow for the development of future habitat for Greater Glider colonisation and population expansion. VEAC's proposal to establish the Wombat-Lerderderg National Park and add additional areas of Hepburn Regional Park, would prevent future timber harvesting within Wombat State Forest and protect all 278 Greater Gliders detected by Wombat Forestcare. We strongly recommend that the government accepts the VEAC proposal to protect the Greater Glider population in Wombat State Forest and avoid the extinction of this large and regionally significant population. Full recommendations are outlined in the conclusion of this report.

2. Background on the Greater Glider and its decline

Australia's largest gliding mammal, the Greater Glider (*Petauroides volans*) is endemic to the eastern mainland, distributed from south-eastern Victoria to central-eastern Queensland ¹¹. Once a common species in Victoria, the Greater Glider has seen significant declines in both distribution and abundance in recent years ⁴⁰, a trend which is likely to continue without significant mitigation of threats to the species. The species is listed nationally as vulnerable to extinction under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (Cth) and as threatened in Victoria under the *Flora and Fauna Guarantee (FFG) Act 1988* (Vic) ².

Ecology and Biology

The Greater Glider is unique in that it's the only gliding member of the family Pseudocheiridae, meaning it's more closely related to Ringtail Possums (*Pseudocheirus sp.*) than other Australian gliders such as the Sugar Glider (*Petaurus breviceps*) or the Feathertail Glider (*Acrobates pygmaeus*) ². The Greater Glider is a folivore with a diet consisting entirely of *Eucalyptus sp.*, requiring mature canopy and a preference tending towards new growth ^{11,14}. The Greater Glider is thought to be at the lower limit of body size which can be sustained solely on a foliage diet, making the species preference for *Eucalyptus sp.* containing the lowest toxin-nutrient ratio a clear necessity ^{11,14}. The Glider's specialist diet makes it quite sensitive to changes in habitat quality, climate conditions and disturbance.

Greater Gliders reach sexual maturity in their second year (18–24 months) ⁴⁶, after which they are capable of producing one offspring annually (monotocous) and have a maximum life span of 12–15 years ¹¹. Approximately 50% of female Gliders breed per year with a juvenile mortality rate of ~20% within the first year. These traits create low reproductive output, making the Greater Glider particularly sensitive to increased mortality, breeding failure and processes leading to small isolated populations ^{16,38}.

The Greater Glider is a solitary species, denning exclusively in hollow-bearing trees (HBTs) and using anywhere between 4–20 HBTs within their home-range ^{1,42}. They compete with many other Australian vertebrates also requiring hollows for shelter and breeding ¹¹. Additionally, there is a significant time period needed for the growth of suitable HBTs, with initial hollow development occurring after 120 years and more than 190 years before they will be of a suitable size for Greater Gliders ¹⁹.

Home-range is typically between 1.2–4.1 ha and tends to increase in size with increasing patch size and decreasing population density ³⁷. Males on average have larger home-ranges than females, with home-ranges tending not to coincide, however closely associated animals may overlap during the breeding season ¹¹. Agonistic behaviours have been more frequently observed within sexes than between ^{1,12}. Dispersal in Greater Gliders is primarily natal given their high site fidelity, with overall dispersal ability understood to be poor with small dispersal distance and associated increased mortality. There is a lack of information on in-situ dispersal distances of Gliders in Victoria ^{47,38}.

Threats

The Greater Glider's specialist diet, low reproductive output, hollow-dependence, small home-range and low dispersibility makes it particularly susceptible to disturbance ^{11, 14}. Key threats to the Greater Glider include fire (wildfire, planned or prescribed burns), timber harvesting, habitat loss, fragmentation, climate change, drought and hyper-predation from forest owls ^{40, 44}.

In addition to the direct Greater Glider mortalities and local extinctions resulting from fire (wildfires, prescribed burns and post-harvest burns) and widespread logging operations ^{21, 40}, a key issue with both is the destruction of crucial habitat in the form of mature forest containing HBTs. The increasing rate at which HBTs are being destroyed coupled with the lengthy time associated with their development is seeing a progressive decline of HBTs across the landscape ^{19, 23, 24}. This loss of habitat and subsequent fragmentation creates small isolated patches where reduced population sizes, lack of dispersal and restricted gene-flow dramatically reduce population viability ^{32, 27, 38}. The compounding interplay between fire, logging and climate change, and their influences on habitat-loss and fragmentation are likely the major threats to the species, with drought and hyper-predation adding further pressure.

Decline

There has been significant decline of the Greater Glider documented over recent years, with some 42 sites in the Central Highlands experiencing annual reductions of 8.8% per year between 1987 and 2010 (87% decline) ²¹. Another 2013 investigation showed that in 32 sites across the Central Highlands occupancy was as little as 16% compared to surveys in the 1990s (84% decline) ²⁸. Declines in East Gippsland have been recorded to be as high as 50% when compared with the 1990s, with declines also being reported from Mt Alfred State Park, Cathedral Ranges and Lake Tyers State Park ⁴⁰. There is an absence of Greater Gliders in sites burnt in the 2009 bushfires, including historical populations from the Blue Range ⁴⁰.

