FOI 171109
Document 1

From: s22 delwp.vic.gov.au
To:
Subject: Re: Vic ecosystem accounts report [SEC=UNCLASSIFIED]
Date: Wednesday, 30 August 2017 6:43:09 PM
Attachments: ATT00001.gif
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Leadbeater''s Possum Interim Fuel Management Report (March 2017 - Final).pdf

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Hi s22

thanks for the accounts report. and here is the fire report I mentioned. Some of this work is still on going but it will give you a sense of what is being done.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 30/08/2017 04:01 PM
Subject: Vic ecosystem accounts report [SEC=UNCLASSIFIED]

Hi s22 attached is NESP accounts report – a final draft, I think it was supposed to have been publically released a week or so ago. I'll need to check.

Cheers

s22

[redacted]
Director
Terrestrial Threatened Species
Department of the Environment and Energy

GPO Box 787 Canberra ACT 2601
02 6275s22 [redacted]
[redacted]environment.gov.au

[attachment "Ecosystem Complete Report_V5B[1].pdf" deleted by s22 [redacted]/VICGOV1]

FOI 171109
Document 1a

Leadbeater's Possum Fuel Management Report

Interim Report

East Central Bushfire Risk Landscape (2017)

Environment, Land, Water and Planning

Acknowledgements
Many thanks to the DELWP staff who provided feedback.

Authors
Luke Smith, 609 Burwood Highway, Knoxfield. (03) 9210 9380
Robyn Allchin, 609 Burwood Highway, Knoxfield (03) 9210 9379

Photo credit
Mountain Ash Forest in Melbourne’s water catchment, Robyn Allchin.

Contents

Executive Summary

The Leadbeater's Possum (LBP), Gymnobelideus leadbeateri, is an endemic, arboreal marsupial and the Victorian faunal emblem. Recently listed as critically endangered under the federal *Environment Protection and Biodiversity Conservation Act* (1999) the Leadbeater's possum is threatened by the ongoing reduction in the extent, quality and connectivity of suitable habitat. This threat in part is a historical legacy, in part a consequence of ongoing actions, and in part a future expectation based mostly on factors which are difficult to control, such as bushfire (Commonwealth of Australia, 2016). In June 2013 at the request of the then Minister for Environment and Climate Change, and the Minister for Agriculture and Food Security the Leadbeater's Possum Advisory Group (LPAG) was established and tasked with developing a series of recommendations to support the recovery of the species while maintaining a sustainable timber industry (LPAG 2014). The investigation and implementation of fire management activities that protect identified colonies and high-quality habitat from bushfire formed a part of the recommended package of actions from the LPAG. The Department of Environment, Land, Water and Planning (DELWP) is the lead agency in undertaking this recommendation.

This report is the follow up to a Draft internal report completed in October 2013 by Fire Policy Division and the ECBRL. The current report has been produced for internal and fire agency staff to better understands the risk to the Leadbeater's possum from past and future bushfire events. It also pilots a methodology to develop a fuel management strategy that reduces the risk of bushfire to known colonies and habitat.

Fire has an important influence on the occurrence, extent and viability of the Leadbeater's Possum and its habitat and frequent, extensive and high intensity bushfires recognized as a major threat to the ongoing survival of the species (DEPI, 2014). The 2009 Kilmore-Murrindindi fire had a significant impact on the distribution of the Leadbeater's possum, impacting 34% (68,000ha) of its potential habitat. Post-fire, virtually no Leadbeater's Possums were detected at burnt sites, irrespective of the intensity, including instances where the understorey was burnt but the canopy remained intact (Lindenmayer et al., 2013). Following large scale events like this, analysis using Phoenix RapidFire, indicates that the risk of future destructive fire events impacting the species range is reduced. Yet as time passes fuel re-accumulates in the landscape surrounding remaining and recovering populations and habitat, without fuel management in the landscape the risk of future bushfire to Leadbeater's colonies and habitat will climb. DELWP's Fire Operations Plan (2017-2019) was analysed to measure its impact on the future risk levels to the species. Modelling demonstrated that fully implemented the fuel management program would reduce the risk to species to below 80% of maximum levels.

This report piloted risk modelling techniques to investigate a fuel management strategy that would reduce the risk to the meta-population one of the Leadbeater's possum. Seventeen burn units were identified as requiring treatment as a BMZ, both for burn interval and coverage to maximise the risk reduction to the meta-population. The strategy stretched across both public and private land to take advantage of all fuel management options.

The methodology outlines in this report will be applied to the remaining five meta-populations of the central highlands.

1. Introduction

1.1 The Leadbeater's Possum

The Leadbeater's Possum (LBP), Gymnobelideus leadbeateri, is an endemic, arboreal marsupial and the Victorian faunal emblem. It exists in three distinct habitat types; montane ash forests and sub-alpine woodlands both found in the Victorian Central Highlands, and lowland floodplain forest in the Yellingbo Nature Conservation Reserve (Lindenmayer et al. 1989; Harley 2004). Historically the possum's home range is thought to have included areas of central Victoria (near Macedon), east Gippsland (near Buchan and Omeo) and parts of south-eastern New South Wales (Larwill et al. 2003; Harley 2004). However, since European settlement this habitat range has been reduced as a result of timber harvesting, land clearing and fires. Figure one outlines the original modelled habitat (Species Distribution Model (SDM)), which before 2009 was thought to be the species post European settlement home range. This figure also displays the LBP Occupancy Model (where the probability of occupancy is greater than 30%), which was created after the 2009 bushfires and represents the LBPs current (predicted) home range. Its home range covers forests across the Murrindindi, Yarra and Latrobe DELWP Fire Districts and is entirely within the East Central Bushfire Risk Landscape (ECBRL).

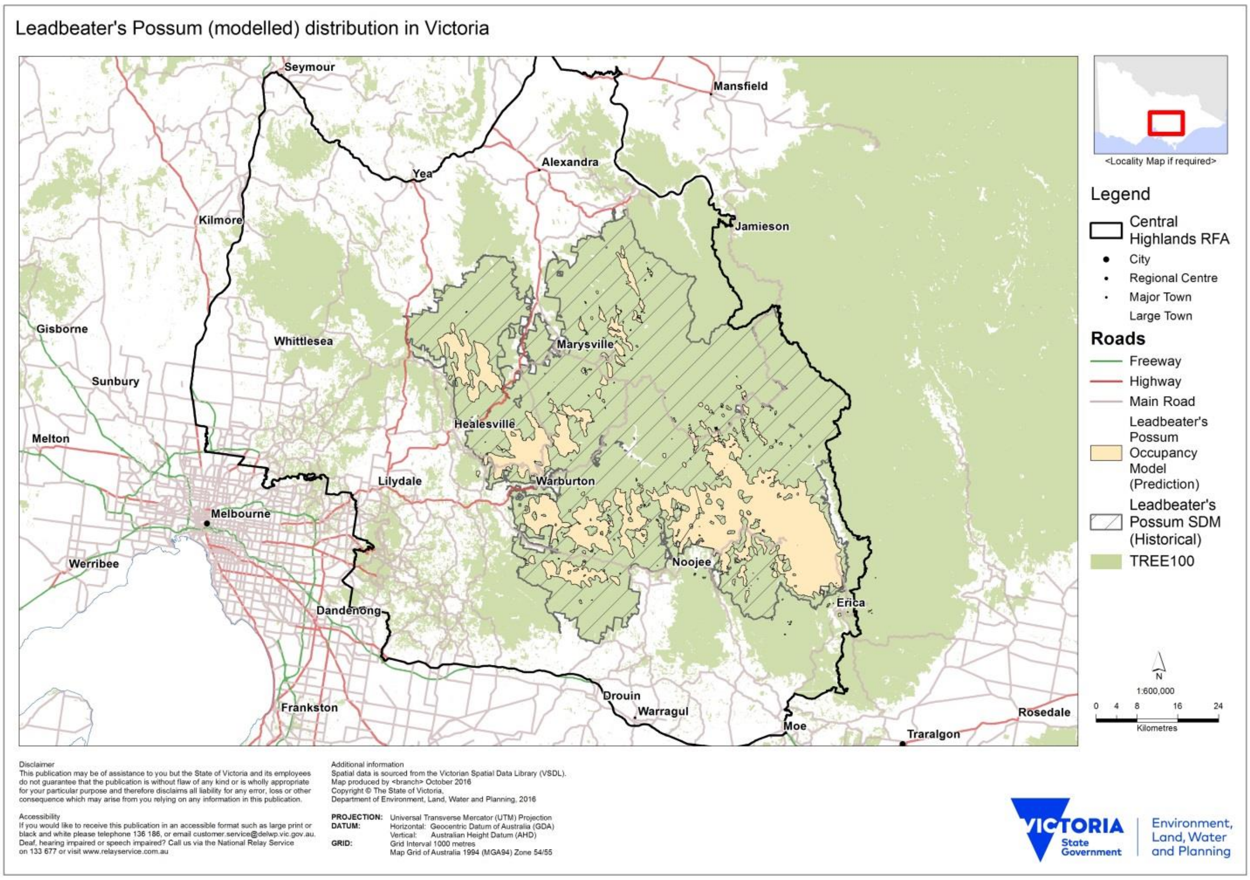

Figure 1. Leadbeater's Possum (modelled) distribution in Victoria (historical Species Distribution Model (SDM) pre 2009 – grey hatched area, and predicted Occupancy Modelled habitat (probability of occupancy >30%) post 2009 – cream solid area)

In April 2015, the species was up-listed to Critically Endangered under the federal *Environment Protection and Biodiversity Conservation Act* (1999), due to the severe decline of the population in recent years (last three generations of possums; 18 years) (Commonwealth of Australia 2016). It is also listed as threatened under the Victorian *Flora and Fauna Guarantee Act* (1988).

There are six meta-populations of the Leadbeater's Possum identified across the Central Highlands (figure 2). These are spatially distinct populations that interact at some level.

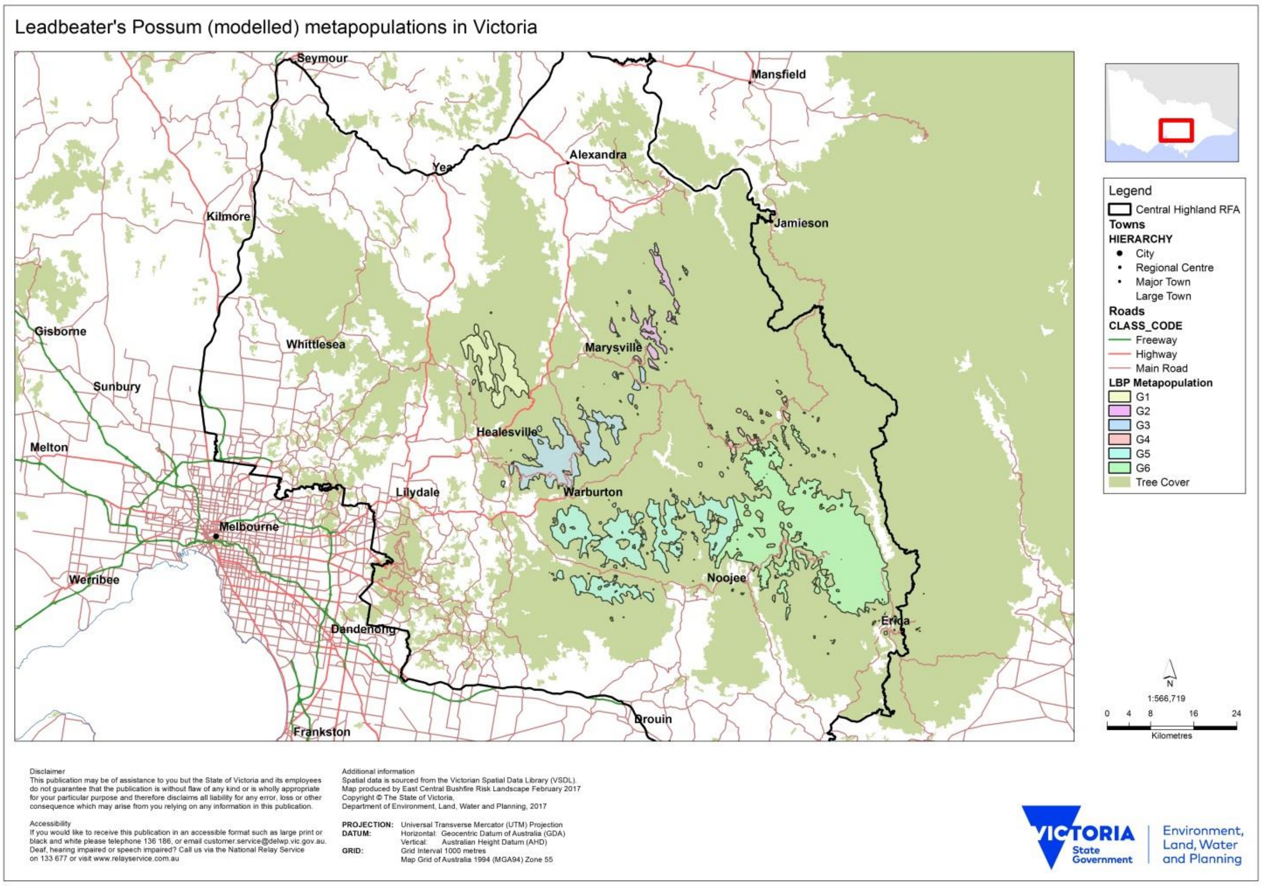

Figure 2. Leadbeater's Possum (modelled) meta-populations in Victoria (probability of occupancy >30%).

One of the major threats to the species is from fire; both the impact from severe fire and changes in fire regime. Research conducted post the 2009 bushfires has shown that regardless of fire severity, the abundance of LBPs decreases with fire. The results also indicated that the population reduction effects were disproportionately higher than the bushfire's extent, i.e. even unburnt areas surrounding fire affected areas had reduced abundance of possums (Lindenmayer et al. 2013; Lindenmayer et al. 2015). With the species being so sensitive to fire it is paramount that the DELWP ensures its preparedness and response activities are capable of mitigating this risk.

1.2 Leadbeater's Possum Advisory Group

Concern for Leadbeater's Possum increased significantly after the 2009 bushfires which burnt a third of the Leadbeater's Possum total potential range (Lindenmayer et al. 2013), and about 45% of a reserved system set aside specifically for the species (LPAG 2014). These fires intensified ongoing habitat decline of the species. Over the preceding few decades a significant loss of hollow-bearing trees has been recorded. Long-term monitoring over the last 30 years in the Central Highlands has shown that approximately 3.5 per cent of dead trees collapsed per year during that period and approximately 1.5 per cent of large, live hollow-bearing trees died per year (these figures are higher in burnt areas) (Lindenmayer et al. 2012). This loss of hollow-bearing trees is predicted to continue into the future, with most of the remaining dead trees from the 1939 fires predicted to collapse in the next few decades. There is currently negligible development of new hollow-bearing trees, as the majority of younger age-classes of live trees that now dominate the forest (1939 regrowth) are yet to form hollows. The combination of the loss of existing hollow-bearing trees and a lack of formation of new hollow-bearing trees is predicted to lead to a severe shortage of suitable habitat in the next 30-70 years (Lindenmayer et al. 1990; Lindenmayer et al. 2012). Modelling predicts the population of Leadbeater's Possum will fall to low levels during this time, increasing the risk of extinction, with any future bushfires further exacerbating this situation (LPAG 2014).

Given the increased vulnerability of the species, in June 2013 at the request of the then Minister for Environment and Climate Change, and the Minister for Agriculture and Food Security, the Leadbeater's

Possum Advisory Group (LPAG) was established to develop recommendations to support the recovery of the species while maintaining a sustainable timber industry (LPAG 2014). The advisory group consisted of representatives from Zoos Victoria, VicForests, Parks Victoria, Victorian Association of Forest Industries and the Leadbeater's Possum Recovery Team. The group's recommendations were aimed at slowing the projected decline of the Central Highland populations and to maintain population viability as the species recovers from habitat loss whilst passing through the habitat bottleneck.

In total, there were 13 recommendations:

1.) Protect Leadbeater's Possum colonies

2.) Delay harvesting in areas of anticipated high probability of occupancy

3.) Transition to retention harvesting

4.) Revised regeneration practices

5.) Buffer old growth

6.) Amend the definition of Leadbeater's Possum Habitat Zone 1A

7.) Target future old growth ash forests for protection

8.) Fire management of known colonies and high quality habitat

9.) Install nest boxes

10.) Accelerate hollow development

11.) Translocation

12.) Community engagement

13.) Monitoring and review

In 2013 a joint report was produced by Regional Services and Fire Policy divisions of DELWP was completed as a preliminary investigation into the LPAG recommendation 8. A summary of this report is outline below.

In 2015 the ECBRL employed a Leadbeater's Possum Project Officer to undertake a more detailed analysis and to complete the tasks associated with recommendation 8.1 and 8.2 on behalf of DELWP.

This interim report relates specifically to recommendation 8.2 'Investigate and implement active fire management activities to protect identified colonies and high quality habitat from bushfire'

1.4 2013 Leadbeater's Possum bushfire risk modelling report

In 2013 a joint report into bushfire modelling across Leadbeater's Possum habitat was drafted (DEPI 2013) as a preliminary investigation into the LPAG recommendation 8. Regional Services, Fire Management Policy Division and Arthur Rylah Institute (ARI) collaborated on the project to model the impact of bushfire on Leadbeater's Possum habitat and population within the Central Highlands RFA. The reports two main objectives were to:

1. Provide an understanding of the impact of major bushfires on Leadbeater's Possum habitat over the last 30 years and understand the effect of the Department's fuel management strategy (at the time) in reducing major bushfire risk to Leadbeater's Possum; and

2. Provide indicative fire paths and associated impact areas for the six Leadbeater's Possum meta-populations.

The report detailed the impact of large scale bushfires over the last 30 years on the risk of bushfire to the Leadbeater's Possum. The results show following both the 1983 and 2009 bushfires the risk to remaining habitat was significantly reduced, but as fuel accumulated post fire, so did the risk of future fires to the species.

The report also analysed the role planned burning would have on the risk of future fire events to the species. At the time, modelling indicated that the three year Fire Operations Plan (2013-15) was likely to only reduce rate of risk increase or keep the risk at consistent levels (DEPI 2013). This suggested that while the FOP had some risk reduction benefit, it was not targeted enough in strategic areas to effectively reduce fuel and risk to benefit the Leadbeater's Possum (figure 3).

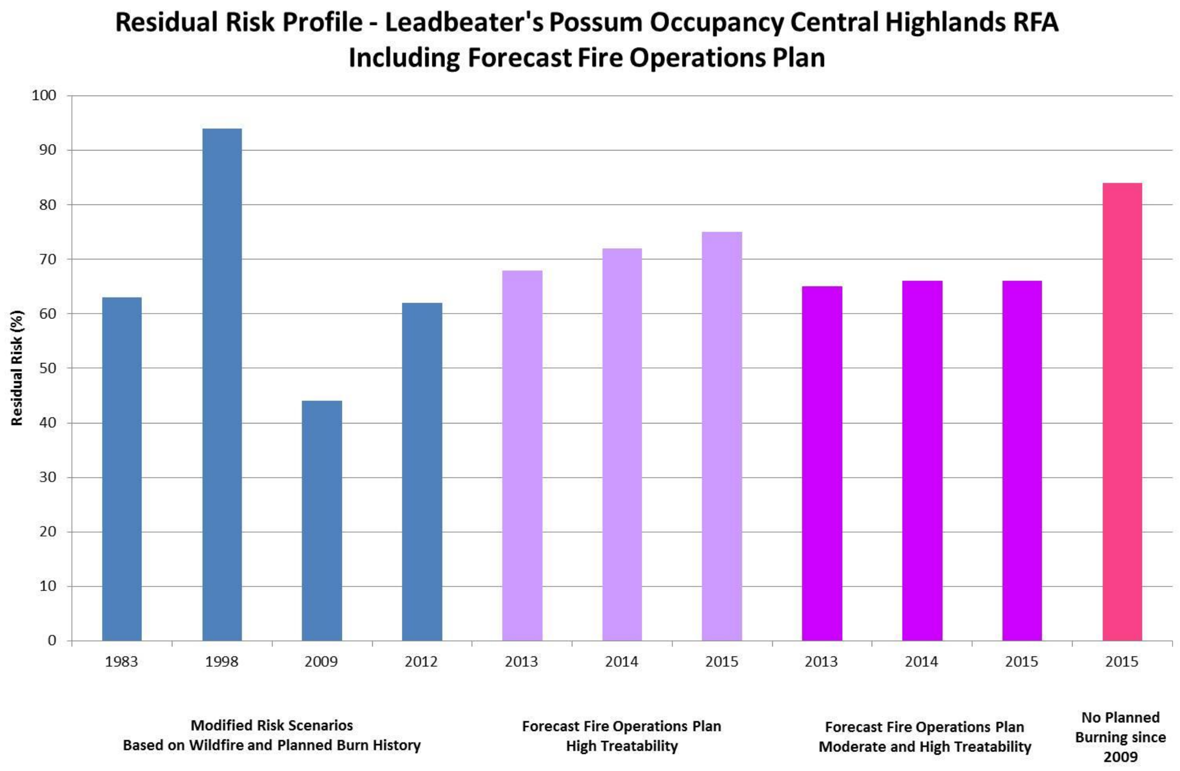

Figure 3: Residual risk profile for the areas predicted to be occupied by the Leadbeater's Possum (FFDI 130, Grass at 2 tonne/ha) – modified risk scenarios for 1983, 1998, 2009 and 2012, Fire Operations Plan 2012/13 – 2014/15, and 2015 with no planned burning since 2009.

The report was the first of its kind undertaken by DELWP to trial a bushfire risk modelling techniques on a natural value rather than a life and property asset. The report was able provide the first estimate of landscape-scale bushfire risk to the Leadbeater's Possum (modelled occupancy) and highlighted the need to determine where the bushfire risk lays on public and private land and analyse the effectiveness of the next iteration of the Fire Operations Plan.

This report forms the basis for future work which will determine specific areas of risk in the landscape to the species and determining how this risk can be reduced in line with recommendation 8 of the LPAG.

Addressing these points as well as piloting a methodology to develop a fuel management strategy that reduces the risk of future bushfire to meta-population one that can be applied to the other five meta-populations will be explored in this interim Leadbeater's Possum Fuel Management report.

2. Analysing and Addressing the Risk of bushfire to the LBP

The aims of the interim Leadbeater's Possum report are:

- To update the results of the residual risk profile of the Leadbeater's Possum completed in the 2013 draft report with the most up to date fire history and analyse the current FOP to determine its effectiveness at reducing the risk of bushfire to the species and its potential habitat using the most up to date spatial layers; and

- Trial a methodology for developing a cross tenure fuel management strategy to one of the six identified meta-populations (referred to as meta-population one) which can then be applied to the other five meta-populations.

2.1 Understanding the risk to the Leadbeater's Possum

Bushfire Risk Modelling

Phoenix RapidFire is a computerised bushfire model which has been developed by the University of Melbourne in collaboration with the Bushfire Cooperative Research Centre and DELWP. It is used to simulate and measure bushfire risk on a landscape scale. In the model, simulated bushfires are ignited at points on a systematic grid across Victoria. Fires are ignited and simulated individually.

An initial set of bushfire simulations is used to create a "maximum risk scenario". The maximum risk scenario model shows the average impact fire would have on an asset (in this case Leadbeater's Possum habitat) if the fuel in the landscape was at the highest possible level. Because higher fuel loads equate to higher bushfire risk, this model can be used to establish the benchmark for maximum bushfire risk within the Victorian landscape.

A second set of bushfire simulations is then used to establish a "modified risk scenario". The modified risk scenario shows the average impact fire would have on occupied habitat if the amount of fuel in the landscape had been reduced by a particular combination of bushfires and/or planned burning. The modified risk scenario draws on records of past fires and planned burns.

Many different modified risk scenario models can be produced, each representing a different combination of bushfires and planned burning. These modified risk scenarios may be based on past records of fire occurrence, or predicted occurrence of fire such as future planned burning related to a fuel reduction strategy, or a hypothetical occurrence of fire that may be used to investigate the effectiveness of particular management options.

By comparing the impact on occupied habitat in the benchmark maximum risk scenario with the impact on occupied habitat in the modified risk scenario, DELWP can investigate how different fuel reduction regimes affect the impact of severe bushfires. The difference between the maximum and modified risk scenarios is referred to as residual risk: the ratio of the average occupied habitat impact of the modified risk scenario to the average occupied habitat impact of the maximum risk scenario, reported as a percentage. In other words, residual risk represents the percentage of maximum bushfire risk that remains in the landscape following fuel reduction due to a particular planned burning and bushfire history.

Methodology

Phoenix RapidFire

The results in this report were developed using methodologies devised by the Future Fire Group and using the fire simulation tool Phoenix (RapidFire) version 4.0.0.7

Detailed description of the methodology is provided in the following documents:

- Andrew Ackland, Andrew Blackett & Owen Salkin (2013) *VICTORIAN BUSHFIRE RISK PROFILES – A Foundational Framework for Strategic Bushfire Risk Assessment*, Department of Environment and Primary Industries, Victoria

- Frazer Wilson, Jill Gallucci, Robyn Allchin, Hayley Coviello & Peter West (2013) *East Central Bushfire Risk Landscape Risk Profile Report September 2013*, Department of Environment and Primary Industries, Victoria
- Department of Environment and Primary Industries, (2013) *DEPI Standard Operating Procedure: Bushfire Risk Assessment Draft*
- Kevin Tolhurst and Derek Chong, (2010) *Phoenix RapidFire User Manual – Introduction and Exercise DRAFT*

Data and Inputs

While some outputs in this report use the latest data when available, the majority of Phoenix modelling has been carried out using data as at December 2015. The source of the data is clearly stated in each output.

Fuel Types

The Phoenix RapidFire standard 'fuel types' and underlying dataset were used. Non-native grasslands have been modelled at 2 tonnes/ha as during the worst scenarios (i.e. FFDI 130) the environment would expect to be under drought conditions therefore in these conditions 2t/ha is appropriate.

Numerous models in this document refer to "Maximum Fuel Load", that is the amount of fuel that would be in the environment should no disturbance (logging or fire) ever take place or over a very long period of being undisturbed. The 'Maximum Fuel Load' is a modelled value that varies by vegetation type throughout the environment. As part of continual improvement fuel load modelling is changing over time as our monitoring improves the base data.

Ignitions

Ignitions for Phoenix analysis were based on the East Central bushfire risk landscape 1km ignition grid. Using this modelling it was determined that there were 915 fires from the 1km ignition grid that would impact on meta-population one. This was the ignition set selected for the scenarios in this report.

Weather Scenario

All Phoenix RapidFire simulations used in the creation of this document are based on two fire weather scenarios.

Weather scenario 1: FDI 130

The first weather scenario has a FFDI of approximately 130. This weather scenario happens once a decade. FFDI 130 was chosen as the worst case scenario and acts as a direct comparison with the risk modelling undertaken for life and property.

Table 1: Weather used for Forest Fire Danger Index 130 modelling

FFDI 130	Time	Temp (C)	RH (%)	Wind Dir	Wind (km/hr)	Drought Factor	Curing (%)	Cloud (%)
	9:00	35	25	360	20	10	100	0
	10:00	36	22	350	30	10	100	0
Fire Start	11:00	37	18	350	40	10	100	0
	12:00	38	15	340	50	10	100	0
	13:00	40	10	340	50	10	100	0
	14:00	42	8	330	50	10	100	0
	15:00	43	7	330	50	10	100	0
	16:00	43	7	320	50	10	100	0
	17:00	43	7	310	50	10	100	0
Wind Change	18:00	33	20	250	80	10	100	0
	19:00	30	35	240	40	10	100	0

	20:00	28	40	230	30	10	100	0
	21:00	27	45	220	30	10	100	0
	22:00	24	55	220	20	10	100	0
Fire End	23:00	22	60	210	15	10	100	0
	0:00	20	65	200	10	10	100	0

Weather scenario 2: FDI 75

For the second weather scenario a maximum FFDI of 75 was selected. Weather data collected over the last 12 years from across the Leadbeater's Possum habitat indicated that FFDI 75 was typically the worst conditions each year. The exception to this is of course in 2009 on the 14th of February, when the FFDI peaked at 110, however after analysis this was concluded to be an outlier, therefore while the modelling was completed at FDI75, it was validated at FDI130 to ensure that it was also suitable in the higher FDI range.

Table 2: Weather used for Forest Fire Danger Index 75 modelling

FFDI 75	Time	Temp (C)	RH (%)	Wind Dir	Wind (km/hr)	Drought Factor	Curing (%)	Cloud (%)
	9:00	26	35	360	15	10	100	0
	10:00	28	30	350	20	10	100	0
Fire Start	11:00	31	25	350	30	10	100	0
	12:00	34	20	340	40	10	100	0
	13:00	36	16	340	40	10	100	0
	14:00	37	13	330	40	10	100	0
	15:00	38	12	330	40	10	100	0
	16:00	38	12	320	40	10	100	0
	17:00	38	12	310	40	10	100	0
Wind Change	18:00	35	25	250	50	10	100	0
	19:00	29	35	240	30	10	100	0
	20:00	26	45	240	20	10	100	0
	21:00	24	55	220	15	10	100	0
	22:00	22	60	210	10	10	100	0
Fire End	23:00	20	65	200	10	10	100	0
	0:00	19	70	190	5	10	100	0

Fire History

Reconstructed fire history datasets for each year back to 1980 have been created from DELWP corporate datasets, incorporating fire history, and logging history. Ecological Vegetation Classes (EVCs) were linked to expert opinions on treatability, and areas not considered likely to have burnt excluded from these layers.

In order to determine the theoretical maximum risk scenario and create a benchmark from which to measure historical, current and future risk levels, Phoenix Rapidfire is also run using a 'No Fire History'. The removal of past disturbance from the modelling allows for the analysis of geographic risk without bias from recent fire events and should be considered a 'Maximum Fuel Loads' scenario.

Suppression

First Attack suppression was used.

Leadbeater's Possum habitat layers

The impact of bushfire is not directly modelled on Leadbeater's Possum individuals or colonies. Instead the bushfire impacts are modelled on a spatial layer of occupied habitat, which is considered to be a proxy for the Leadbeater's Possum. This methodology assumes a loss of occupied habitat due to bushfire impact is correlated with the loss of individual possums and colonies.

There were three habitat models used in the initial stages of the modelling, one was discarded early on due to questions of suitability. The other two habitat layers used in the analysis were the Leadbeater's Possum Occupancy Model and the Leadbeater's Possum Potential Habitat Layer. For the purposes of this report and testing of this methodology, one of six identified meta-populations was analysed. It is expected the remaining five meta-populations will be analysed and included in the final version of this report.

- *(i) Occupancy Model*

The LBP Occupancy Model was developed by the Arthur Rylah Institute (ARI) and identifies areas most likely to be currently occupied by Leadbeater's Possums. Further information about the model can be found in Lumsden *et al*. (2013). When reporting on risk and this model, this report is reporting on the bushfire risk to the current occupied habitat post the 2009 fires. For the purpose of this report, based on advice from ARI and to maintain consistency with the DRAFT DEPI (2013) report, the probability (of occupancy) threshold of >30% was used for the Occupancy Model.

- *(ii) Potential Habitat Layer*

The LBP Potential Habitat Layer consisted of a range of modelled and actual species recorded data. This included buffered species records (LBPAG_BUFF_CHRFA_v20150716), modelled old growth (LBP_MOGAB_CHRFA_v20150716), the Leadbeater's Possum reserve system (lbp_DSE_Final_gda_z55mga_poly) and a thresholded version of the Leadbeater's Possum Species Distribution Model (SDM) (LBP_PHAB_CHRFA_v20150716). The thresholds were applied to the SDM based on advice from modellers and wildlife scientists at ARI. This model was developed to represent the full range of possum habitat; both the current and previously suitable habitat (pre 2009 bushfires).

Defining when habitat is 'impacted' by fire.

The potential habitat impact of ignitions is calculated for each ignition on a 1km grid of fires. The loss value is an estimate of the number of hectares of habitat that will experience fire behaviour at or above thresholds for habitat loss (Low Intensity Fire at or above a flame height of 2.5 meters) from an ignition at each individual 1km grid point. The low intensity scenario was chosen as previous sensitivity analysis found little to no difference between two other scenarios (DEPI 2013). The use of this scenario is also warranted as previous research has indicated that even low intensity fire has a significant impact on Leadbeater's Possum abundance (Lumsden *et al* 2013; Lindenmayer et al. 2013; Lindenmayer et al. 2015b).

Known Errors and Limitations

Phoenix RapidFire

All analysis complete for this report was done so using Phoneix RapidFire version 4.0.0.7. Phoenix RapidFire is a computerised bushfire model which has been developed by the University of Melbourne in collaboration with the Bushfire Cooperative Research Centre and DELWP.

Like all models, Phoenix provides only an approximation of reality and the accuracy of its outputs is dependent on the quality of its inputs. Phoenix uses a range of data inputs to model bushfire behaviour, including fuel types, ignition locations, weather variables, topography and previous fire history. While DELWP strives to use the most accurate data possible, it is acknowledged that these datasets vary in accuracy and there is need for further improvement.

As the model is sensitive to minor differences in inputs, small shifts in the weather, fuel accumulation functions, or time of ignition, can cause large differences in results. The result being that actual fire spread may not be reflected in model guidance.

It is acknowledged that Phoenix is a tool primarily designed for research and that in this case it is being used operationally. DELWP however believes that Phoenix is currently the most appropriate tool to be used for bushfire modelling and analysis in Victoria.

Weather

The weather simulations used are consistent across the entire risk landscape. It is, however, known that expected weather conditions vary across the landscape. Into the future additional weather analysis and scenarios will be added to better reflect local conditions.

Because of the chosen weather scenario, modelled bushfires are restricted to those that do their most damaging runs in a single day. The risk posed by multi-day bushfires (i.e. “campaign fires”) is explicitly excluded from the current analysis. The greatest losses of life and property in Victorian bushfires have historically been caused by severe single day bushfires.

Likelihood

A full understanding of bushfire risk requires consideration of both the likelihood and consequence of bushfire impacts on values. The likelihood of all ignitions throughout the East Central bushfire risk landscape is considered to be equally likely in the present analysis, whereas in reality the likelihood of fires occurring in any given location does vary. The current methodology does not incorporate likelihood. It is acknowledged by the authors that likelihood is just as important as assessing consequence of bushfires; however there is currently no tested method to do this using Phoenix RapidFire.

Leadbeater’s Possum habitat

As discussed above bushfire impact on the Leadbeater’s Possum is not modelled directly. Instead, the spread and impact of bushfires on Leadbeater’s Possum occupied habitat and Potential Habitat Layer is modelled, and this impact is considered to be a proxy for the impact of bushfire on the Leadbeater’s Possum.

Risk is always estimated using the occupancy model dataset (post 2009 fires). This means that changes in bushfire risk as a result of previously occupied areas is not captured in this analysis.

Results

Leadbeater's Possum Occupancy Model

The residual risk profile for the Leadbeater's Possum Occupancy Model (as detailed in the Data & Inputs section) habitat is shown in figure four below. The historical residual risk (since 1995) for the modelled habitat is represented by the blue line, and as mentioned earlier this is expressed as the proportion of maximum risk to the modelled habitat in the ECBRL footprint.

This profile shows that following the 1983 Ash Wednesday fires fuels steadily re-accumulate in areas of risk to the Leadbeater's Possum and returned to pre-1983 levels and remained consistently over 90% between 1995 and 2008. Following the 2009 Black Saturday fires the residual risk dropped to below half of the possible maximum to 46%, indicating that these fires reduced fuels in strategically important locations. Since 2009 the residual risk has been increasing rapidly to where it is now; as at 2016, the current residual risk is 83% (Figure 4).

Figure four also shows the predicted risk over the next three years (2017-19). One of these predicted scenarios is what the risk level would be over the next three years without planned burning since 2016; which results in a steady increase to around 93% in 2019 and continue rising beyond. This is approximately the level seen prior to the Black Saturday fires in 2009.

Figure four also shows two alternative scenarios. These scenarios show the impact on the residual risk curve if all the burns on the 2017-19 Fire Operations Plan (FOP) are implemented; the first scenario being just the highly treatable vegetation (orange square) and the other both highly and moderately treatable vegetation (maroon square) (Figure 4). The two scenarios are used to simulate both favourable and unfavourable burning conditions in a given year; with the highly and moderately treatable scenario representing favourable conditions (i.e. drier years) and the highly treatable scenario representing unfavourable conditions (i.e. wetter years).