With much of the species range being burnt in the 2003, 2006-2007 and 2009 bushfires and with the current 2019-2020 fires having already impacted 26% of the species range (projected to rise to 47%) ³, compounded by salvage logging (known to reduce abundance of HBTs), the full scale of current and ongoing species decline is unknown ²⁶.

Wombat State Forest and Wombat Forestcare Inc

Wombat State Forest (WSF) is located in Central Victoria near the town of Daylesford and forms part of The Great Dividing Range. As one of the last remaining large intact patches of native vegetation in the area, it has very high conservation values. WSF contains two endemic plant species – the Wombat Leafless Bossiaea (*Bossiaea wombata*) and Wombat bush-pea (*Pultenaea reflexifolia*) – more than 57 threatened flora species, 52 threatened fauna and 13 threatened ecological vegetation classes (EVCs) within the local area ^{50, 53}. WSF forms part of a significant water catchment, supplying water both inland towards the Murray-Darling system via Loddon, Coliban and Campaspe rivers and southward to Bass Strait via Moorabool, Werribee, Lerderderg and Maribymong rivers ⁵⁰.

Aboriginal association with the area extends for many tens of thousands of years and is deeply linked to the natural environment. The traditional owners are the Dja Dja Wurrung, Wurundjeri, Taungurung

and Wadawurrung people. Culturally significant values include but are certainly not limited to creation, burials, stone, mound/occupation site, routes, history, and flora and fauna ⁵⁰. The confluence of the area is reported as a key significant feature, "Water is a significant element in the Indigenous customary economy, as it is the source of creation stories, resources traditionally used by Aboriginal people, and carries with it long traditions of cultural practices and history. ⁵⁰"

During the 1830s European settlers arrived in the area, initiating a period of dispossession for the Aboriginal people ⁵⁰. In the 1830–1840s Europeans began taking up land in the region, quickly converting much of the fertile valleys and plains from native vegetation into pastures and isolating the Wombat-Lerderderg area from surrounding vegetation with a large barrier of farmlands. A gold mining boom in the 1850s saw this degradation intensified. Further land was cleared for prospecting and timber harvested for infrastructure, firewood and to fuel boilers ⁵⁰. In 1899, it was acknowledged that WSF had been severely overharvested and a royal commission was successful in ceasing logging ¹³. However, timber harvesting soon returned to WSF with selective logging undertaken from the 1930s up until the mid-1970s ³¹. A modified type of clearfell logging known as the 'Shelterwood System' was then introduced, overharvesting WSF up until 2006 ⁵⁰.

The intensive harvesting occurring under the 'Shelterwood System' led to significant local community outcry, reaching a boiling point in the 1990s with both activists and loggers demanding a review into government harvesting quotas. So ensued a conflict between government and local community over the management of WSF, with consultative processes, community lobbying, studies and reviews occurring between 1990–2002 to resolve the issues ³¹. In 2002, the Department of Environment, Land, Water and Planning (DELWP) (formerly Department of Sustainability and Environment (DSE)) introduced community forest management (CFM) in an attempt to align forest management practices to local community values. This process largely failed at resolving the polarised values of community members and was terminated in 2006 after a key stakeholder group pulled out the process, however community pressure kept logging from recommencing and remaining saw-log licences were bought out by government ³¹. In more recent times, the Victorian Environmental Assessment Council's (VEAC) Central West Investigation called for the WSF to form part of a proposed 'Wombat-Lerderderg' National Park which would see the WSF and Lerderderg State Park transformed into a 49,553 ha national park ^{50, 51}.

Community group Wombat Forestcare Inc (WFC) was incorporated in 2006 with targeted surveys for Greater Gliders starting in 2016. WFC undertakes spotlighting and stagwatching surveys, and records GPS locations where each Greater Glider is sighted. Surveys are often targeted to areas subject to planned burning, to inform the government about Greater Glider locations and prevent the incidental loss of HBTs (WFC, personal communications). Data collected from WFC surveys is the subject of this report.

In June 2017 the Greater Glider was uplisted to vulnerable to extinction under the EPBC act with an action statement later released in 2019 ². With the anticipated significant impacts of the 2019-2020 bushfires ³, there is an increased importance for protecting remaining habitat and populations, and the need for a comprehensive understanding of WSF Greater Gliders has never been greater. For that reason, this report aims to investigate the extent and significance of the Greater Glider population and habitat within the WSF and assess the impacts that VEAC's proposed changes to public land use would have on the population.

3. Investigation into WSF Greater Glider population

Isolation and uniqueness of WSF population

To visually analyse the isolation and uniqueness of the WSF population of Greater Gliders, records of the species were derived from the Victorian Biodiversity Atlas (VBA) and mapped spatially over the extent of Victoria in addition to records collected by WFC in WSF. Data collected before 2010 was excluded from this investigation, due to:

- A. Catastrophic bushfires impacting much of the population in 2009 ¹⁸ and
- B. The overall life history of the Greater Glider ^{22, 25, 46}.

The records were mapped in QGIS in correspondence with the state forest, state park and national park, which contains much of the overall habitat for the Greater Glider. Watercourses within WSF were also buffered with 50m and 100m to analyse the proximity of Gliders to wet gullies. EVCs were also added to spatial mapping to identify key habitats for the Greater Gliders in WSF.