The results also shows that for both favourable and unfavourable years that burning areas on the current FOP will reduce the risk compared to no burning after 2016. It also shows that in a favourable year the residual risk falls to below the current 2016 level at 79%. This suggests that the current planned burning program is effective in reducing bushfire risk to the species.

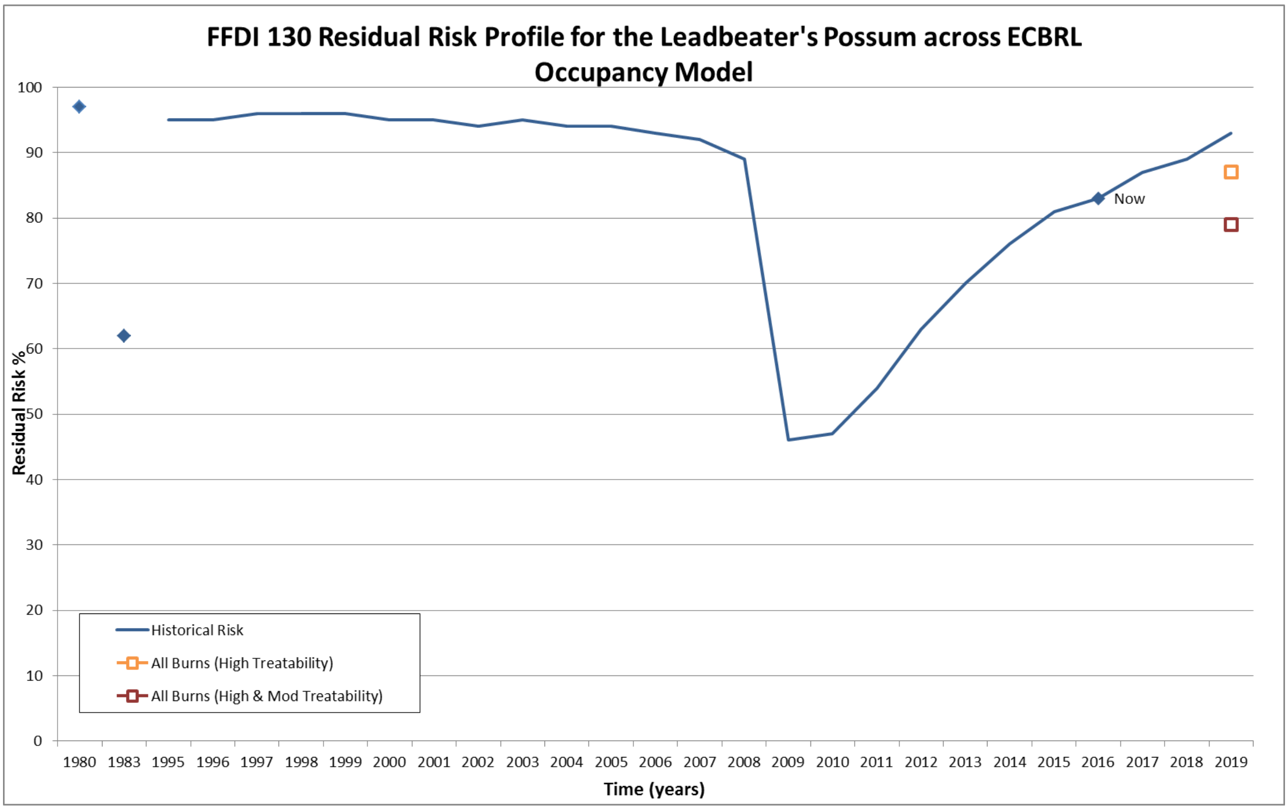

Figure 4. Residual risk profile for the Leadbeater's Possum Occupancy Model (>30% probability) at Forest Fire Danger Index 130 (Grass at 2 tonne/ha) for the East Central Bushfire Risk Landscape - including predicted risk after the implementation of the 2017-19 Fire Operations Plan.

Leadbeater’s Possum Potential Habitat Layer

The residual risk profile for the Leadbeater’s Possum ‘Potential Habitat Layer’ (as detailed in the Data & Inputs section) is shown in figure five. It shows a similar trend to the residual risk profile as for the ‘Occupancy Model’, whereby after the re-accumulation of fuel post 1983 Ash Wednesday fires, the residual risk remains at or around the pre-1983 levels; ~96% (Figure 5). Again the 2009 Black Saturday fires caused a reduction in residual risk, but for this model, the risk was reduced to about a third of the maximum risk at 33%. A reason for this could be the increased area of the ‘Potential Habitat Layer’ compared to the ‘Occupancy Model’; where the ‘Potential Layer’ has had more landscape strategic risk reduction.

The current residual risk in 2016 is 80% (Figure 5). The same prediction scenarios used for the ‘occupancy layer’ were completed for the ‘Potential Habitat Layer’ and show a similar trend; with no burning conducted after 2016 leading to an increase in residual risk to 91% and would continue to rise (Figure 5). Figure five also shows that areas on the current 2017-19 FOP are in areas of strategic risk reduction locations due to both the highly and the highly-moderately treatable scenarios reducing risk below the no burning scenario.

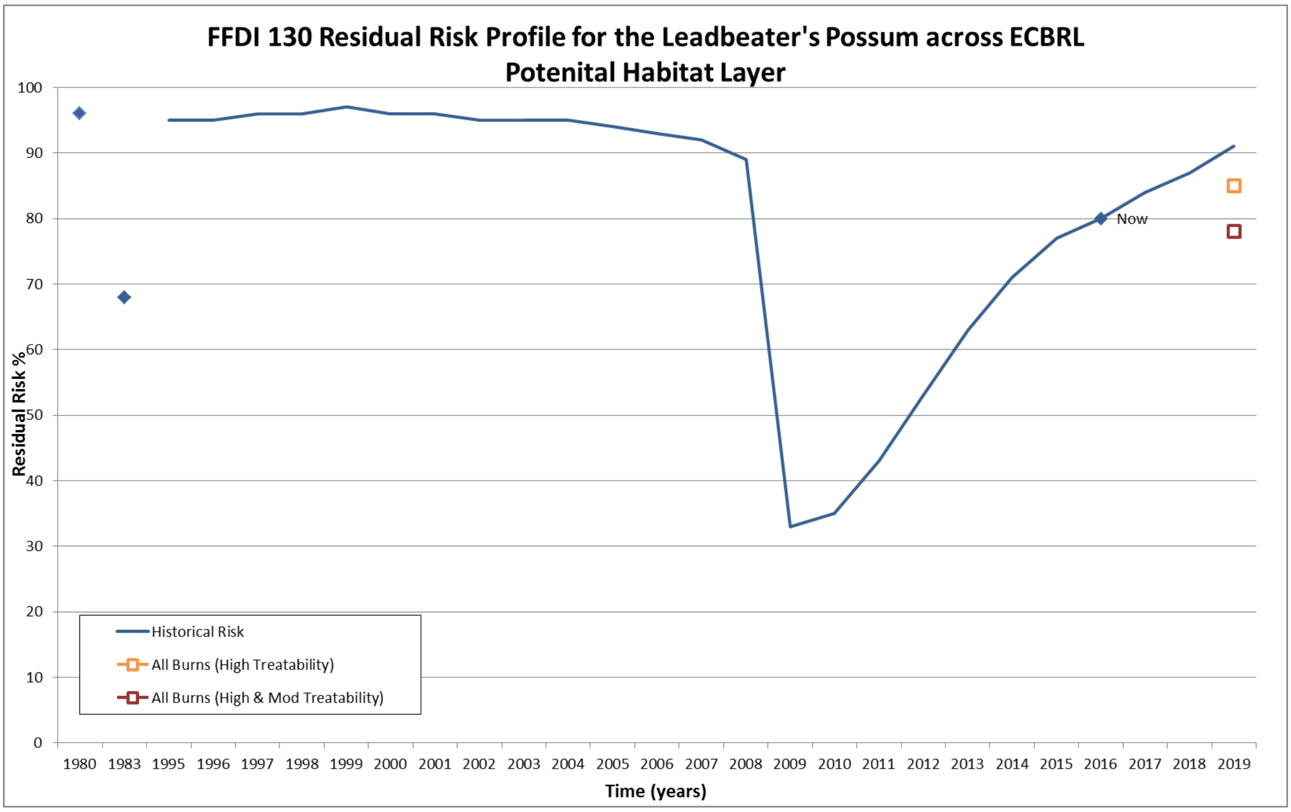

Figure 5. Residual risk profile, including predicted risk after the implementation of the 2017-19 Fire Operations Plan, for the Leadbeater’s Possum Potential Habitat Layer at Forest Fire Danger Index 130 for the East Central Bushfire Risk Landscape

2.2 Developing a fuel management strategy for the Leadbeater's Possum

The second part of this report looks into developing a methodology to develop a fuel management strategy that reduces the risk to the Leadbeater's Possum and it's habitat

Aims

The main aims of this pilot were to determine:

- Where in the landscape bushfire risk existed for Leadbeater's Possum populations
- How, using fuel modification (including planned burning), to best reduce the bushfire risk
- Appropriate recommendations to adjust the current fire management zoning

Method

1. The first step in this process was to model the ignition threat for the entire 'Occupancy Model' area. An ignition threat map was created, which represents, on a 1km grid and at FFDI 75 conditions with no fire history, the source of an ignition that would impact the habitat layer. Each ignition point had a value of the hectare amount of habitat predicted to be impacted by fire. The ignition threat information was generated for each of the six meta-populations as well as the overall Occupancy Model area. A total of 15677 ignitions were selected as impacting on the modelled habitat, and 1095 ignitions for meta-population one.
2. From the ignition threat map, burn units were selected based on the weighted area (hectares) from ignition points found within each burn unit. This then created a Leadbeater's Possum fire catchment, which was then broken down into meta-population sub-catchments for modelling. For each catchment a 1km ignition grid was created.
3. The selected burn units were then intersected with land tenure information. This was done so that bushfire risk could be displayed across public and private land.
4. In total there were 148 burn units chosen for meta-population one. However this was a considerable amount to model and the size of burn units was grossly uneven. Therefore some burn units were merged together so that they were of similar size to neighbouring burn units. This then formed 62 'groups' of burn units, which were then modelled individually using the ignition grids. Treatability was also taken into account and untreatable vegetation classes were not simulated (usually wet EVCs). Some burn units were found to be ineffective in isolation but effective when used in combination with nearby burn units. For each catchment, combinations of burn units were also examined.
5. Results were broken up by individual localities in the catchment for each burn unit run and added together to form a catchment total. Comparing this result against no fuel management in the identical catchment gave the residual risk score.
6. The next step was to create a first set of scenarios, often 10 or 20, using all of the best burn units or burn unit combinations that gave good residual risk reductions, then selectively including the burn units with lesser risk reductions and finally avoiding those that increased risk.
7. Scenarios were refined a number of times to attempt to get a better risk reduction with less burning where possible. Before the final strategies were selected, the refined burn units were intersected with the current Fire Management Zones layer. This was used to highlight which of the current Landscape Management Zones would be the most effective at reducing risk.
8. There were three final strategies created, which contained between 12 and 29 burn units. There was a DELWP strategy (public land only), Private land (only) and a Cross tenure strategy (public and private land). These strategies were then modelled and reported on (figure six)
9. After this point a theoretical rezoning proposal is made. It then goes to the Fire Districts, Biodiversity staff and Parks Victoria for discussion and comment. If discussions resulted in changes to the modelled output, these changes are re-modelled as per steps five and six.

The Strategies

Three strategies were identified and modelled for meta-population one of the Leadbeater's Possum.

1. **Public land strategy**. The public land strategy, identified as areas marked in green in figure six, includes 17 burn units, across 9,869ha. For the purposes of this report all burn units in this strategy were assumed to have been treated on the same day in autumn. The risk reduction was measured using a grid of fires started in the following summer.
2. **Private land strategy**: The private land strategy, identified as areas marked in red in figure six, includes 12 burn units, across 3,274ha. For the purposes of this report all burn units were assumed to have been treated on the same day in autumn. The risk reduction was measured using a grid of fires started in the following summer.
3. **Cross-tenure strategy.** The cross tenure strategy was a combination of both the public and private land strategies.

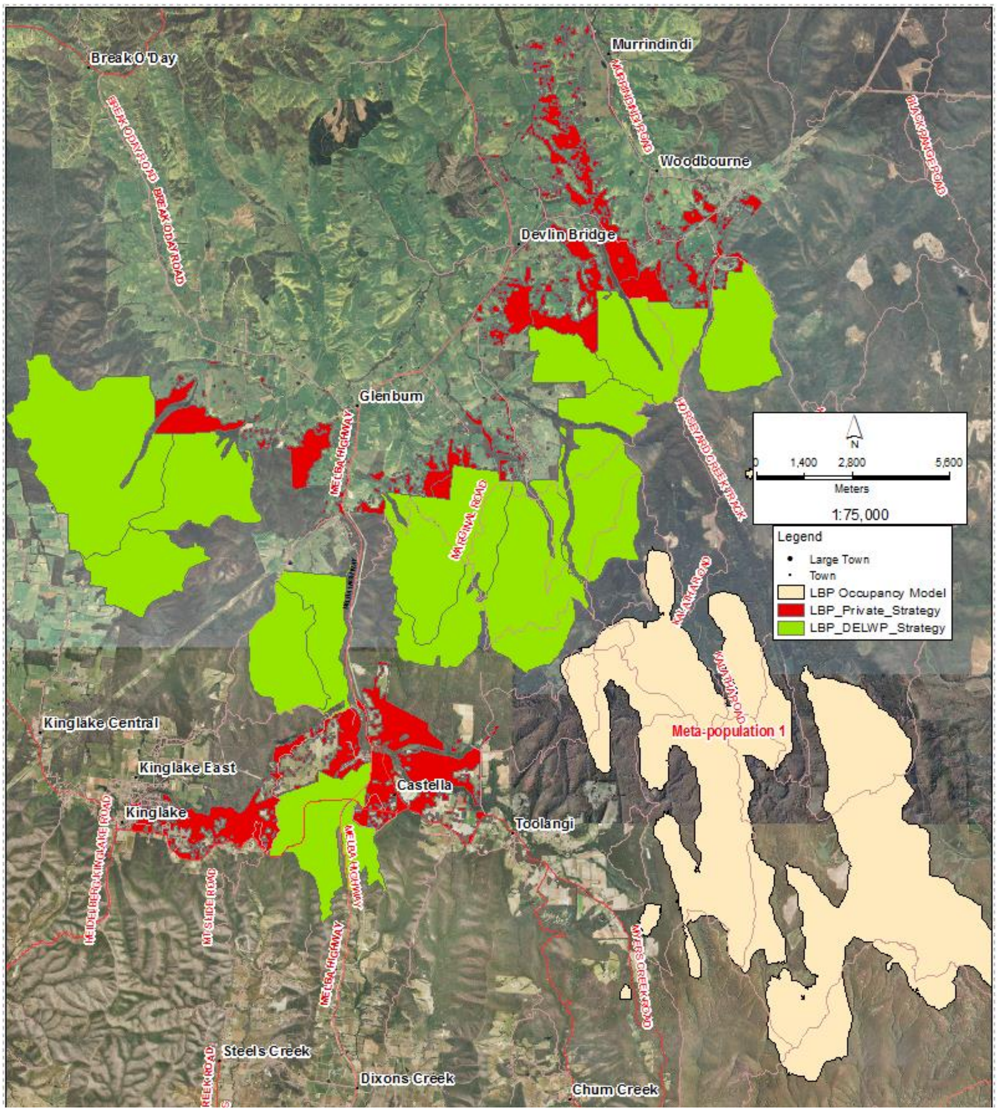

Figure 6. Map of the Leadbeater's Possum Occupancy Model, meta-population one including the Leadbeater's DELWP, Private land and Cross tenure fuel management strategies

Results

While the modelling was completed at FDI75 based on local weather information over the last 12 years, there was an outlier of Black Saturday in 2009 which had weather at FDI130. Therefore the results here are presented at both FDI75 'Indicative weather scenario' and FDI130 'Worst case scenario' to ensure that the proposed strategy holds up at all possible FDI ranges. At the time of writing this report the risk modelling data for assessing the effectiveness of the proposed fuel management strategies has only been produced for the Leadbeater's Possum 'Occupancy Model'. The 'Occupancy Model' was prioritised for the modelling process as it best represents the current occurrence of Leadbeater's Possum across the landscape.

FFDI 130 – worst case scenario

The 'Occupancy Model' residual risk profile for meta-population one, under the FFDI 130 scenario, is displayed in figure six. The historical risk is displayed by the solid blue line and shows that prior to 2006 the residual risk for meta-population one was approximately at its maximum, ranging between 97-99% (Figure 6). In 2006 the residual risk dropped to 87% which corresponds to a bushfire that occurred approximately 16kms north east of the meta-population (source: VSDL FIRE_HISTORY_LASTBURNT). Then in 2009 the residual risk drops to approximately 10%, as a result of the Black Saturday bushfires (source: VSDL FIRE_HISTORY_LASTBURNT). Since 2009 the residual risk has been increasing as the fuel hazard re-accumulates, to where it currently is for 2016 at 77% (Figure 6).

As with the previous residual risk profiles, there were predicted scenarios of risk into the future. Firstly, under a 'no burning' scenario after 2016, the residual risk reaches 89% and keeps increasing (Figure 7). Then there are the hollow squares on the graph in 2019, which represent the implementation of the current 2017-19 FOP. The yellow is highly treatable vegetation and the dark red high and moderate treatable vegetation. The results show that the current FOP is in areas of strategic risk reduction for this meta-population as both high and high-moderate scenarios reduce residual risk to around 81% and 76% respectively (Figure 7).

This graph also shows the three fuel management strategies as mentioned earlier. There is a DELWP Strategy (green solid line), Private Strategy (dark red solid line) and a Cross tenure Strategy, which is the combination of the DELWP and Private (orange solid line). These fuel management strategies represent a long term benchmark for fuel management and the lowest residual risk that could be achieved under this scenario. The DELWP strategy over the long term reduces the risk to around 77%, compared to the Private Strategy which maintains residual risk to around 93% (Figure 6). This suggests that the predominant amount of risk for meta-population one is on public land, which isn't surprising considering the amount of forested public land compared to the predominantly paddocked private land adjacent to the population. When these strategies are combined under the Cross tenure Strategy the residual risk is reduced to 72% (Figure 7). This last strategy is the lowest the risk could be reduced for meta-population one under an FFDI 130 scenario using planned burning.