Greater Glider density analysis

Greater Glider records obtained from WFC were mapped and analysed using QGIS to produce estimations on Greater Glider densities across WSF. Spotlighting transect data was used for this analysis. Records from individual stagwatches, incidental observations and camera traps were excluded from this investigation.

Greater Glider detections were mapped for each night of spotlighting undertaken by WFC and transects were produced between these waypoints using the 'points to path' function in QGIS. Transects were constructed based on the chronological detections of Greater Gliders and transects selected for this analysis consisted only of those which were linear in nature and therefore did not pose a risk of re-counting the same individual Glider.

Suitable transects were then measured using GIS software, and transects exceeding 500m in length were used to analyse Greater Glider density in accordance with similar methodology undertaken in the Strathbogie Ranges ³³. As survey transects in this study varied in length, an estimate of Greater Glider detections over a 500m and 1km transect was determined based on how many Gliders were detected over each corresponding transect length:

$$\text{Greater Gliders per 500m transect} = 500 / (\text{Transect length} / \text{Gliders Detected})$$

As WFC surveyors searched approximately 25m either side of each transect, a width of 50m was assumed for 1km transects and the total area surveyed per 1km transect was 5 ha ³⁰. This total area was used to provide detection rates of Gliders per hectare along each suitable transect:

$$\text{Greater Gliders per ha} = \text{Gliders per 1km transect} / 5$$

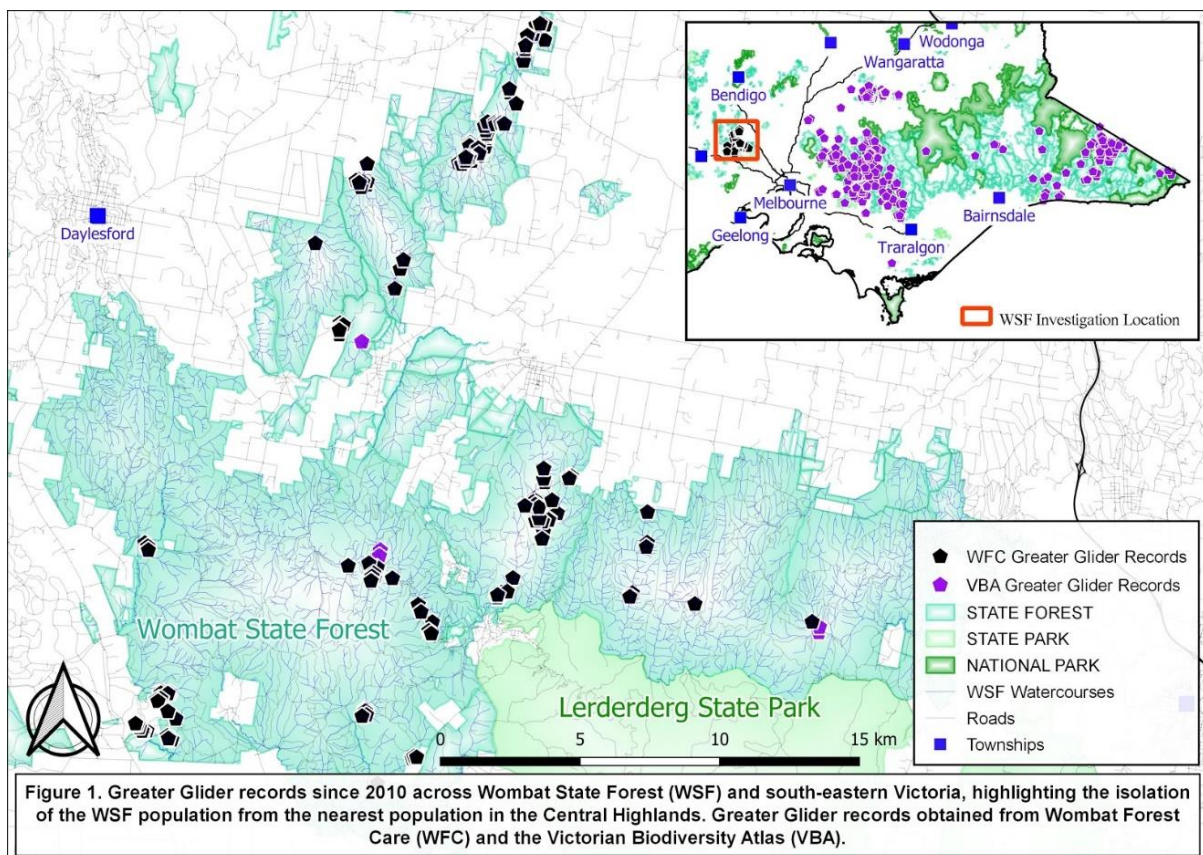
Impact of VEAC's proposed changes to land use

The Central West investigation undertaken by VEAC was analysed to assess how the proposed changes to public land use in WSF would impact the population of Greater Gliders. An image of the proposed changes to the Wombat-Macedon block⁵¹ was sourced from the VEAC report⁵⁰ and georeferenced in VicGrid94. The Greater Glider records were then overlaid with this image to assess how changes to public land use would affect Glider populations in WSF. VicForests' current Timber Utilisation Plan (TUP) was also overlaid to assess what impact the proposed changes would have on timber harvesting in WSF⁴⁹.