The reason that the historical risk went well below what could be achieved through our benchmarks was due to the 2009 fires that burnt significant areas of land that could not have normally been treated (i.e. Wet Forest). With the risk continuing to rise, our goal will be to stabilise the risk to around our strategy levels.

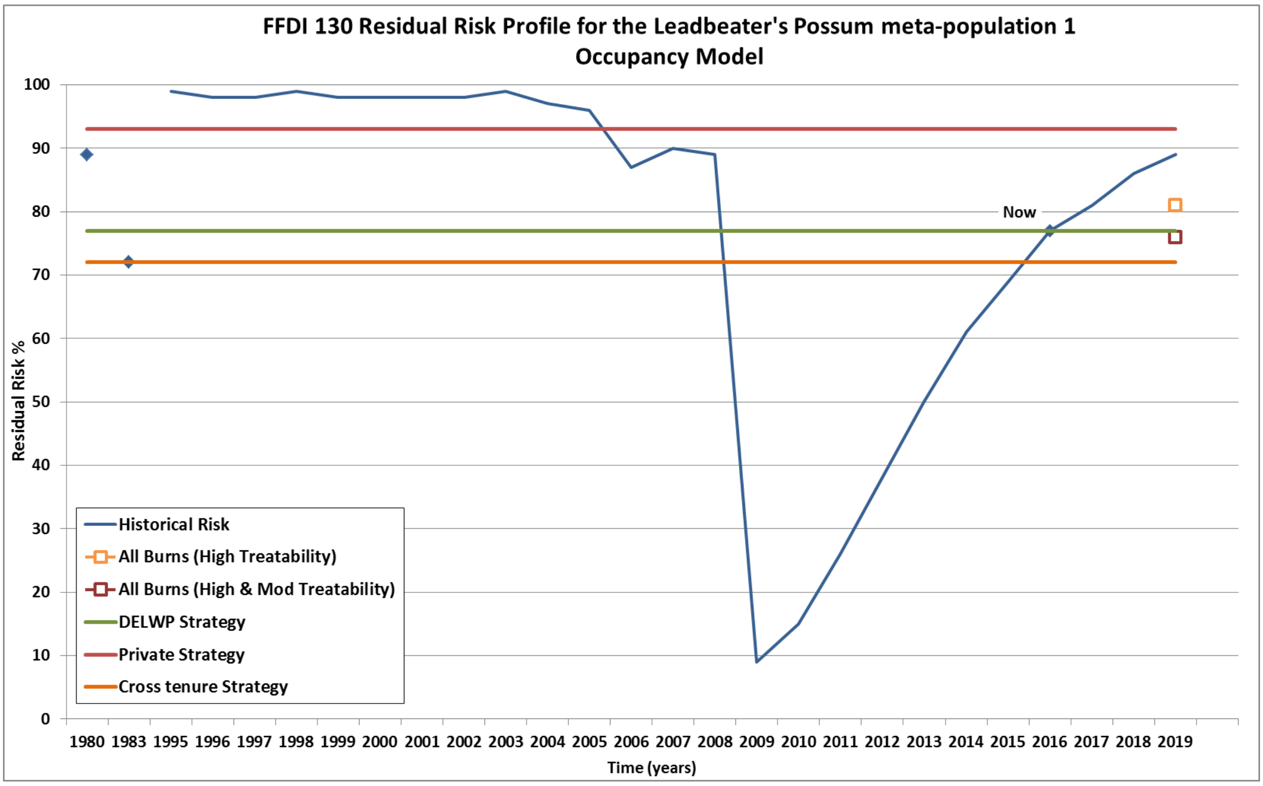

Figure 7. Residual risk profile for the Leadbeater's Possum Occupancy Model (>30% probability) at Forest Fire Danger Index 130 (Grass at 2 tonne/ha) for Meta-population 1 - including predicted risk after the implementation of the 2017-19 Fire Operations Plan, the Leadbeater's DELWP, Private land and Cross tenure bushfire risk reduction Strategies.

FFDI 75 weather scenario

The 'Occupancy Model' residual risk profile for meta-population one, under the FFDI 75 scenario, is displayed in figure eight. Unlike previous profiles, figure eight only shows the direct comparison between the proposed three fuel management strategies with the current residual risk and a predicted residual risk with no burning after 2016. It has also been modelled at FFDI 75, which was found to be the highest FFDI to occur on average per year over a 12 year period, across the LBP habitat area.

Firstly, the current residual risk as of 2016 is 77% (Figure 8). Next are the fuel management strategies with the DELWP Strategy reducing the risk to 54% and the Private Land Strategy maintaining residual risk to 79% (Figure 8). Again this suggests that the predominant amount of risk for meta-population one is on public land. However for the combined Cross tenure Strategy the residual risk is reduced to 50%. This last strategy is the lowest the risk could be reduced for meta-population one under an FFDI 75 scenario using planned burning. In comparison under a no burning scenario after 2016, the residual risk reaches 88% (Figure 8). This indicates that each of the fuel management strategies, if implemented, would be effective at reducing the residual risk to meta-population one.

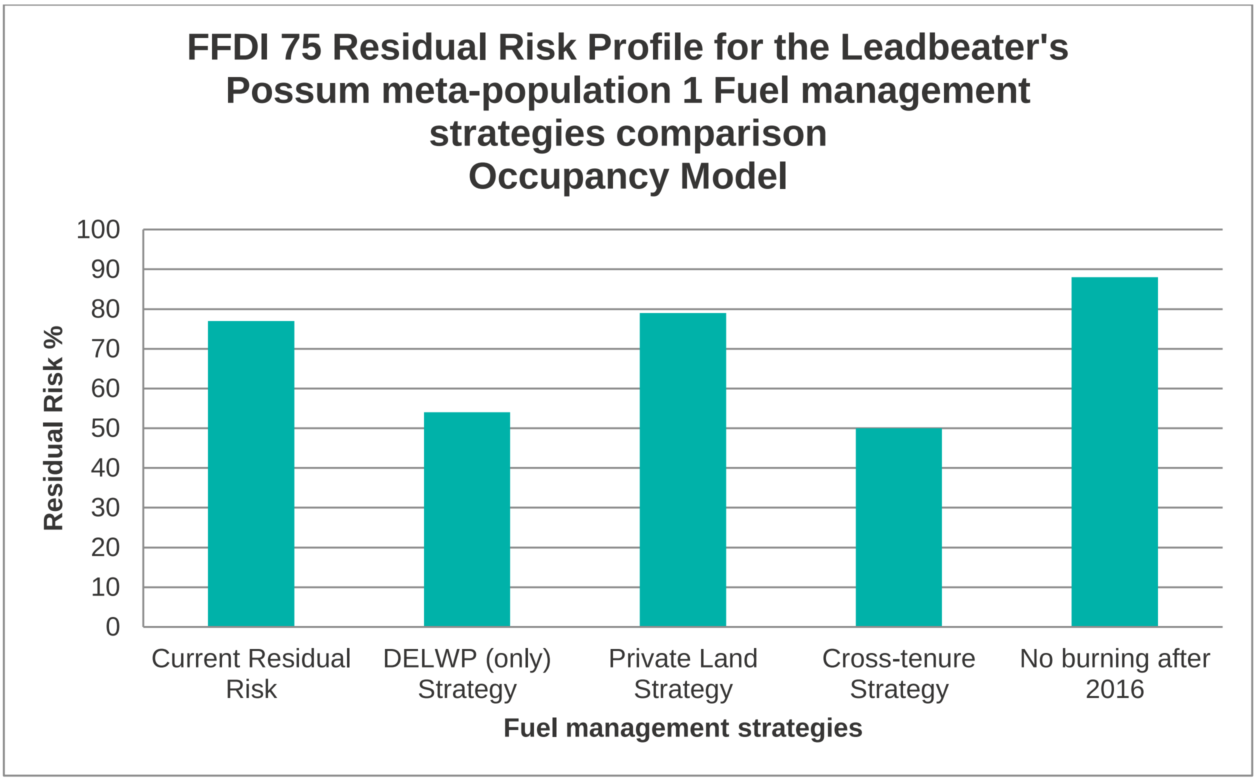

Figure 8. Residual risk profile for the Leadbeater's Possum Occupancy Model (>30% probability) at Forest Fire Danger Index 75 for Meta-population 1 – including the Current Residual Risk, the Leadbeater's DELWP, Private land and Cross tenure fuel management strategies, and predicted residual risk if there was no burning after 2016

Recommendations

The DELWP Strategy for meta-population one consisted of 17 burn units, with five being in Landscape Management Zone (LMZ) and the remainder in Bushfire Moderation Zone (BMZ) (Figure 9). For the purpose of effective risk reduction all burn units in the strategy should be treated as a BMZ, both for burn interval and coverage, as was done in the case study.

It was recommended that the five burn units in LMZ, across approximately 3,400ha, to be rezoned from LMZ to BMZ and the complete DELWP Strategy for LBP meta-population one (Figure 9). This recommendation was presented recently (September 2016) to both the Murrindindi and Yarra DELWP Fire and Land districts, as part of the ECBRL fire management zone (FMZ) rezoning process. Amendments were made to the current zoning to reflect the intention of the strategy and the operational feasibility of the plan. A review of the effectiveness of the strategy should be undertaken in the near future.

The case study highlighted the distribution of bushfire risk according to land tenure, as was recommended by the DEPI (2013) report. For meta-population one the majority of the risk exists on public land compared to private land. However with a cross-tenure approach the risk reduction benefits to LBPs can be effectively reduced to below the current level of risk. It is therefore worthwhile to investigate the feasibility of treating risk across both tenures for this meta-population

Next Steps

The results from the meta-population one case study demonstrated that an effective fuel management strategy at reducing residual bushfire risk can be developed for a natural value such as the LBP.

This success means that risk modelling work should continue for the remaining five LBP meta-populations to produce an overall bushfire management strategy for the species. This would also fulfil the recommendations from both the LBPAG report (2014) and the Draft DEPI (2013) report. This work should also include the following steps:

- Complete the remaining five meta-population fuel management strategies for the Occupancy and Potential Habitat Layer Models, at both FFDI 75 and 130
    - Include land tenure analysis
- Complete historical residual risk profile at 75 FFDI for the Occupancy and Potential Habitat Layer Models
- Report on findings for each meta-population to the relevant DELWP districts and seek comment and feedback, particularly regarding zoning changes
- Seek Biodiversity comment/values assessment on any proposed zoning changes
- Review spin off affects for other species, including any potential detrimental impacts
- Nominate zoning amendments where necessary and get LBP fuel management strategy implemented
- Monitor the effectiveness of the strategy at reducing residual risk, i.e overall fuel hazard monitoring, burn mapping, review the residual risk after implementation of each meta-population strategy etc
- Work with CFA and other relevant agencies to implement LBP strategies on identified private land

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DRAFT Leadbeater's Possum Fuel Management Report East Central Bushfire Risk Landscape Project 2015/16 31

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delwp.vic.gov.au

FOI 171109
Document 2

From: s22
To:
Cc:
Subject: Re: LBP Conservation Advice - s22 comments [SEC=UNCLASSIFIED]
Date: Tuesday, 14 November 2017 8:42:24 AM
Attachments: s22 edits TSSC 70 Item 7.4.1 Gymnobelideus leadbeateri - Consultation CA.docx

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Hi s22 and all

Please find attached my on-document edits to the LBP document.

Let me know if you need anything clarified. Highlighted bits were where the language or issue caught my eye. Comments should explain what the issue was.

Well done to you and s22 on all the hard work.

Thanks

s22

From: s22 @environment.gov.au>
Sent: Monday, 13 November 2017 2:19:45 PM
To: s47F
s22
Subject: RE: LBP Conservation Advice - s22 comments [SEC=UNCLASSIFIED]

Thanks s47F

I'm looking at some additional comments from s22 at the moment too. I think I'll take an approach of going through comments and if they're simple corrections of fact or improvement to readability I'll put them in now. But if they're matters of judgement, I'll put them to the TSSC first so that I can minimise the double handling and multiple clearance of changes.

I imagine I'll have to circulate a revised copy post-meeting to TSSC members for clearance, so if they're comfortable with it I'll run it by you folks at the same time.

Cheers,
s22
****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s47F monash.edu]
Sent: Monday, 13 November 2017 2:16 PM

s22

Subject: LBP Conservation Advice - s22 comments

Hi s22
It was good to meet you last week - the meeting was very useful and interesting. As discussed attached are my comments on the draft CA. Overall its a great piece of work which shows the considerable effort you have put into this.

As indicted on Friday I think the threat section could be made a bit clearer - but feel free to ignore my comments - its not a deal breaker - although I do think some mention of all the threats to LBPs should be included then then focus on the ones that are the main drivers of decline. Climate change should be included as a separate threat.

In the criteria assessments I think a summary table with the outcome for each sub criterion by criterion would be a great addition as I found it hard to find the right outputs for each.

We didn't get to management actions but as always I'm in favour of making them more SMART.

Happy to chat as needed. All the best with the wrap up.
Cheers
s47F

--
s47F
Principal Consultant
Water's Edge Consulting
9 McDermott Ave
Mooroolbark VIC 3138
03 9727 5649
s47F
www.waters-edge.com.au

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****
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****

FOI 171109
Document 3

From: s22 @delwp.vic.gov.au
To: s22
Cc:
Subject: Confidential - Draft LBP assessment
Date: Monday, 6 November 2017 4:20:29 PM
Attachments: ATT00001.gif
ATT00003.gif
ATT00004.gif
ATT00005.gif
ATT00006.gif
ATT00007.gif
TSSC 70 Item 7.4.1 Gymnobelideus leadbeateri - Consultation CA.docx

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Dear all

Please find attached the draft conservation advice, including assessment against the IUCN criteria.

We will go through the document in detail on Friday but feel free to raise queries with s22 as per his offer below.

Please treat the draft as strictly confidential.

Regards

s22 **Manager, Threatened Species Policy | Biodiversity Division**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

Level 2, 8 Nicholson St, East Melbourne, Victoria 3002
T 03 963 s22 | **F** 03 9637 8451 | **E** s22 @delwp.vic.gov.au

----- Forwarded by s22 /VICGOV1 on 06/11/2017 03 50 PM -----

From s22 @environment.gov.au>
To s22 @delwp.vic.gov.au>,
Cc s22 @delwp.vic.gov.au>
Date 06/11/2017 03 12 PM
Subject RE Update on draft LBP assessment [SEC UNCLASSIFIED]

Hi s22

I ve been to check with s22 and the answer is apparently: now

The draft of the Conservation Advice is attached You may note that it s been once in full to s22 I ve incorporated her comments, but not passed them by her again to check I got it spot on

By the way, if any of the members want to ask me questions, or ask me to bring any particular materials to the meeting, I m more than happy for them to drop me a line via phone or email

Cheers,

s22
[redacted]
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 4

From: s22 @delwp.vic.gov.au
To: s22
Subject: RE: Fw: Another LBP question [SEC=UNCLASSIFIED]
Date: Wednesday, 4 October 2017 4:14:02 PM
Attachments: ATT00001.gif
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ATT00021.gif

Don't envy you that's for sure, there's certainly a mountain to get your head around.

Good luck !

s22 | s22 | **Wildlife Ecology | Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water & Planning
123 Brown Street, VIC 3084 | PO Box 137, Heide berg, VIC 3084, Australia
T: s22 | **F:** 03 9450 8799 | **E** s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Cc:
Date: 04/10/2017 03:45 PM
Subject: RE: Fw: Another LBP question [SEC=UNCLASSIFIED]

Thanks s22

I *think* I get it now. Will let you know if I confuse myself further.

I'm currently grappling with the Lindenmayer et al. Cross-section v longitudinal study paper and compensatory responses. I also *think* I get this, but trying to synthesise all the work on such a well-studied animal is more than a little daunting.

I'm sure your latest report will just be the icing on the cake.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275s22
****

From: s22 @delwp.vic.gov.au]
Sent: Wednesday, 4 October 2017 3:20 PM
To s22
Cc
Subject: Re: Fw: Another LBP question [SEC=UNCLASSIFIED]

Hi s22

I can see what's happened - ARI did survey 48 sites in the >65% probability of occupancy category as we say in both reports, and we detected LBPs at 25 of these sites (here sites where LBPs are detected are synonymous with colonies), as in Table 2 in the targeted survey report.

The 42 new colonies detected in the >65% area referred to in Section 2.1.5 of the review is the total number detected in this area during the moratorium i.e. 25 ARI + 17 by community groups (mostly), which is 21% of the 200 new colonies.

We probably should have been a little clearer in the paragraph at the bottom of p. 17 that we're talking about ARI and other's records as it doesn't follow that well from the proceeding paragraph, but hopefully isn't too confusing when read in the context of this report.

Hope this clarifies it for you.

Cheers,

s22

s22 | s22 | **Wildlife Ecology | Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water & Planning
123 Brown Street, VIC 3084 | PO Box 137, Heide berg, VIC 3084, Australia
T s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22
To: s22
Date: 04/10/2017 02:00 PM
Subject: Fw: Another LBP question [SEC=UNCLASSIFIED]

Hi s22

hmm - good question! I will get s22 to look into this and send you a reply (I am just about to zap off to run a course). s22 - can you work out what has happened here? thanks

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F:** 03 9450 8799 | **E:** s22 @delwp.vic.gov.au

www.ari.vic.gov.au

----- Forwarded by s22 VICGOV1 on 04/10/2017 01:47 PM -----

From: s22 environment.gov.au>
To: s22
Date: 29/09/2017 02:34 PM
Subject: Another LBP question [SEC=UNCLASSIFIED]

Hi s22

I'm just reading through the July 2017 report (A review of the effectiveness and impact of establishing timber harvesting exclusion zones around Leadbeater's Possum colonies).

I'm looking at section 2.1.5 where it says that 48 sites in the >65% probability sites were surveyed. In the 3rd para it says 42 new colonies in these areas. So I read that as 42/48 or about 85% occupancy.

But in the table (for the upcoming report) that I photographed down at ARI (Table 2) it says that there were only 25/48 (52%) of the >65% sites where LBP were detected.

Are you able to see what I'm missing?

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 5

From: s22
To:
Subject: Vic ecosystem accounts report [SEC=UNCLASSIFIED]
Date: Wednesday, 30 August 2017 3:55:06 PM
Attachments: Ecosystem Complete Report_V5B[1].pdf

Hi s22 attached is NESP accounts report – a final draft, I think it was supposed to have been publically released a week or so ago. I'll need to check.