4.Results

WSF Greater Gliders

Within the WSF there are only 13 public records since 2010 from the VBA, with majority of the records (212) sourced from WFC surveys (Figure 1). The records from WFC document 278 individual Greater Glider detections, with detections occurring via spotlighting, stagwatching, incidental observations, fur sampling and predatory diet analysis. Greater Gliders were recorded within 9 EVCs across WSF: Shrubby Foothill Forest, Herb-rich Foothill Forest, Damp Forest, Heathy Dry Forest, Shrubby Dry Forest, Sedgy Riparian Woodland, Creekline Herb-rich Woodland, Riparian Forest & Grassy Dry Forest. Amongst the data collected by WFC, Greater Glider records were generally found near the watercourses of WSF, with 49% of detections located within 50m and 93% within 100m respectively.



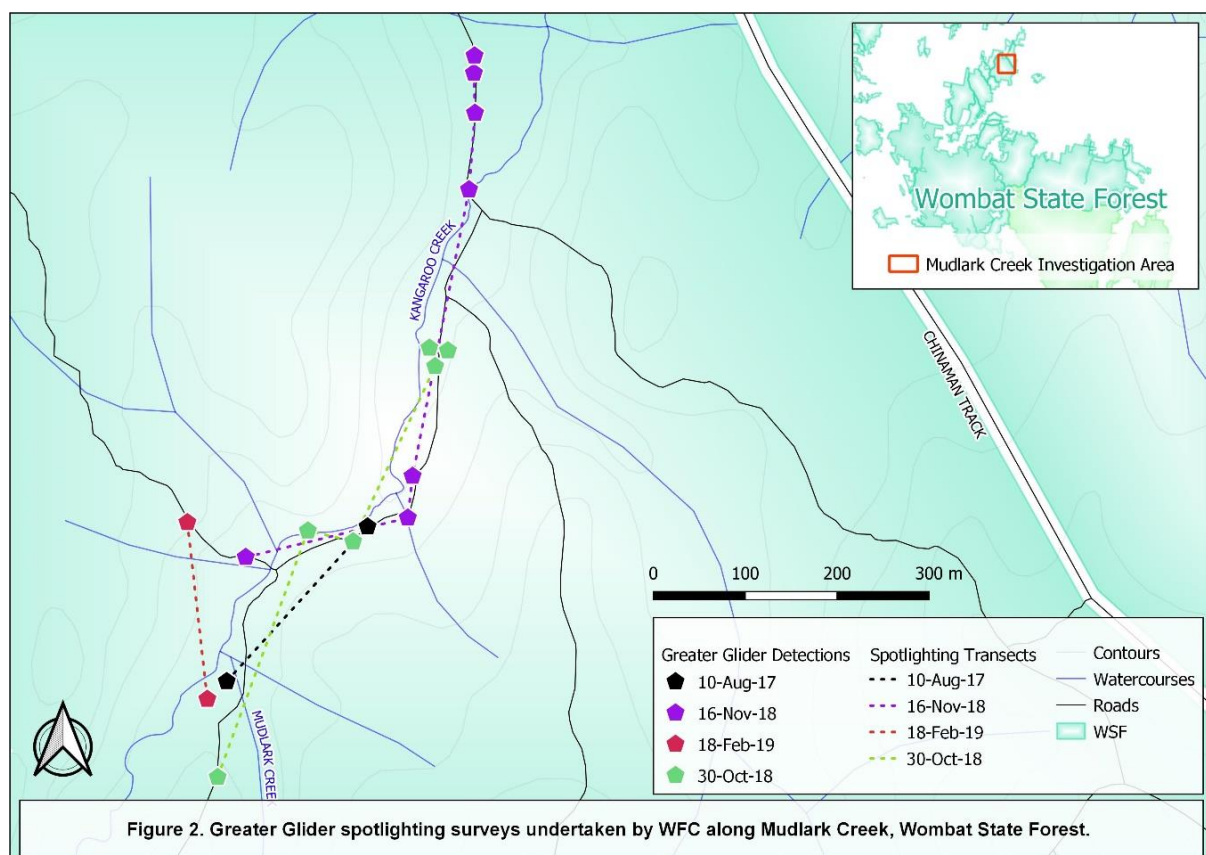
Looking east of WSF, the main three populations of Greater Gliders east of Melbourne are in the Central Highlands, East Gippsland (far east) and the Strathbogie Ranges (north) (Figure 1). WSF is the only population of Greater Gliders west of Melbourne, and a range-edge population of Greater Gliders in Australia (Figure 1). Upon analysing the isolation of WSF Gliders from the closest population in the Central Highlands, the distance between nearest neighbouring records was approximately 80km.

Greater Glider density analysis

Figures 2 and 3 highlight WFC surveys which have documented significant populations of Greater Gliders in WSF, located along Mudlark Creek and Henry Track respectively.

Notably in Figure 2, a spotlighting survey by WFC on 30 October 2018 documented 6 Greater Gliders along a transect of 546m, and another survey on 16 November 2018 documented 7 Greater Gliders along a transect of 690m.

Along Henry Track, a spotlighting survey by WFC undertaken on 26 June 2019 documented 13 Greater Gliders over a transect of just 473m (Figure 3), and another survey on 18 September 2019 documented 8 Greater Gliders along a transect of 668m. Some of the survey results as seen in Figures 2 and 3 appear in Table 1 below, which provides estimates for Greater Glider density based on WFC survey results along transects exceeding 500m in length.



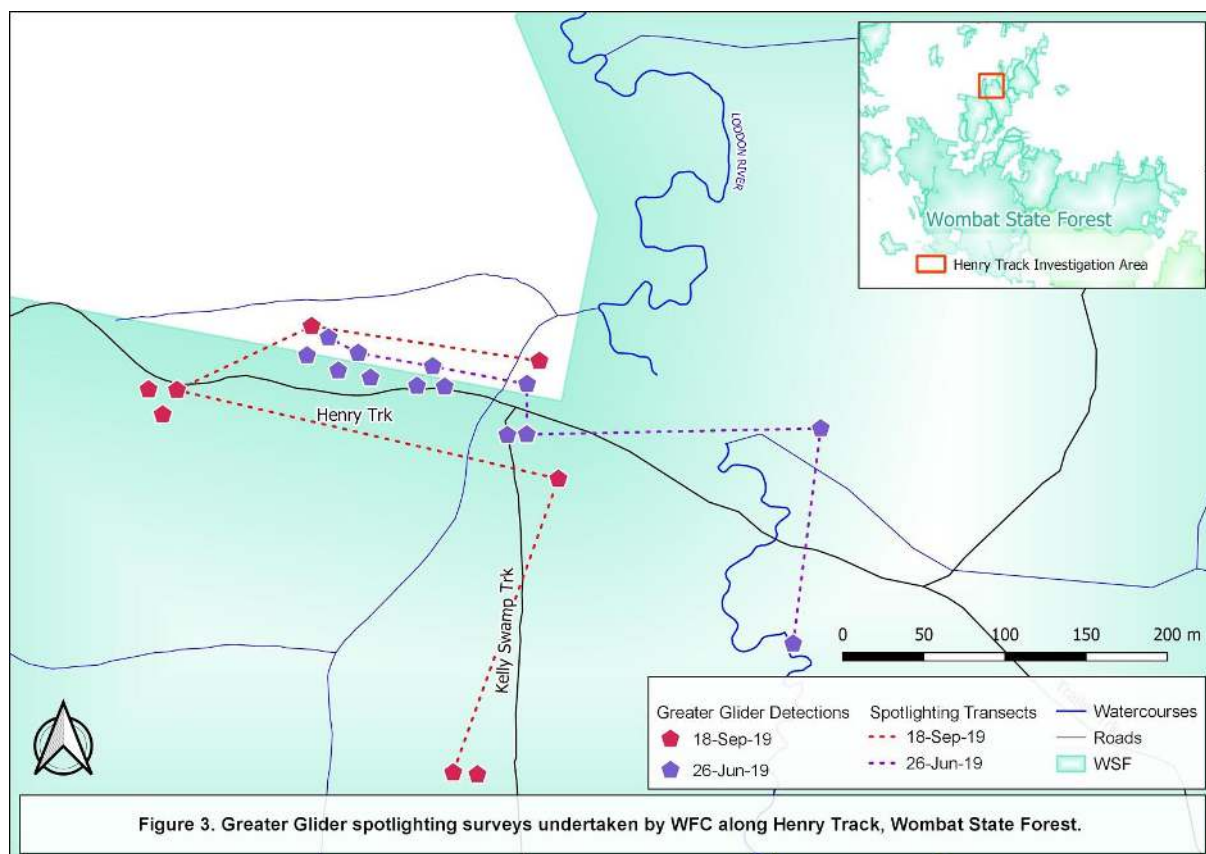


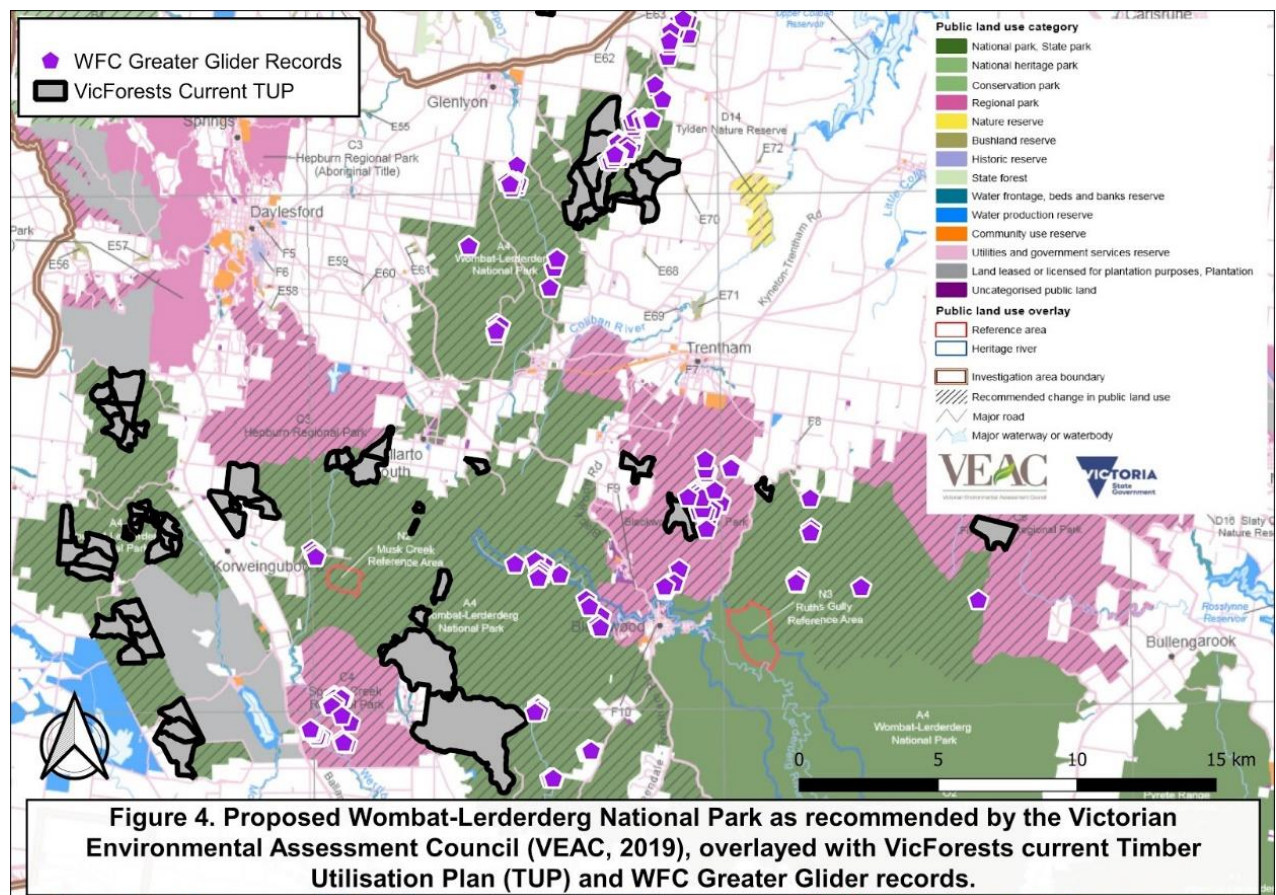
Table 1. Greater Glider detections and detection rates in WSF recorded by WFC along linear transects over 500m in length. *Assuming that twice the number of Greater Gliders would be detected if transects were 1km as opposed to 500m.

Survey Date	Location	Transect Length (m)	Greater Glider Detections	Greater Gliders per 500m	Greater Gliders per 1km	Greater Gliders per hectare (ha)
12-Dec-2017	McGees Road 2	661	8	6.1	12.1	2.42
30-Oct-2018	Mudlark Creek	546	6	5.5	11	2.2
16-Nov-2018	Mudlark Creek 2	690	7	5.1	10.1	2.0
17-Dec-2018	Countess Track 2	545	7	6.4	12.8	2.56
18-Sep-2019	Henry Track	668	8	6.0	12.0	2.4
19-Dec-2019	Countess Track 1	509	4	3.9	7.9	1.6

There were 6 spotlighting transect surveys by WFC which covered over 500m in length (Table 1). The number of Greater Gliders detected on these surveys ranged between 4 and 8 individuals, and detection rates per km ranged from 7.9 to 12.8 (Table 1). Five of the 6 surveys (83%) resulted in an estimated detection rate >10 Greater Gliders per 1km, detection rates which equate to >2 Greater Gliders per ha searched (Table 1).