Cheers

s22
Director
Terrestrial Threatened Species
Department of the Environment and Energy
GPO Box 787 Canberra ACT 2601
02 6275 s22
environment.gov.au

FOI 171109
Document 6

From: s22 @delwp.vic.gov.au
To:
Subject: Re: Quick question [SEC=UNCLASSIFIED]
Date: Tuesday, 17 October 2017 11:50:19 AM
Attachments: ATT00001.gif
ATT00002.gif
ATT00003.gif
ATT00004.gif
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ATT00007.gif

Hi s22

s22

on your earlier question re the decline of suitable habitat - I think looking at the total ash habitat would be a good way to go - given that we only know a small proportion of where they occur, looking across the whole potential range could be much better. You would need to also include the snow gum in this not just the ash

and yes I would be interested to see what you have come up with.

good luck with it all

bye

s22

s22 | s22 Wildlife Ecology| Arthur Rylah Institute
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F:** 03 9450 8799 | **E:** s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 17/10/2017 11:32 AM
Subject: Quick question [SEC=UNCLASSIFIED]

Hi s22

I was just wondering – have you done any sampling for possums using the new techniques in ANU sites where they haven't been recorded? It occurs to me that it would be a good way of evaluating the ANU occupancy/suitability models.

I'm just going over comments from one of our TSSC members on my rough draft of the past decline criterion. I hope I can pass it on to you relatively soon (if you want to see it).

s22 and I are having a phone meeting with s22 about our cooperation on the assessment on Wednesday. I presume it'll just be free exchange of drafts/comments but I guess we'll wait and see.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 7

From: s22
To:
Cc:
Subject: RE: Visit re LBP [SEC=UNCLASSIFIED]
Date: Friday, 8 September 2017 9:52:39 AM
Attachments: image001.gif
image002.gif
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s22 - material irrelevant to scope

s22

s22

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Document 7c

Supporting Information

Table A. List of environmental variables used to construct Maxent models of four priority fauna species in the Central Highlands of Victoria.

Variable name	Permutation importance	Description	Source
B04	30.2	Temperature seasonality (standard deviation *100)	ANUCLIM [1]
B05		Max temperature of warmest period (°C)	ANUCLIM [1]
B06	8.1	Min temperature of coldest period (°C)	ANUCLIM [1]
B10	20.8	Mean temperature of warmest quarter (°C)	ANUCLIM [1]
B14	25.2	Precipitation of driest period (mm)	ANUCLIM [1]
Dist_to_water		Distance to any permanent water source (decimal degrees)	[2]
Dry_runs†		Number of consecutive dry days (with <1mm rainfall)	[3]
EVC*		Grouped ecological vegetation classes (1: Wet forest, Montane wet forest, Montane riparian thicket, Sub-alpine treeless vegetation; 2: Sub-alpine woodland, Sub-alpine wet heathland/Alpine valley peatland mosaic; 3: Damp forest; 4: Montane damp forest; 5: Cool temperate rainforest)	Created by CT & NC
Prop_forestrank_1km#	2.5	Proportion of area containing live & dead hollow-bearing trees within a 1km radius	Created by CT & NC
Prop_forestrank_2km#		Proportion of area containing live & dead hollow-bearing trees within a 2km radius	Created by CT & NC
Relief		Topographic relief – elevation range (m)	[2]
T5†		5th percentile of minimum temperatures	[3]
T95†	11.4	95th percentile of warmest temperatures	[3]

* Records of Leadbeater's Possum were recorded in EVCs consisting of Wet Forest, Montane Wet Forest, Montane Riparian Thicket, Sub-alpine Treeless Vegetation, Sub-alpine Woodland, Sub-alpine Wet Heathland/Alpine Valley Peatland Mosaic, Damp Forest, Montane Damp Forest and Cool Temperate Rainforest.

\# Forest condition layers included forest type, ecological vegetation class (EVC), disturbance history (logging and fire), regeneration year, forest condition and ranking (where 0 indicated areas that contained no hollow bearing trees, 1 indicated areas with dead hollow bearing trees within regenerating forest and 2 indicated areas with live and dead hollow bearing trees).

† For the 5th and 95th percentile temperature layers, and the consecutive dry runs layer, daily and monthly climate data were obtained from the Australian Water Availability Project for the period 1977 – 2012 [4,5] at 0.05 spatial resolution (~ 5-km). Temperature data were corrected with an adiabatic lapse rate of 0.00645 C m-1 [6,7] from the original 0.05 values to a resolution of 0.01

Commented [LI1]: This is the first variable to explicitly include hollow trees, and explains only 2 5% of the variation

Not sure what this means Does it imply that it's not necessary to explicitly look for hollow trees and that the MaxEnt model can be relied upon to identify like LBP habitat?!
If so, then available habitat may be much greater than previous estimates

(~1 km) based on a digital elevation model (DEM) resampled from its original 0.0025 to 0.01 resolution (GEODATA 9-second DEM v.3, Geoscience Australia).

Appendix S1: Description of the MAXENT models used for the analyses

All models were initially fitted using all available feature types, with 10-fold cross-validation. The background points for the possum and glider species were the presence records of the other two species combined. This is a common approach accounting for bias in presence-only modelling (called Target Group Sampling), where records of species that are surveyed using similar methods can be used as background points. The Sooty Owl background points used presences for all owls in the Central Highlands region that were available on the Atlas of Living Australia (www.ala.org.au), with <1000m accuracy. The models for each species were then refined by removing variables that contributed <1% of the permutation importance in the initial model, and by assessing the most appropriate feature types to capture species' responses to environmental gradients. Ultimately, all four species' final models were fitted using only hinge features, which produced complex, smoothed response curves that were easily interpretable. The contribution of each environmental variable included in final MAXENT model for each species is shown in Tables B to E below, alongside the cross-validated test AUC for that model. The mean AUC_{diff} for each model is also shown. AUC_{diff} describes the minimum difference between the AUC of the training dataset and that of the test dataset [8]. This represents another way of assessing the performance of the models; where a smaller AUC_{diff} value indicates a less over-fitted model. Other common validation statistics such as the True Skill Statistic (TSS) [9] were not used as the model predictions were not thresholded (to avoid losing information when it is not necessary [10]) and therefore this statistic is not relevant to this work. All variables listed in Tables B to E contributed >1% permutation importance in the initial model.

Table B. Leadbeater's Possum (AUC: 0.77±0.02; AUC_{diff}: 0.024±0.027)

Variable	**Permutation importance**
B10	20.8
T95	11.4
EVC	0.9
B04	30.2
B06	8.1
B14	25.2
Relief	0.9
Prop_forestrank_1km	2.5

Table C. Greater Glider (AUC: 0.63±0.03; AUC_{diff}: 0.012±0.035)

Variable	**Permutation importance**
T5	23.8
EVC	3.3
B06	33.5
Dry_runs	3.2
Prop_forestrank_1km	1.1
T95	11.9
B10	22.9
B04	0.4

Table D. Yellow-bellied Glider (AUC: 0.72±0.04; AUC_{diff}: 0.019±0.047)

Variable	Permutation importance
B04	11.6
T5	28.6
B14	17
Dist_water	4.9
Dry_runs	12.6
B05	15.5
T95	3.9
B06	4
Prop_forestrank_1km	1.8

Table E. Sooty Owl (AUC: 0.79±0.05; AUC_{diff}: 0.012±0.052)

Variable	Permutation importance
T5	59.6
Dry_runs	2.7
B14	13.1
Prop_forestrank_2km	0.4
B04	14.9
Relief	0.9
B06	8.5

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FOI 171109
Document 8

From: s22
To:
Cc:
Subject: RE: Occupancy [SEC=UNCLASSIFIED]
Date: Monday, 9 October 2017 3:33:30 PM
Attachments: image001.gif
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image007.gif

Thanks!

Am still wondering what to do about habitat (and bear in mind that ultimately it will be the TSSC who direct this so I could be steered in an entirely different direction than at present). I'm actually leaning towards just using total Ash forest. The reason being that we probably don't have sufficient resolution on suitable habitat to confidently estimate the actual area of occupancy all that well, but also that the threats (harvesting, fire and tree collapse) are all essentially "LBP-blind". That is, we have estimates for areas lost to fire and harvesting, but they don't tend to be broken down by LBP/not-LBP so it's probably better to present everything in the same "currency'.

Anyway, shall enlighten myself further by reading the report this afternoon (and probably into tomorrow).

Thanks again,

Cheers,
s22

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s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Monday, 9 October 2017 3:21 PM
To: s22
Cc:
Subject: Re: Occupancy [SEC=UNCLASSIFIED]

Hi s22

sorry for the delay in getting back to you on various things.

on your question below - I think they just got it wrong (this is something I picked up too). I think your interpretation is correct. We know they occur extensively in SF so it has to be included in the calculations.

we have looked at the success rate in the four occupancy model categories to compare the final year of data where the sites were randomly selected to see if the model performed any better on these (since it was developed on randomly selected data) and the answer is that it isn't much different. While there is still a difference between >30% and <30% there isn't any differentiation in the ranges >30%. So we know that the model using just the mapped variables isn't much better than random (despite at a broad scale it matches up pretty well). At a finer scale it doesn't work well. So we would really strongly advise against using the occupancy model as your indication of suitable habitat. It will get severely criticised, especially when our report comes out showing it really isn't that good. It was very useful when it was developed to give a general indication of where we think the species occurs but it has passed its usefulness. It was based on only a relatively small sample size (180 sites sampled but only 29 with LBPs) and does not factor in all the new records that have been collected since then - ie up to 600 new records. I really don't think we can go back to using just this limited sample when there is now so much more data available. s47F is critical of our model and we know it is not perfect and recommend it is not used for this purpose. Believe me if you base the IUCN reassessment on our OM all hell will break loose and I fear the credibility of the reassessment will suffer, and all the other logic and rational arguments you will use will be overshadowed by this one point.

I have attached the draft report - it might have a few final tweaks but it is close to finished and wont change substantively. You will see the review of the model in it.

I am away in the field for the next couple of days but s22 will be around if you have any questions

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 09/10/2017 02:32 PM
Subject: Occupancy [SEC=UNCLASSIFIED]

Hi s22

I have what might be a dumb question: I'm reading the 2015 LBP advice and it says:
Lumsden et al. (2013) also note that while there are 43,501 ha of unburnt ash forest protected in parks and reserves within the Central Highlands at 2013, not all this area is likely to be suitable and occupied by Leadbeater's possum, with modelling based on post-2009 fire surveys estimating that the possum is likely to only occupy 15,000 ha.

I'm noting that the figure is used repeatedly, but when I look at where I think they're getting it (Lumsden et al. 2013 – Strategic approach to biodiversity management….", **Table 4 on p25**) I think they've mis-used it, as there's another 20,000 ha of state forest with estimates >50% occupancy. It *might* have been a precautionary approach that assumed that anything in state forests *could* be harvested, but if so that hasn't been made clear.

So, just so I know I'm reading it correctly myself, can you confirm whether I'm right or wrong in thinking that Table 4 shows 35,764 of >50% occupancy of which 20,521 could be harvested and 15,243 is protected?

Thanks,
s22

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s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 8a

ARI LBP surveys - testing against the 2012 occupancy model categories

2016-17 randomised stratified sampling design

Predicted probability of occupancy	No. of sites surveyed 2016-17	No. of sites LBP detected	% of sites LBP detected	% of the total percentage
0 - 30%	88	26	30%	0.81%
30 - 50%	40	20	50%	1.35%
50 - 65%	16	7	44%	1.19%
65 - 100%	5	2	40%	1.08%
Total	**149**	**55**	**37%**	

2014-16 - very targeted, non-random sampling design

Predicted probability of occupancy	No. of sites surveyed 2014-16	No. of sites LBP detected	% of sites LBP detected	% of the total percentage
0 - 30%	75	31	41%	0.79%
30 - 50%	81	47	58%	1.12%
50 - 65%	85	46	54%	1.04%
65 - 100%	48	25	52%	1.00%
Total	**289**	**149**	**52%**	

while the overall detection rate in 2016-17 was lower due to the randomised sampling design, the relative proportions in each of the occupancy model categories is r roughly the same

FOI 171109
Document 8b

Targeted surveys to improve Leadbeater's Possum conservation

J.L. Nelson, L.K. Durkin, J.K. Cripps, M.P. Scroggie, D.B. Bryant, P.V. Macak and L.F. Lumsden

October 2017

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

Technical Report Series No. 278

Arthur Rylah Institute for environmental research

VICTORIA State Government

Environment, Land, Water and Planning

Targeted surveys to improve Leadbeater's Possum conservation

Jenny L. Nelson, Louise K. Durkin, Jemma K. Cripps,
Michael P. Scroggie, David B. Bryant, Phoebe V. Macak
and Lindy F. Lumsden

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
123 Brown Street, Heidelberg, Victoria 3084

September 2017

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

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

Citation: Nelson, J.L., Durkin, L.K., Cripps, J.K., Scroggie, M.P., Bryant, D.B., Macak, P.V. and Lumsden, L.F. (2017). *Targeted surveys to improve Leadbeater's Possum conservation.* Arthur Rylah Institute for Environmental Research Technical Report Series No. 278. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: Leadbeater's Possums photographed during targeted surveys (DELWP, ARI)

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Printed by (insert printing company name, suburb)
Edited by YYYYY

ISSN 1835-3827 (print)
ISSN 1835-3835 (pdf))
ISBN xxx-x-xxxxx-xxx-x (print)
ISBN xxx-x-xxxxx-xxx-x (pdf)

Accessibility

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DRAFT

Acknowledgements

This project was funded by the Victorian Government’s Department of Environment, Land, Water and Planning (DELWP) through the implementation of the Leadbeater's Possum Advisory Group recommendations.

We thank James Todd, Beverley Smith and Kim Lowe (DELWP) for their support and facilitation of the project.

This project could not have been done without the expertise of tree canopy specialists from Treetec led by Mark Cashmore and including Harry Cole, Dave Coleman, Matt Lee, Kyle McLoughlin, Lucas Pearce, Ben Richards, Philipp Robeck, Russell Scott and Hayden Watt.

Dan Purdey (ARI), Dave Caldwell, Claire McCall, Rena Gaborov, Aileen Collyer (all Wildlife Unlimited), Bronwyn Hradsky (Treetec) and Lisa Beilharz (DELWP) assisted with field work. Lisa Beilharz assisted with some examination of photographs.

We thank the following people for assistance with logistics and site information: Wally Notman and Nigel Brennan (Powelltown, DELWP), Kerrie Bayne (DELWP, Noojee), Geoff Kennedy (DELWP, Erica/Parkers Corner), John Towt (DELWP Toolangi), Craig Rutherford (VicForests, Noojee) and Chela Powell and Krystina Kny (VicForests, Melbourne).

This project was conducted under *Wildlife Act 1975* and *National Parks Act 1975* Research Permit Number 10006167 and 10007449, and Animal Ethics Committee approval number AEC 15/07.

DRAFT

Summary

In 2014 the Leadbeater's Possum Advisory Group made 13 recommendations to support the recovery of the Critically Endangered Leadbeater's Possum *Gymnobelideus leadbeateri* in the Central Highlands. One of these recommendations was to protect colonies by establishing timber harvesting exclusion zones, or buffers, around records from 1998 onwards and all new verified records, with individual records representing the presence of a colony at that location. To support the implementation of this recommendation, the Arthur Rylah Institute for Environmental Research commenced a 3-year program of targeted camera trapping surveys to locate new records of Leadbeater's Possums. In the first year (2014–15), surveys targeted areas of State forest predicted by modelling to have a high probability of occupancy by Leadbeater's Possum. Surveys also targeted areas close to existing records and to any new records obtained during surveys, to potentially form clusters of buffered colonies. Surveys in the second year of the targeted surveys (2015–16) followed the same approach and also surveyed areas of the species' range that were not surveyed in 2014–15. Field assessments of critical habitat elements for the possum were undertaken at all sites surveyed since the project commenced in 2014. These data were analysed to improve understanding of the habitat requirements of Leadbeater's Possum. This report summarises the results of the second year of the targeted surveys, and the results of the habitat assessments and analyses from both years of surveying. The results of the first year of targeted surveys are summarised in Nelson *et al*. (2015).

A total of 176 sites were surveyed for the presence of Leadbeater's Possum between September 2015 and April 2016, using three camera traps per site deployed for 3–4 weeks, totalling 13,196 camera-trap nights. Overall, 289 sites were sampled during the two years of targeted surveys. Site selection generally targeted forest stands containing habitat features known to be important to Leadbeater's Possum, particularly well-connected midstorey vegetation. Sites were surveyed in forest stands ranging in age from 10 to 77 years and included timber harvesting regrowth, 1983 bushfire regrowth and 1939 bushfire regrowth. Habitat assessments were undertaken on 1 ha sampling plots at sites surveyed over both years of the targeted survey program. Attributes assessed included age class, dominant eucalypt species, density and form of hollow-bearing trees, basal area of wattle (*Acacia* spp.) and extent of vegetation connectivity. Data were analysed to investigate if habitat attributes differed at sites where Leadbeater's Possums were detected compared to sites where they were not detected. Survey data were also analysed to assess the efficacy of the camera-trap survey method for detecting the species, and to evaluate the predictive performance of existing occupancy models.

In the second year of the targeted surveys, Leadbeater's Possums were detected at 99 sites (56% of surveyed sites) across all age-classes, with the highest proportion of records from multi-aged sites containing both 1939 bushfire regrowth (77 years old) and 13–29-year-old timber harvesting regrowth. Since targeted surveys commenced in November 2014, Leadbeater's Possums have been detected at 149 (52%) of the 289 sites sampled. Timber harvesting exclusion zones have been established around these sites, including 38 sites (2015–16 surveys) within areas designated for timber harvesting under the 2013–2016 Timber Release Plan. Thirty-five of the records formed part of a cluster comprising between two and 16 buffered records. These clusters have provided protection for a larger number of colonies and their habitat within close proximity, increasing the prospect for long-term persistence of the species by protecting contiguous colonies or 'neighbourhoods' rather than just individual colonies.