VEAC Recommendations

Figure 4 represents the proposed changes to public land use around WSF as recommended by VEAC ^{50, 51}. The proposed changes include the establishment of Wombat-Lerderderg National Park and additional areas of Hepburn Regional Park, which would prohibit timber harvesting within VicForests' scheduled TUP in those areas ⁴⁹. These new protective areas would encompass 62 coupes on the current TUP and prevent the harvesting of approximately 4115 ha. All 278 of Greater Glider detections by WFC would be protected under the Wombat-Lerderderg National Park and Hepburn Regional Park (Figure 4).



5. Discussion

Greater Glider detectability

Despite being reasonably easy to detect with spotlights due to their large size and bright eyeshine ^{20, 52}, the overall detectability of Greater Gliders whilst spotlighting is low ^{20, 33}, often due to dense foliage in the canopy preventing the detection of eyeshine. Studies from Lindenmayer (et al., 2001) ²⁰ documented a 26% detection rate amongst radio-tracked Gliders known to be in the vicinity, and studies from Nelson (et al., 2018) ³³ documented that only 21% of Greater Gliders were seen by both observers who commenced the same transect just 15 minutes apart during surveys in the Strathbogie Ranges. Thus, the estimated densities of Gliders in WSF (Table 1) are likely a large underestimate of abundance and densities at each site and form a low-end estimate of the true population dynamics in WSF.

Density analysis

This study relies on the rigorous field data obtained from WFC, a credible citizen science group operating in the WSF for many years. As seen in Figure 1, there are an abundance of recent (2015 to the present) Greater Glider records documented by WFC in WSF. There are clusters of records, particularly in north WSF (Figure 1), indicating that a strong population of Greater Gliders persists in the WSF.

As seen in Table 1, areas thoroughly surveyed by WFC (transects 500m+) documented high detection rates of Greater Gliders in four areas: McGees Road, Mudlark Creek, Countess Track and Henry Track. Five of the 6 transect surveys (83%) documented detection rates of >10 Gliders per 1km, the equivalent to 2 Greater Gliders per ha surveyed (Table 1). Greater Glider threshold densities of 2 individuals per ha, or 10 individuals per 1km have been used to protect significant Greater Glider populations across State Forest in East Gippsland, triggering 100 ha of Special Protection Zone (SPZ) and excluding disturbances such as timber harvesting within the SPZ if threshold densities are documented and verified ⁴.

The density analysis in Table 1 suggests that Greater Glider populations in four key areas of WSF would likely trigger the protective prescriptions for the species used in East Gippsland ⁴ and provide legislative protection across these areas of WSF. A spotlighting survey at Henry Track on 26 June 2019 (Figure 3) exceeded the threshold density along a transect of only 473m, detecting 13 Greater Gliders at 5.5 Gliders per hectare.

Greater Glider densities have been analysed in the Strathbogie Ranges, resulting in estimated densities of 2–4 Gliders per hectare ³³. Results from WSF surveys suggest that densities could match that of the Strathbogie Ranges (Table 1), and potentially exceed densities of over 5 Gliders per hectare (Figure 3). Following the density analysis study in the Strathbogies ³³, the Action Statement for the Greater Glider was released which included the protection of the large and regionally important population of Gliders in the Strathbogies, putting an end to native forest logging in the Strathbogie Ranges ². Results from the WSF density analysis supports the contention that the Greater Glider population in WSF is large and regionally important and should be protected from future threats to avoid localised extinctions.

Key threats to the population

This large and regionally important population of Greater Gliders is under future threat from timber harvesting, mining and fire (both wildfire and prescribed). Scheduled logging coupes remain on VicForests TUP for WSF, estimating a further 3324 hectares of forest to be logged on the current schedule ⁴⁹. In 2013, the Department of Environment and Primary Industries (DEPI) commissioned a review of commercial forestry management in Western Victoria, which found that after having had ten years of reduced activity, the Wombat State Forest could sustain an ongoing sawlog yield of over 10,000 cubic metres per annum ⁴⁸. Additional sawlog harvesting in WSF will continue to fragment the landscape and reduce Greater Glider populations ^{23, 24, 34}, preventing regenerating forests from reaching a mature age class capable of hollow production and Glider colonisation ³².

Current and pending mining licenses, specifically MIN4305 & MIN5460 ⁵, are within close proximity to Greater Glider records from WFC and could potentially impact populations through clearing of habitat ⁵³. Prescribed burns are widespread throughout WSF ⁷, and are likely to reduce the available habitat for the Greater Glider in WSF through the incidental loss or decay of HBTs ^{35, 41, 50}. Currently, Forest Fire Management Victoria (FFMV) are acknowledging data collected from WFC on suitable habitat and confirmed denning trees of the Greater Glider, and adapting management practices accordingly within those areas to avoid the loss of HBTs (WFC, personal communications). Prescribed burns are listed for areas that have not been surveyed for the Greater Glider, which further highlights the need for a comprehensive scientific study on Gliders in WSF to fully understand population dynamics and key habitats.

Between the WSF and the Central Highlands lies major barriers preventing genetic flow of Greater Glider populations, including the Calder Freeway, Hume Freeway and overall the heavily cleared landscape and lack of suitable habitat (Figure 1). As this range-edge population of Greater Gliders is isolated, catastrophic events such as wildfire and severe drought pose major threats to population viability ². As a range-edge population of the Greater Glider, Gliders in WSF play a critical role in the persistence of the species under current and future climatic changes ³⁹. Range-edge populations often maintain unique genetic adaptations that promote colonisation of newly suitable habitats under changing climates ^{8, 10}. They can also have high degrees of local adaptation and contain unique genotypes necessary to species persistence under future climates ⁹.

Key threats to this population of Gliders must be negated to ensure the persistence of this species into the future. Controllable threats such as timber harvesting, which is known to reduce and isolate populations, must cease within WSF to protect remnant habitat and ensure for the development of additional habitats in the future. Cessation of timber harvesting will reduce emissions and increase carbon storage, which in turn will help fight climate change and the pressures it places on Glider populations ¹⁷. Burning regimes must ensure the retention of HBTs which are crucial to the Greater Glider.

Greater Glider habitat in WSF

Glider populations in WSF have likely declined due to a harsh history of disturbance and habitat destruction in the area, most notably by land clearing and timber harvesting. The proximity of Glider records to watercourses suggests that the wet gullies of WSF are acting as a refuge from historical fires and logging and providing much of the suitable habitat for Greater Glider persistence ^{36, 50}. Surrounding these gullies, the accessibility of the forest to logging has led to an extremely

fragmented landscape and a large reduction in the availability of HBTs required for denning ^{23, 24}. Gliders are documented to respond poorly in response to local disturbance, with individuals losing body condition in just a number of days when impromptu dispersal is required ³².