A total of 717 hollow-bearing trees were measured over the two years of surveying. Numbers of hollow-bearing trees per site varied from zero to 21 (average 2.5). Fifty-five percent of the sites sampled had no or very few hollow-bearing trees (0 or 1). Of the sites where Leadbeater's Possums were recorded, 25% contained no hollow-bearing trees within the 1 ha sampling plot. Camera traps detect the possums while they are moving through the forest and foraging, so these animals were most likely nesting in hollow-bearing trees in areas of their home ranges that were outside our 1 ha sampling plots. Only 28% of surveyed hollow-bearing trees met the definition of a hollow-bearing tree as defined in the Leadbeater's Possum survey standards. Although habitat assessments were limited to 1 ha, if it was assumed that similar

densities of hollow-bearing trees occurred in the 3 ha areas around each site to what we observed on the 1 ha plots, then only 2.8% of sites would meet the criteria for high quality habitat for Leadbeater's Possum (Zone 1A habitat) as defined by survey standards. Similarly, only 3.4% of the 149 sites where Leadbeater's Possums were detected over both years of surveys would meet the criteria for Zone 1A habitat. Sites where Leadbeater's Possums were detected had significantly higher basal areas of live wattle, and midstorey connectivity scores, than sites where the species was not detected.

Our results indicate that hollow-being trees are in low numbers across the areas of State forest we surveyed. The remaining hollow-bearing trees will be critical to provide denning habitat for Leadbeater's Possum in coming years. There remains however, a predicted future shortage of hollows and so it may be necessary to supplement these natural hollows using alternative approaches for providing den sites while natural hollows develop over the coming decades. Stands of multi-age forest are likely providing a mixture of older forest containing den sites in remnant large, old hollow-bearing trees and younger forest providing the dense structure required by the possums for movement, and wattles for foraging. This is consistent with the foraging requirements of Leadbeater's Possum; gum produced by wattles are an important component of the possum's diet, while structurally well-connected vegetation provides a dense layer for these small non-gliding possums to move through. These variables have also proved to be important as predictors of habitat quality for Leadbeater's Possum.

Camera trapping was found to be an effective method for detecting Leadbeater's Possum. The method we used in 2015–16 where three cameras were set for 3–4 weeks, resulted in a high probability of detecting possums on occupied sites (i.e. >0.80). The detection probability analysis showed that deploying more camera traps at each site and increasing the length of deployment, increased the probability of detection. Other covariates including the Reconyx camera model, camera height, season and camera placement, had little impact on detectability. Detection probabilities in 2015–16 were around 10% higher than when two camera traps were deployed in surveys in 2014–15, reducing the possibility of failing to detect possums on occupied sites.

Analysis of the predictive performance of the GIS-based occupancy model that was developed from survey data collected at randomly selected sites in 2012, found that this model performed poorly at predicting the presence or absence of Leadbeater's Possum at sites that were surveyed in 2014–16. The version of the model that incorporated on-site structural and habitat data improved the model's predictive accuracy, highlighting the importance of these variables as predictors of habitat quality for the possum. Spatial data layers of some of these critical habitat features are currently being developed from remotely-sensed LiDAR and infra-red imagery data. This has the potential to contribute greatly to the development of improved models for predicting the presence of Leadbeater's Possum for management purposes.

The two years of targeted surveys have been effective in locating colonies of Leadbeater's Possum which have now been protected from timber harvesting. The surveys have also provided information on the species current distribution in State forest throughout the range, the critical habitat elements present in areas occupied by the possums and some insights into the range of forest age classes used. However, due to the very targeted nature of the sampling design, these data have limited use in improving predictive models. Therefore, in the final year of the surveys in 2016-17, the sampling design will be changed with sampling in all land tenures and will include areas burnt in the 2009 bushfires, using a randomised sampling design. Once available, spatial data layers will be incorporated, together with the 2016-17 randomised survey data, into an updated occupancy model with the aim of improving capacity to accurately predict where Leadbeater's Possum occurs throughout its geographic range.

1 Introduction

Victoria's state faunal emblem, Leadbeater's Possum *Gymnobelideus leadbeateri*, is listed as Critically Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and Threatened under Victoria's *Flora and Fauna Guarantee Act 1988*. Leadbeater's Possum has a highly restricted distribution occurring in an area of approximately 70 x 80 km in the Central Highlands of Victoria, northeast of Melbourne. Most of the Leadbeater's Possum population occurs in montane ash forests, dominated by Mountain Ash *Eucalyptus regnans*, Alpine Ash *E. delegatensis* or Shining Gum *E. nitens* (Lindenmayer *et al.* 1989, Harley 2004). There is approximately 196,000 ha of montane ash forest in the Central Highlands, which accounts for 96% of the potentially suitable habitat within the species' range (Leadbeater's Possum Advisory Group 2014a).

Extensive bushfires in 2009 burnt 34% of the potentially suitable habitat for Leadbeater's Possum throughout its Central Highlands range (Leadbeater's Possum Advisory Group 2014a). Fire is a direct and indirect threat to Leadbeater's Possum, resulting in mortality, destruction of food resources, alteration of forest structure and loss of hollow-bearing trees, with the dead hollow-bearing trees that are typically used by the possums for nesting at particular risk (Lindenmayer and Possingham 1995). Leadbeater's Possum was severely impacted by the 2009 bushfires, with subsequent surveys indicating the possums failed to survive in burnt areas, irrespective of fire intensity (Lindenmayer *et al.* 2013a, Lumsden *et al.* 2013, Harley 2016).

Loss of critical habitat resources as a result of timber harvesting is also a threat to Leadbeater's Possum. About one third of the possums' potential habitat across the Central Highlands is available for timber harvesting (Leadbeater's Possum Advisory Group 2014a). During clearfelling, the traditional method of timber harvesting in Victorian ash forest, all merchantable trees are removed in a single operation, resulting in an even-aged stand of regrowth forest with few or no hollow-bearing trees. Harvest rotations are typically 60-80 years which is too short for hollows to form (hollow formation commences at approximately 120 years: Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991a). Hollow-bearing trees are therefore restricted to adjacent protected areas, parts of the coupe retained for biodiversity or operational reasons, or during retention regrowth harvesting. The dense midstorey vegetation required by Leadbeater's Possum for foraging and movement is also removed during harvesting, although this regenerates relatively quickly compared to the time taken for hollows to develop, and may become suitable within 15 years of harvesting (Smith and Lindenmayer 1992).

In 2013, the Leadbeater's Possum Advisory Group (LPAG) was established to provide recommendations that support the recovery of Leadbeater's Possum while maintaining a sustainable timber industry. A key recommendation from LPAG was to protect known Leadbeater's Possum colonies by establishing a 200 m radius timber harvesting exclusion zone around records from 1998 onwards and around all new verified records (Leadbeater's Possum Advisory Group 2014b). All 13 LPAG recommendations were accepted by the Victorian government and are currently being implemented.

As the locations of only a proportion of all extant colonies were known, a key LPAG action was to undertake targeted surveys to locate additional colonies for protection. The targeted surveys were initially planned to be undertaken over five years, but were accelerated for completion within three years to ensure that new colonies were identified and protected more quickly. The Arthur Rylah Institute for Environmental Research (ARI) was engaged to conduct the survey program, which commenced in 2014 (Nelson *et al.* 2015).

Another LPAG recommendation was to delay harvesting for two years in areas predicted to have a high probability of occupancy by Leadbeater's Possum, to enable surveys to be undertaken and colonies protected where found (Leadbeater's Possum Advisory Group 2014b). The moratorium was based on the area predicted to have a greater than 65% likelihood of being occupied by the species using an occupancy model developed from survey data collected throughout the Central Highlands in 2012 (Lumsden *et al.* 2013).

In the first year of targeted surveys (2014–15), surveys were undertaken at 113 sites across the range of Leadbeater’s Possum; new colonies were located at 50 (44%) of these sites (Nelson *et al.* 2015). Timber harvesting exclusion zones were immediately implemented to protect these colonies and their habitat. These surveys were very targeted, focusing on areas of the species’ range where the possum was predicted by the occupancy model to be most likely to occur (>65% and surrounding areas). The surveys also focused on areas with Leadbeater’s Possum records from the past 15 years (from 1998 onwards) and close to newly located colonies. This strategy of developing clusters of exclusion zones provides protection for larger numbers of colonies in close proximity, increasing the prospect for long-term persistence of the species in these areas. This is because larger, near contiguous areas of occupied habitat support more colonies of the possum, are demographically more stable and are less prone to loss of genetic diversity and extinction than a series of smaller, isolated occupied patches of the same total area (Lande 1988, Lindenmayer and Lacy 1995, Lindenmayer 2000).

A key aim of the second year of targeted surveys (2015–16) was to survey additional sites predicted to have a high probability of possums being present, and to continue to build clusters of exclusion zones by surveying habitat in close proximity to previous records. In addition, surveys in 2015–16 targeted areas of State forest that were not surveyed in 2014–15, in order to increase protection from timber harvesting for colonies across the species’ range. A secondary aim was to complete field assessments of critical habitat elements for the possum across all sites surveyed since targeted surveys commenced in 2014. These data have now been analysed, together with the survey data from both years of sampling, to build on existing habitat models that contribute to our understanding of the habitat requirements of Leadbeater’s Possum. These analyses have included an assessment of the efficacy of the camera-trap survey method for detecting Leadbeater’s Possum and an evaluation of the predictive performance of the existing occupancy models from Lumsden *et al*. (2013) when predicting the presence of Leadbeater’s Possum throughout the range.

This report summarises the results of the second year of the targeted surveys, and reports on the results of the habitat assessments and analyses from both years of surveying. Nelson *et al*. (2015) summarises the results from the first year of targeted surveys.

2 Methods

2.1 Study area

This study was conducted within the Central Highlands of Victoria, south-eastern Australia (37° 20' – 37° 56'S; 145° 26' – 146° 23'E), in the Central Highlands Regional Forest Agreement Area. Leadbeater's Possum habitat within the montane ash forest of this area ranges from 500 m to 1,300 m in altitude. The climate is characterised by mild summers and cool, humid winters. Mean annual rainfall varies from 914–1,480 mm, with periodic snow on the higher peaks (Bureau of Meteorology Online Climate Statistics, www.bom.com.au).

Twenty-one Leadbeater's Possum Management Units (LMU) have been delineated across the known range of Leadbeater's Possums within the Central Highlands to assist with management (Smith and Morey 2001, Leadbeater's Possum Advisory Group 2014b). These are based on forest blocks and factor in the extent and spatial distribution of montane ash forest in the region. Each LMU generally contains 6,000–10,000 ha of ash forest, in contiguous patches. LMUs have been used in this report to make geographic comparisons within the species' range.

2.2 Site selection

As the primary aim of the targeted surveys was to maximise the number of new Leadbeater's Possum colonies located for protection, all sites were positioned within State forest in areas available for timber harvesting, i.e. General Management Zone (GMZ) or Special Management Zone (SMZ), and in vegetation types known to be used by Leadbeater's Possum, i.e. montane ash forest (Nelson *et al.* 2015). The targeted sampling approach used in surveys in 2014–15 was again adopted in 2015–16, focusing on areas identified as most likely to be occupied by the species. This included targeting:

- unsurveyed areas modelled as 'high probability of occupancy' from ARI's spatial occupancy model (Lumsden *et al*. 2013) focusing on the greater than 65% probability areas, plus adjacent areas with lower probability of occupancy;
- locations near Leadbeater's Possum records from within the past 15 years and close to newly located colonies to develop clusters of protected colonies; and
- known hotspot areas with a high density of records (e.g. 1983 fire regrowth in the Yarra State Forest between Warburton and Powelltown).

As in 2014–15, a wide range of forest age classes (10 – 77 years) and disturbance histories were surveyed (timber harvesting regrowth, 1983 bushfire regrowth and 1939 bushfire regrowth) although timber harvesting regrowth from the last 10 years and areas burnt in 2009 were avoided as these had a lower probability of colonies being present (Lindenmayer *et al.* 2013a, Lumsden *et al.* 2013). Sites were spread throughout the species' geographic range to increase the likelihood of new protection zones in a number of different areas to spread the risk to the species from future large bushfires. In the second year of surveys, areas that were not surveyed in 2014–15 were targeted. These new areas included: State forest north east of Marysville (Rubicon State Forest, Snobs Creek Leadbeater's Possum Management Unit (LMU)); north and east of the upper Yarra Catchment (Big River and Tanjil State Forests, Big River and Thomson LMUs, respectively); north west of Noojee (LaTrobe and Noojee State Forests, Brimbonga LMU); and south of the Powelltown-Noojee Road (LaTrobe and Yarra State Forests, Tarago LMU) (see Figure 3 in the Results section for a map of these areas). These areas generally had either little or no habitat predicted to have a high probability of occupancy, hence they were not surveyed in 2014–15. However, some recent records of Leadbeater's Possum, together with a visual assessment of potential survey sites in these areas, indicated suitable habitat was present.

The camera trapping method used in these surveys (see Section 2.3 below) relies on detecting animals while they are moving through the forest and foraging. Well-connected layers of midstorey and shrub layer vegetation (including wattle i.e. *Acacia* spp.) are known to be important habitat features used by the possums for movement and foraging (Smith 1984a, Lindenmayer *et al.* 1991b, Smith and Lindenmayer 1992). As a result, site selection was targeted towards forest stands containing these habitat attributes.

2.2.1 Site selection based on the occupancy model

In 2014–15, 65 potential survey sites were delineated in areas predicted by occupancy modelling to have a greater than 65% probability of occupancy by Leadbeater's Possum. Forty-three of these sites were surveyed in that year (Nelson *et al.* 2015). In 2015–16, we aimed to survey the remaining 22 sites. Pre-survey site inspections were undertaken to determine whether sites could be feasibly accessed (i.e. were within 400 m of a track) and to assess the presence of potentially suitable habitat for the possums, especially a dense midstorey and the presence of wattles. Sites within the >65% probability area but without reasonable access and/or that lacked sufficient midstorey connectivity, were not sampled.

2.2.2 Site selection to develop colony clusters

During surveys undertaken in 2014–15, 50% of the records of Leadbeater's Possum were from sites adjacent to either existing buffered records (i.e. records from 1998 onwards with existing timber harvesting exclusion zones) or new records obtained during the surveys (Nelson *et al*. 2015). This result illustrates the efficacy of sampling areas near existing records. Targeting areas close to buffered records also provides added protection for adjacent colonies by building clusters of protected areas, increasing the prospect for long-term persistence (Lande 1988, Lindenmayer and Lacy 1995, Lindenmayer 2000). Based on the success of this strategy, a key criterion for site selection in 2015–16 was to continue sampling close to existing records. Clusters were built by locating new sites in potentially suitable habitat adjacent to existing buffered records such that any new record obtained was at least 400 m from the existing records, to reduce any overlap in buffers and hence maximise the area protected. If Leadbeater's Possums were detected in the adjacent site, then additional sites were surveyed in the surrounding area on subsequent field trips to further build up the cluster.

2.3 Survey method

As in surveys conducted in 2014–15, sampling was undertaken using camera traps set above the ground by tree canopy specialists (Treetec, Menzies Creek) working with ARI staff to identify suitable habitat and locations for camera traps at each site (Nelson *et al.* 2015). To increase the probability of detecting Leadbeater's Possums, three camera traps were deployed at each site instead of the two camera traps per site used in 2014–15. Three models of Reconyx survey cameras were used (Reconyx, Inc., supplied by Faunatech/Austbat, Bairnsdale; either Professional Series PC900 Professional Covert IR, or HyperFire Series HC600 Covert IR or HC500 Semi-covert IR), with a mixture of models generally deployed at each site, including at least one PC900 and either one or two HC600s. The distance between each camera trap was generally 50–80 m with the configuration depending on habitat present at each site – in forest stands where suitable habitat was fairly homogenous, cameras were generally set in a triangle, while in stands where suitable habitat was more linear, such as along a gully, cameras were set in a line. Camera traps were set as described in Nelson *et al.* (2015), with cameras mounted on a tree trunk and set 2–3 m from a bait station containing creamed honey (Figure 1). The bait station was located either on a suitable branch of the same tree as the camera, or on a trunk or a branch of an adjacent tree. Advanced camera settings were used including a high sensitivity level for the motion detector, five images per trigger, a RapidFire image interval and no delay between successive triggers. To avoid false triggers caused by sunlight shining directly on the face of the camera, Hyperfire cameras were set facing roughly south. Professional series cameras were programmed to turn off during the day (feature not available with Hyperfire cameras) providing more flexibility in camera placement. Camera traps were left on site for 3–4 weeks.

All camera traps were set targeting areas of well-connected vegetation where Leadbeater's Possums were likely to be moving/foraging at the height of the camera trap and could trigger the camera when moving along lateral branches, as well as when they investigated the bait station. As a result, the height at which each camera trap was set varied considerably (1.0–46.6 m), depending on the height and density of the vegetation layers at each site. The camera height, camera model, its position in the forest stand (lower storey, midstorey, upper storey), and whether the camera/bait combination was on the same tree or on different trees were recorded for each camera trap. This allowed analyses of variables related to how the camera trap was set that may influence the probability of detecting Leadbeater's Possums. However, the placement of cameras at each site was based on optimising detecting possums rather than as part of a designed experiment. Therefore, our ability to infer causal relationships between these various aspects of camera placement and the resulting probabilities of detection was limited.

After the cameras were retrieved, images were downloaded and thoroughly scrutinised for the presence of Leadbeater's Possum. Other species seen in the images from each site were also documented. Records of all species detected during the surveys have been uploaded to the Victorian Biodiversity Atlas.

Figure 1. Tree canopy specialist setting a camera trap consisting of a Reconyx survey camera (circled left) set 2–3 m from a bait holder containing creamed honey (circled right).

2.4 Habitat assessments

A key component of the targeted surveys was to improve the understanding of Leadbeater's Possum's habitat requirements. To achieve this, measurements of habitat attributes known to be strongly correlated with the presence and abundance of Leadbeater's Possum were collected at each site. These included age class, dominant eucalypt species, density and form of hollow-bearing trees, basal area of wattle and extent of vegetation connectivity (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b; Lumsden *et al*. 2013). Hollow-bearing trees were assessed based on the definition of mature or senescent, ash, hollow-bearing trees used for Zone 1A or 1B habitat identification in the Leadbeater's Possum survey standards (DELWP 2015). Trees were also assessed using an ecological criterion that included any tree that contained hollows and hence may provide den sites for Leadbeater's Possum, irrespective of the age or species of the tree. This means that non-eucalypts, such as Myrtle Beech *Nothofagus cunninghammii* were also recorded, although the extent of the use of such hollows by Leadbeater's Possum is unknown. These data allowed an evaluation of the availability of potential denning resources for Leadbeater's Possum at each site.