Timber harvesting of Glider habitat in WSF has likely caused declines and local extinctions of Gliders across the landscape ^{21, 15, 29, 6, 45}, leaving remaining populations isolated in gully refuges and remnant patches of mature forest undisturbed from logging. These isolated populations are likely surrounded by regenerating forest unsuitable for colonisation, which in tandem with poor dispersal ability, high probability of genetic isolation, and high sensitivity to forest fragmentation, leaves the populations in WSF extremely threatened to localised extinctions ^{32, 43}.

The viability of isolated populations is relative to patch size, population size, dispersal ability and genetic diversity. Populations that occupy patches of forest at 100 ha or less are found to have a much higher probability of extinction over several years, with patches of 1000 ha or more having much higher chances of persistence into the future ³⁴. The severe historical disturbance and fragmentation of Glider habitat in WSF is causing significant stress on remnant populations. The importance of refuge habitat, such as that along gullies and undisturbed mature forest is extremely crucial to the viability of Gliders in WSF. It is also paramount that the surrounding forest is left to regenerate and mature to in future provide habitat suitable of colonisation by Gliders and allow for dispersal and increasing populations. The further reduction of Glider habitat through additional timber harvesting (Figure 4), would be catastrophic for the Glider population in WSF and place the population at risk of extinction.

6. Conclusion and recommendations

Our results support the contention that the population of Greater Gliders in WSF is large and regionally significant. WFC transect data contains Glider densities which do, and densities which are predicted to exceed the thresholds of Gliders used in East Gippsland to protect significant populations of Gliders from timber harvesting. Glider densities in WSF are likely to match, and could even exceed densities documented in the Strathbogies, which resulted in the protection of the Strathbogies forests under the Greater Glider Action Statement and the release of the Greater Glider IPA's. Our density estimates do not account for Gliders which were missed by surveyors, thus providing low end estimates across WSF. This highlights the need for further studies using mark-recapture methods for density estimates, such as that used by ARI in the Strathbogie Ranges, which account for the statistically low rates of Glider detectability.

Our findings highlight the importance of intact Glider habitat in WSF, and the future risks which are threatening to reduce this available habitat. Timber harvesting has severely fragmented the landscape and reduced the suitable habitat in WSF, leaving Glider populations isolated to gullies and undisturbed patches of mature forest. The lack of mature forest surrounding these populations is a huge limitation to Glider dispersal and colonisation, leaving them vulnerable to genetic isolation and localised extinctions. Remnant habitat within WSF must be protected immediately, as must the surrounding forest which is still regenerating from past logging. It's critical to the persistence of this population that these recovering forests are left to reach maturity, which will in turn provide suitable habitat in the future and allow for the dispersal and expansion of populations in WSF.

The proposed changes to public land use, as recommended by VEAC ^{50, 51}, would protect all WSF Glider populations and their surrounding forests from timber harvesting. The proposal would protect

Gliders through the establishment of the Wombat-Lerderderg National Park, and through additional areas of the Hepburn Regional Park ^{50, 51}, whereby no further timber harvesting would be permitted. Timber harvesting is known to have significant detrimental impacts on Gliders and proposed future harvesting outline in VicForests TUP would severely threaten this population with extinction. We view timber harvesting and the further reduction of habitat as the biggest threat to the persistence of this population and the species as a whole. Therefore, we strongly recommend that the proposed changes to public land use as outlined by VEAC are accepted by the government, as outlined in our final recommendations below.

VEAC proposed changes to public land use

We strongly recommend that the Victorian government accepts the proposed changes to public land use ^{50, 51}, and protects this large and regionally significant population of Greater Gliders through the Wombat-Lerderderg National Park & Hepburn Regional Park. VEAC, highly respected by the government as an independent scientific organisation, has delivered a thorough scientific report with recommendations which upon acceptance, would prevent future threats likely to cause the extinction of this range-edge population of Greater Gliders.

Timber Harvesting

Logging within the Wombat State Forest should permanently cease and sawlog harvesting should not return to the area. Areas of dense regrowth should be managed ecologically where possible with minimum disturbance to the forest.

Planned Burns

Long term research and monitoring should be undertaken to increase understanding on the impacts of fuel reduction burns on Greater Gliders. Specific management plans for areas with Greater Gliders must be enforced, specifically aimed at the protection of HBTs from incidental loss or decay associated with prescribed burns. Greater Glider surveys must be undertaken in areas scheduled for planned burns. Prescribed burns should only occur and occur at rates which are based on the most updated ecological, biological and zoological science.

Mining

No new exploration and mining licenses within the Wombat State Forest, including no additional clearing of vegetation for mining.

Further studies

A comprehensive study on Greater Glider densities in Wombat State Forest, using mark-recapture analysis to account for low Glider detectability. Genetic studies on the Gliders in Wombat State Forest to assess the degree of genetic isolation and unique genetic adaptations within the population.

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