2.4.1 Measurement of habitat attributes

At each site sampled by two (in 2014–15) or three (in 2015–16) cameras, a site centroid was determined at the point equidistant between the cameras, and a 1 ha (100 x 100 m) square habitat sampling grid was generated, centred over the site centroid, with grid margins running north-south and east-west. A central transect through each grid had sampling points at 20 m, 40 m, 60 m and 80 m (S1-S4, Figure 2).

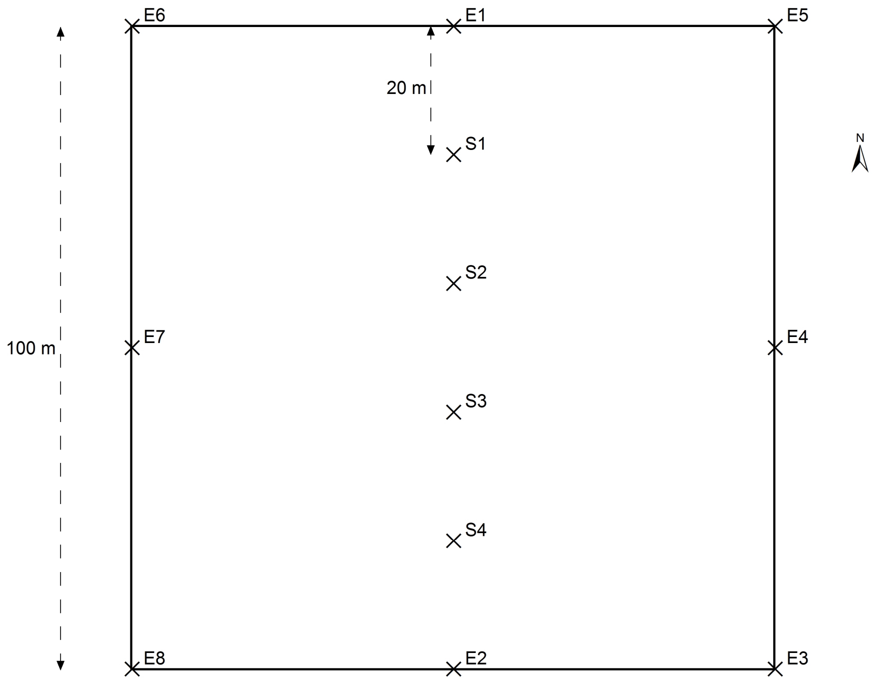

Figure 2. One hectare habitat sampling grid used to assess habitat variables at the Leadbeater's Possum survey sites. Sampling grids were oriented over the centroid of each site with the grid margins running north-south and east-west. Four sampling points S1-S4 were aligned along a central transect. The edge of the grid was delineated by points at the corners and at 50 m along each boundary (E1-E8).

The age of the forest stand within each 1 ha sampling grid was determined using a combination of mapped fire and timber harvesting history, and ground-truthing while conducting habitat assessments. Forest age is reported as the number of years since the last stand-replacing disturbance event, whether that be fire or timber harvesting. Salvage logging after the 1939 and 1983 bushfires occurred to varying degrees on some sites. However, as the stand replacing event was the fire, sites were classified as fire regrowth. Sites affected by disturbance events that did not kill the dominant cohort of trees (i.e. 1939-cohort trees with a very low severity fire in 2009) were assigned to the most recent stand-replacing disturbance event (in this case 1939 bushfire regrowth, or stand age of 77 years). Sites were considered multi-aged when two or more age cohorts were present within the 1 ha sampling grid and each cohort comprised more than 10% of the grid.

The dominant eucalypt species was recorded within each grid and all trees that were greater than 40 cm diameter at breast height (DBH) were examined with binoculars for the presence of fissures and hollows. Data were collected on every hollow-bearing tree, including tree species, DBH, tree height (using a rangefinder, Nikon Forestry Pro), hollow type (i.e. trunk hollow, spout, fissure, broken top) and height above ground of the most prominent hollow, UTM coordinates of each hollow-bearing tree, and notes including any typical Leadbeater's Possum keyhole entrances or visible nesting material. The form of the hollow-bearing tree was also recorded using a 1–8 scale (based on Lindenmayer *et al.* 1991a: 1, mature, living tree; 2, mature, living tree with a dead or broken top; 3, dead tree with most branches still intact; 4, dead tree with 0-25% of the top broken off, branches remaining as stubs only; 5, dead tree with the top 25-50% broken away; 6, dead tree with the top 50-75% broken away; 7, solid, dead tree with ≥75% of the top broken away; 8, hollow stump). A category of '0.5' was added to record hollow-bearing trees that were not yet 'mature', using the definition of 'mature' in the Leadbeater's Possum survey standard (DELWP 2015). Each measured tree was also classified into one of two categories, either a 'survey standard' hollow-bearing tree or an 'ecological' hollow-bearing tree. Live survey standard trees were defined as mature or senescent Mountain Ash, Alpine Ash and Shining Gum with hollows greater than 3 cm entrance size, and dead survey standard trees were those more than 6 m in height and greater than 1.5 m DBH (DELWP 2015). Any hollow-bearing tree that fell outside those definitions was termed an ecological hollow-bearing tree.

At points S1-S4 along the central transect of each grid (Figure 2), basal area of live and dead wattles and eucalypts were measured with a basal area wedge prism (Department of Environment and Climate Change and Water 2010) and the contributing species recorded for each. At points S1-S4, vegetation connectivity in a 10 m-radius plot was scored on a 0–3 scale at the understorey, midstorey and canopy layers, and the contributing species at each layer recorded. These scores aimed to represent the ease with which a Leadbeater's Possum could move through the vegetation. They were defined as: 0 (connectivity was absent; 1 (connectivity present, but minimal); 2 (connectivity present but not continuous, Leadbeater's Possums could move around relatively easily but may need to use multiple layers); and 3 (connectivity continuous, Leadbeater's Possums could move easily through that layer). Each site assessment thus resulted in a mean m^2ha^{-1} of live and dead wattles, live and dead eucalypts, and a mean understorey, midstorey and canopy connectivity score.

2.5 Data analysis

2.5.1 Analysis of habitat attributes

To investigate if habitat measurements differed at sites where Leadbeater's Possum was detected compared to sites where the species was not detected, we used a Wilcoxon rank sum test of the mean basal area of live and dead wattles, live and dead eucalypts, and connectivity scores for each layer, at each site. We also used Wilcoxon rank sum tests to compare the total number of hollow-bearing trees and the number of live and dead hollow-bearing trees, at sites where the possums were detected and sites where they were not detected. All results were considered significant if $P < 0.05$.

2.5.2 Assessing the probability of detection using camera traps

Over the two years of survey, data were available from 289 survey sites. At each site, either two (2014–15 surveys) or three (2015–16 surveys) camera traps were deployed for 3–4 weeks. Each group of two or three cameras deployed within a site was treated as a single site for the purpose of occupancy modelling. Daily detection histories (one or more Leadbeater's Possum detected or not during each 24-hour period) for each individual camera were compiled (detection or not each night). Examination of the data, together with observations of images of possums collected from camera traps set opposite artificial hollows (ARI unpublished data), indicated it was highly likely that individual possums habitually and repeatedly used particular paths through the forest. Statistically, this would mean that nightly detection histories would be serially dependent, and that different cameras at the same site could have large and consistent differences in their probabilities of detecting Leadbeater's Possum, due to the extent to which each camera's detection zones coincided with locations regularly used by possums. Attempts to account for this between-camera variability using camera-level random effects terms in the detection model were unsuccessful (the statistical models consistently failed to converge), probably because of the limited replication associated with having only two or three cameras at each site, and the inherent uncertainty in the true occupancy states of sites where no detections were made.

Because of the apparent non-independence in nightly detection, for the purposes of analysis, the nightly detection histories for each camera were collapsed down to a single detection/non-detection. The detection data for each site was therefore simply condensed down to whether or not each of the cameras deployed at the site detected Leadbeater's Possum over the full period cameras were deployed. The length of each camera's deployment (number of nights cameras were deployed) was used as a measure of survey effort.

Conditional on occupancy of a site by Leadbeater's Possum, the probability of detection at each camera per night was modelled as being dependant on the camera model used, to allow for possible variation in the detection characteristics of the three camera models:

$$\text{logit}(p_{ij}) \sim \beta_0 + \beta_1 * \text{Cam600}_{ij} + \beta_2 * \text{Cam900}_{ij}$$

where p_{ij} is the probability of detecting a possum during the course of the entire survey period at the i^{th} site, using the j^{th} camera, β_0- β_2 are regression parameters associated with the three camera models used (model numbers HC500, HC600 and PC900 respectively, and $Cam600_{ij}$ and $Cam900_{ij}$ are binary covariates, coding for the use of camera models 600 and 900 (use of camera model 500 was treated as the default level of the regression, so is encoded in the intercept term, β_0).

A priori, occupancy of all sites was considered equally likely for the purposes of assessing detectability using the camera trapping methodology. In reality, sites varied in perceived habitat quality, but as the focus of this part of the analysis was the assessment of detection probabilities using arboreal camera traps, we treated all sites as equally likely to be occupied by Leadbeater's Possum – this should have little impact on the estimates of detection probability obtained from the analysis, as the variation attributable to differences in occupancy among sites is determined by the model's occupancy parameter. As the sites surveyed were a highly biased and non-independent sample of locations within the range of Leadbeater's Possum, we did not include covariates in the occupancy component of the model. In any case the purpose of the model was to assess detection probabilities using the camera trapping survey method, not to produce a model for explaining or predicting occupancy more broadly.

We used the Bayesian state-space formulation of the basic, single-season occupancy model (i.e. assuming no difference between seasons), as described by Royle and Kery (2007). The detection model was fitted to the data using Bayesian methods, implemented in the software 'Just Another Gibbs Sampler' (JAGS, Plummer 2003).

As camera traps are typically deployed for a period of 3–4 weeks, rather than a single night, the quantity of interest for assessing the performance of the survey method were the overall probabilities of detection after a 3 or 4–week deployment. For each single camera, this quantity can be computed from the nightly detection probability (p) using the equation:

$P_{cam} = 1 - (1\text{-}p)^{N}$

Where N is the number of nights surveyed, p is the nightly detection probability for the specified camera model (see equation above), and P_{cam} is the overall detection probability for a single camera after N nights.

In turn, the overall predicted probability of detection when using multiple cameras at the same site, can be calculated from P_{cam} using the equation:

$$P_{TOT} = 1 - \prod_{j=1}^{j=k}(1 - P_{CAMj})$$

where P_{CAM} is the predicted detection probability for a single camera, and k is the number of cameras deployed. The quantities P_{CAM} and P_{TOT} were calculated within JAGS, so that the uncertainty in the estimates of the parameters from which they were derived was propagated into the estimates of these parameters. This was done by generating a replicate value from the posterior of P_{CAM} and P_{TOT} at each update of the Markov Chain Monte Carlo (MCMC) algorithm that was used to fit the model to the data. Collectively, these repeated estimates of P_{CAM} and P_{TOT} can be considered as samples from the joint posterior probability distributions of these derived parameters – we are hence able to obtain both point estimates and estimates of uncertainty such as standard errors and Bayesian credible intervals for these parameters from the distribution of MCMC samples thus obtained.

Some additional, more complex models were also fitted to the data, allowing for camera-level covariates to influence the probabilities of detection for each camera deployment. Effects of the height at which cameras were placed, the height of the tree on which the camera was placed, placement of cameras relative to baits (on the same tree, or on an adjacent tree) and effect of a seasonal trend in detectability (using the midpoint date of deployment) were all examined as part of the model fitting process.

2.5.3 Testing predictive performance of existing occupancy models for Leadbeater's Possum

We used Receiver Operating Characteristic (ROC) analysis, a widely used, threshold-independent method for evaluating binary classification models (Vaughan and Ormerod 2005, Elith *et al.* 2006) to examine the performance of the occupancy models for Leadbeater's Possum from Lumsden *et al.* (2013) when predicting the presence of Leadbeater's Possum at the camera trapping sites.

ROC curves are widely used in the evaluation of the ability of probabilistic species distribution models to predict presence/absence of species. A ROC curve involves plotting the sensitivity of the model's predictions (proportion of true presences correctly predicted as presences) against 1 minus the model's specificity (proportion of true absences correctly classified as absences), for each of a range of threshold values of the predicted probabilities of presence at the test sites (which in this case are the 289 sites sampled during the 2014–16 targeted surveys). The information in an ROC curve is typically summarised by computing the area under the curve (AUC) statistic. As the predictive performance of a model increases, the AUC statistic approaches a value of one, while a model with very poor predictive performance will have an AUC statistic close to 0.5 (Hanley and McNeil 1982). Approximate 95% confidence intervals on the AUC statistics were calculated using a non-parameter bootstrap with 1000 random resamples with replacement from the observed occupancy states, and the predicted probabilities of occupancy derived from the models in Lumsden *et al.* (2013).

The occupancy models for Leadbeater's Possum outlined in Lumsden *et al.* (2013) were constructed from presence/absence data collected at a stratified sample of 180 sites across the species' geographic range in 2012. The survey method used was call playback, with detection often assisted by a thermal imaging camera. The occupancy models accounted for the imperfect detection probabilities inherent in the survey method, by using repeated surveys at each of the sites to infer for, and correct for non-detection of the species at sites that were in fact occupied (MacKenzie *et al.* 2002).

The predictive performance of two existing occupancy models were evaluated – firstly, the model presented by Lumsden *et al.* (2013). This model related occupancy of Leadbeater's Possum to mapped (GIS) habitat variables only, including broad ecological, climatic and environmental variables. A second model was also developed incorporating habitat data collected at each call playback site, which extended the spatial model to include habitat variables of known importance to Leadbeater's Possum, including hollow-bearing tree abundance, midstorey connectivity, and abundance of wattle. The first model had the advantage that it was possible to generate spatial predictions of occupancy across the entire species' range from the mapped habitat variables. However, this model was not able to use information on small-scale structural features of the habitat. The second model, which included habitat variables measured at the study sites, could not be used to generate spatial predictions of occupancy, as no GIS layers were available for these habitat variables. Comparison of these two models demonstrated the likely superiority of the model that included on-site habitat variables in terms of model parsimony (as assessed using Akaike's Information Criterion) (ARI unpublished data). This led to a prediction that the model including on-site habitat variables would produce substantially more accurate predictions of occupancy at newly surveyed sites within the species' range, than the model based solely on GIS variables.

The availability of a large body of new survey data collected as part of the targeted surveys in 2014–15 and 2015–16 provided an opportunity to test the performance of the two models, and to test the prediction that the model with on-site habitat variables would provide more accurate predictions of species presence at the newly sampled sites.

Predicted probabilities of occupancy at each of the camera trapping sites from the surveys in 2014–16 were generated using the equations of the two occupancy models fitted to the call-playback survey data collected in 2012, as outlined in Lumsden *et al.* (2013). Equivalent covariate values for the camera trapping sites were obtained from the same GIS layers, and from the locally-measured habitat variables at the camera trapping sites, using the same methodology as was used for collection of habitat data during the surveys in 2012. For each camera trapping site, the centroid of the two or three camera-trap locations was determined from the GPS fixes of each camera location and this location was used as the reference point for predicting probability of occupancy from the models (i.e. this was the point at which the GIS layers were queried).

The predicted probabilities for the two models, and the observed occupancy states (detected/not detected) for each camera trapping site were tabulated. As the detection probability analysis indicated that there was a very high probability (typically >0.8, see Results) of detecting Leadbeater's Possum if they were present on a site using the level of camera trap surveying that was undertaken (see Results Section 3.5), for the purpose of ROC analysis it was assumed that the detection or non-detection of Leadbeater's Possum at each site reflected the actual occupancy state of the site. It is possible though that some false negative assignments of sites to the unoccupied category may have occurred, especially at sites with lower levels of survey effort (i.e. only two cameras deployed, or shorter camera deployments).

ROC curves were computed from the predicted probabilities and observed presence/absences using the *R* statistical package (R Core Team 2016), using the functions provided in the package *ROCR* (Sing *et al.* 2005). For each model, sensitivity (the proportion of true positives actually predicted) was plotted against specificity (proportion of true negatives actually predicted), and the area under the ROC curve (AUC) was calculated. Approximate 95% confidence limits of the AUC for each model were calculated using a non-parametric bootstrap approach.

3 Results

3.1 Survey results

Overall, 176 sites were surveyed for the presence of Leadbeater’s Possum between September 2015 and April 2016 (Figure 3), resulting in a total of 13,196 camera-trap nights. Sites were spread throughout the species’ range, including some areas that were not surveyed in 2014–15. Over 286,990 photographs were obtained and scrutinised for images of Leadbeater's Possums and other arboreal mammals (e.g. Figure 4), with Leadbeater’s Possums detected at 99 sites (56% of surveyed sites).

Since the targeted surveys commenced in November 2014, 289 sites have been surveyed for Leadbeater’s Possum (Figure 3). Over these two years of surveys, the species was detected at 149 of the sites surveyed (52%). The proportion of sites where Leadbeater’s Possum was detected in the second year of surveys (56% of sites) was higher than in the first year (44%).

In 2015–16, records of Leadbeater’s Possum were obtained from throughout the species’ range. Leadbeater’s Possum Management Units with the highest proportions of records were generally in the south of the range between Warburton and Noojee (Powelltown, Ada and Brimbonga LMUs) and in the south east of the range on the Toorongo Plateau and east of Mount Baw Baw National Park (Toorongo, Baw Baw and Thomson LMUs), with up to 80% of sites sampled detecting Leadbeater’s Possums in some LMUs. In contrast, there were fewer records from LMUs in the north west of the range, particularly the adjacent Toolangi and Narbethong LMUs where together the species was detected from less than 20% of surveyed sites (Table 1).

Of the 176 sites surveyed in 2015–16, 54 were in areas designated for timber harvesting under the 2013–2016 Timber Release Plan. Leadbeater’s Possum was detected at 38 of these sites (70%). Timber harvesting exclusion zones have now been established and harvesting will not occur within these areas. When combined with the results from the first year of sampling, Leadbeater's Possums were recorded from 55% of the 96 sites sampled on the Timber Release Plan. This was at a similar rate to the detection at sites outside of the Timber Release Plan (50% of 193 sites).

Leadbeater's Possum was recorded at a range of heights above the ground, from low in the understorey layer to the eucalypt canopy (2.3–24.5 m above the ground, at an average height of 8.2 m). Of the 99 sites with possum detections in 2015–16, possums were detected by one of the three cameras at 45% of sites (45 sites), by two cameras at 33% of sites (32 sites) and by all three cameras at 22% of sites (22 sites). The average time to first detection on a camera at each site was night 6.8 (range 1–23). In 2014–15 when two cameras were deployed at each site, the average time to first detection was similar at 7.4 (range 1–26 nights). Over both years of survey, cameras were generally deployed for at least 3 weeks. At most (86%) of the 149 sites with Leadbeater’s Possum detections, possums had been detected by the end of the second week of survey. However, at three sites, possums were not recorded until the 26th, 23rd and 22nd nights of survey, respectively, and hence would not have been detected at the site if the cameras had only been deployed for 3 weeks. The influence of the number of cameras deployed on survey sites and the length of camera deployment on the probability of detecting the possums is fully explored in Section 3.6 below.

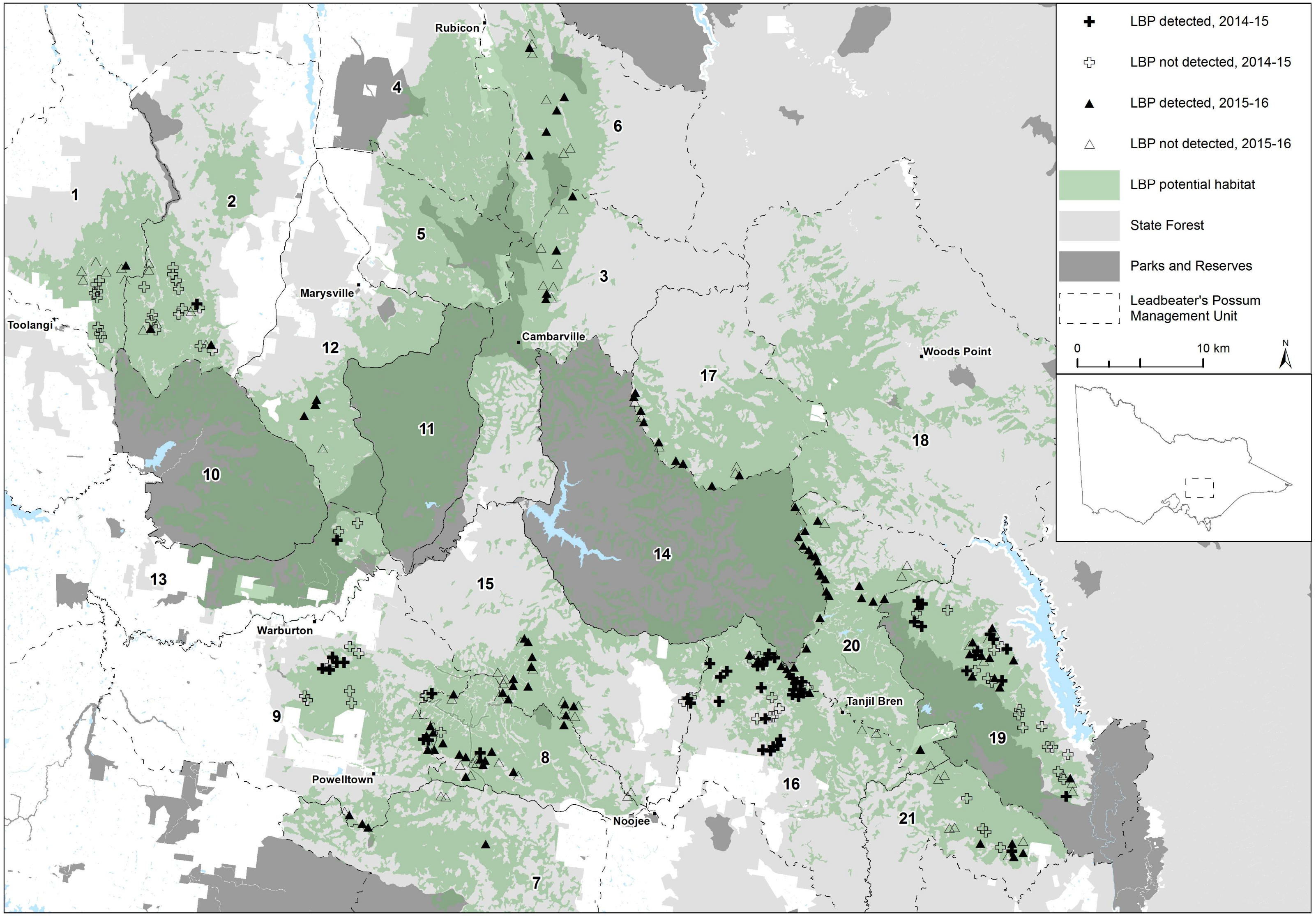

Figure 3. Leadbeater's Possum (LBP) survey sites in Leadbeater's Possum Management Units, showing where the species was detected over two years of surveys in the Central Highlands, November 2014 – April 2016.

Results from surveys conducted in 2014-2015 are indicated by crosses (black crosses display detections, clear crosses display survey sites where Leadbeater's Possums were not detected). Results from 2015–16 surveys are indicated by triangles (black triangles display detections, clear triangles display survey sites where Leadbeater's Possums were not detected). Potential Leadbeater's Possum habitat is shown in green. See Table 1 for Leadbeater's Possum Management Unit names.

Figure 4. Two Leadbeater's Possums detected during camera trap surveys, Toolangi State Forest, October 2015.

Table 1. The number of sites surveyed for Leadbeater's Possum (LBP) using camera traps, and the proportion of Leadbeater's Possum detections in Leadbeater's Possum Management Units across the species' Central Highlands range, September 2015 – April 2016.

Not all LMUs were surveyed as some are entirely within parks and reserves.

Leadbeater's Possum Management Unit	No. of sites	No. of sites with LBP detections	% of sites with LBP detections
1. Toolangi	7	1	14
2. Narbethong	9	2	22
3. Cambarville	10	4	40
6. Snobs Creek	12	5	42
7. Tarago	3	1	33
8. Ada	21	11	52
9. Powelltown	11	8	73
12. Marysville	4	3	75
14. Upper Yarra	1	1	100
15. Brimbonga	22	12	55
16. Toorongo	8	6	75
17. Big River	14	9	64
19. Baw Baw	18	11	61
20. Thomson	26	21	81
21. Tyers	10	4	40
Total	**176**	**99**	**56**

3.2 Detections in relation to occupancy model

In 2014–15, 43 of a possible 65 sites delineated with a greater than 65% probability of occupancy were surveyed for Leadbeater's Possum leaving 22 sites for survey in 2015–16. Only five of these sites were surveyed; the remaining 17 sites were either inaccessible, or were considered unsuitable habitat. Leadbeater's Possums were detected at four of these five high probability of occupancy sites.

Most of the sampling in 2014–15 focused on areas with higher predicted probabilities of occupancy (i.e. >50%), leaving many lower predicted probability of occupancy areas unsurveyed. As unsurveyed areas were targeted in 2015–16, this increased the number of sites surveyed in the lower occupancy categories, providing a pool of sites in each category for assessing the predictive accuracy of the occupancy model (see Section 3.7 Assessing Model Performance). Overall, during the two years of survey, Leadbeater's Possums were detected from a similar proportion of sites in the 30–50%, 50–65% and >65% categories with detection rates of 52–58% across these three categories. In contrast, Leadbeater's Possums were detected at fewer sites (41%) in the lowest probability of occupancy category (Table 2).

Table 2. The number of sites Leadbeater's Possums (LBP) were detected in four categories of probability of occupancy (as predicted by occupancy modelling in Lumsden *et al*. 2013), November 2014 – April 2016.
At 25 sites the camera traps straddled boundaries of occupancy model categories. Where this occurred, the site was assigned based on which category occupied the greatest proportion of the area within 200 m of the site centroid.

Predicted probability of occupancy	No. of sites	No. of sites LBP detected	% of sites LBP detected
0–30%	75	31	41
30–50%	81	47	58
50–65%	85	46	54
>65%	48	25	52
Total	**289**	**149**	**52**

3.3 Colony clusters

To develop clusters of colonies for protection, 73 sites were surveyed that were either close to existing buffered records (1998 onwards) or to new records obtained during the targeted survey program. Leadbeater's Possums were detected at 43 of these sites (59%). Buffered records were considered to be part of the same cluster if the edges of adjacent timber harvesting exclusion zones were within 100 m of each other. Overall, 35 colony clusters have been developed consisting of between two and 16 timber harvesting exclusion zones. Eleven of the 35 clusters consisted of four or more buffers. Clusters were spread throughout the species' range with at least one cluster located in 12 of the 15 LMUs containing survey sites. The LMUs with the highest number of clusters were Baw Baw (5 clusters), Brimbonga (5 clusters), and Toorongo (7 clusters).

3.4 Habitat assessments

3.4.1 Forest age

Sites were surveyed in forest stands ranging in age from 10 to 77 years and included timber harvesting regrowth, 1983 bushfire regrowth and 1939 bushfire regrowth. Ecotones between different-aged stands were often sampled to target areas where Leadbeater's Possums had access to both younger forest for foraging and older forest that may contain remnant large, old trees, for denning. Sites were considered multi-aged when two or more forest age cohorts were present and comprised more than 10% of the 1 ha habitat assessment grid.

Of the 289 1 ha sites surveyed, 212 (73%) were single-age forest stands, and 77 (27%) consisted of two age-classes of forest (Table 3). Leadbeater's Possums were detected across all age classes of forest sampled.

The highest detection rates were from multi-aged sites with 1939 bushfire regrowth (77 years old) and 13–38-year-old timber harvesting regrowth, and from 1983 bushfire regrowth (33 years old), with possums detected at 62% and 59% of sites surveyed in these categories, respectively. The age cohorts with the lowest detection rates were single-aged stands of logging regrowth (39–57 years old) and 1939 bushfire regrowth, with possum detections on 41% and 44% of sites surveyed, respectively (Table 3).

Table 3. The forest age cohorts and most recent stand-replacing disturbance events within 1 ha survey sites, and the number and proportion of Leadbeater's Possum detections in the Central Highlands, November 2014 – April 2016.

Last stand-replacing disturbance event	Stand age (years)	No. sites	No. LBP detections	% of sites LBP detected
1939 bushfire	77	120	54	45%
1983 bushfire	33	39	23	59%
1959 – 1977 timber harvesting	39–57	17	7	41%
1978 – 2005 timber harvesting	11–38	36	18	50%
1939 bushfire + younger timber harvesting regrowth	77 & 13–38	63	39	62%
1939 bushfire + older timber harvesting regrowth	77 & 39–50	14	8	57%
Total		**289**	**149**	**52%**

3.4.2 Habitat attributes

Of the 289 sites surveyed for Leadbeater's Possum during the two years of targeted surveys, habitat assessments were completed at 287 sites between April 2015 and May 2016. Habitat assessments were not undertaken at two sites due to access constraints.

The abundance of all hollow-bearing trees (both eucalypt and non-eucalypt) across the 287 sites varied from zero to 21 (mean per site 2.5 for the combined survey standard and ecological hollow-bearing trees). No hollow-bearing trees were recorded on the 1 ha sampling grid at 104 sites (36%) and only one hollow-bearing tree on 54 sites (19%). Only 28% of surveyed hollow-bearing trees met the criteria for designation as a 'survey standard' hollow-bearing tree under the definition in the Leadbeater's Possum survey standards (DELWP 2015). Eighty-seven sites (30%) contained survey standard trees. Ninety-six sites (33%) only had ecological hollow-bearing trees – i.e. trees with hollows that did not meet the definition of a relevant hollow-bearing tree in the survey standards (DELWP 2015). Only eight sites (2.8%) had four or more live survey standard trees on the 1 ha sampling grid. Although habitat assessments were limited to 1 ha, if it was assumed that similar densities of hollow-bearing trees occurred in the 3 ha areas around each site to what was observed on our 1 ha plots, then only 2.8% of sites would meet the criteria for high quality habitat for Leadbeater's Possum (Zone 1A habitat) as defined by the survey standards. In total, 717 hollow-bearing trees (both categories) were measured. The average DBH of live hollow-bearing trees was 143 cm (n = 303, SD = 67.4, range 44–407 cm) and 132 cm (n = 414, SD = 66.5, range 41–350 cm) for dead hollow-bearing trees. The average height of a hollow in a tree was 9.1 m (SD = 9.0, range 0–51 m).

The abundance of hollow-bearing trees (both eucalypt and non-eucalypt) on the 149 sites where Leadbeater's Possums were detected ranged from 0–21. Forty-eight of these sites (32%) contained no

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hollow-bearing trees. Of the 101 sites where hollow-bearing trees were recorded, 48 contained survey standard trees and 53 contained only ecological hollow-bearing trees. Only 3.4% of the 149 sites where Leadbeater's Possum was detected would have met the criteria for Zone 1A habitat (extrapolating our 1 ha plots to 3 ha). On average, there were slightly more hollow-bearing trees on sites where Leadbeater's Possums were detected (average per site 2.83, range 0–21), compared to sites where the possums were not detected (average per site 2.17, range 0–18) (W = 9061.5, P = 0.07; Figure 5), but this difference was not significant.

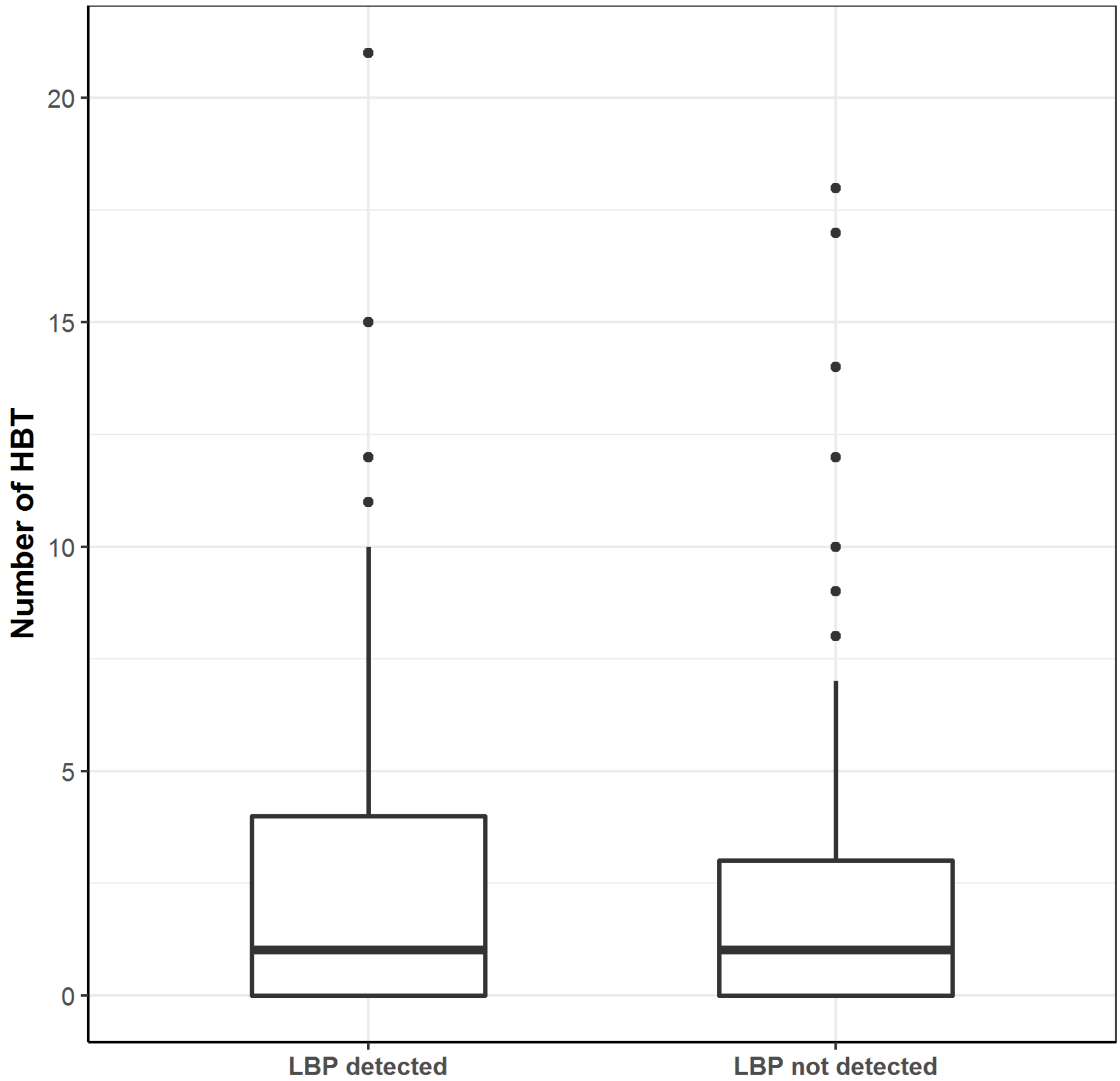

Figure 5. Boxplot of the number of hollow-bearing trees (HBT) counted on 1 ha plots at sites where Leadbeater's Possum (LBP) was and was not detected.
The bottom and top of each 'box' indicates the 25th and 75th percentiles respectively, with the black horizontal line indicating the median value. Black dots are outliers representing sites with large numbers of hollow-bearing trees, compared to the majority of other sites.

At sites where Leadbeater's Possums were detected, there was a slightly higher density of dead hollow-bearing trees (eucalypt and non-eucalypt; 1.7/ha, range 0–11) compared to live hollow-bearing trees (eucalypt and non-eucalypt; 1.1/ha, range 0–13). Hollows were recorded in eucalypts, acacias and in Myrtle Beech. At some sites, several large hollow-bearing Myrtle Beech were measured (mean DBH = 74.7cm, range 0–13). The average density of dead hollow-bearing eucalypt trees was twice that of live hollow-bearing eucalypt trees (1.7/ha, range 0–11; and 0.8/ha, range 0–8, respectively) on sites containing Leadbeater's Possums.

There were similar numbers of live hollow-bearing trees on sites where possums were detected compared with sites where the species was not detected (*W* = 9804.5, *P* = 0.45; Figure 6). There was no significant difference in the number of dead hollow-bearing trees on sites with or without possum detections (*W* = 9179, *P* = 0.08). However, the distribution of the dead hollow-bearing tree data at sites with and without Leadbeater's Possum detections does appear to differ somewhat (Figure 6). Sixty-two per cent of hollow-bearing trees on occupied sites were dead, compared to 52% on unoccupied sites.

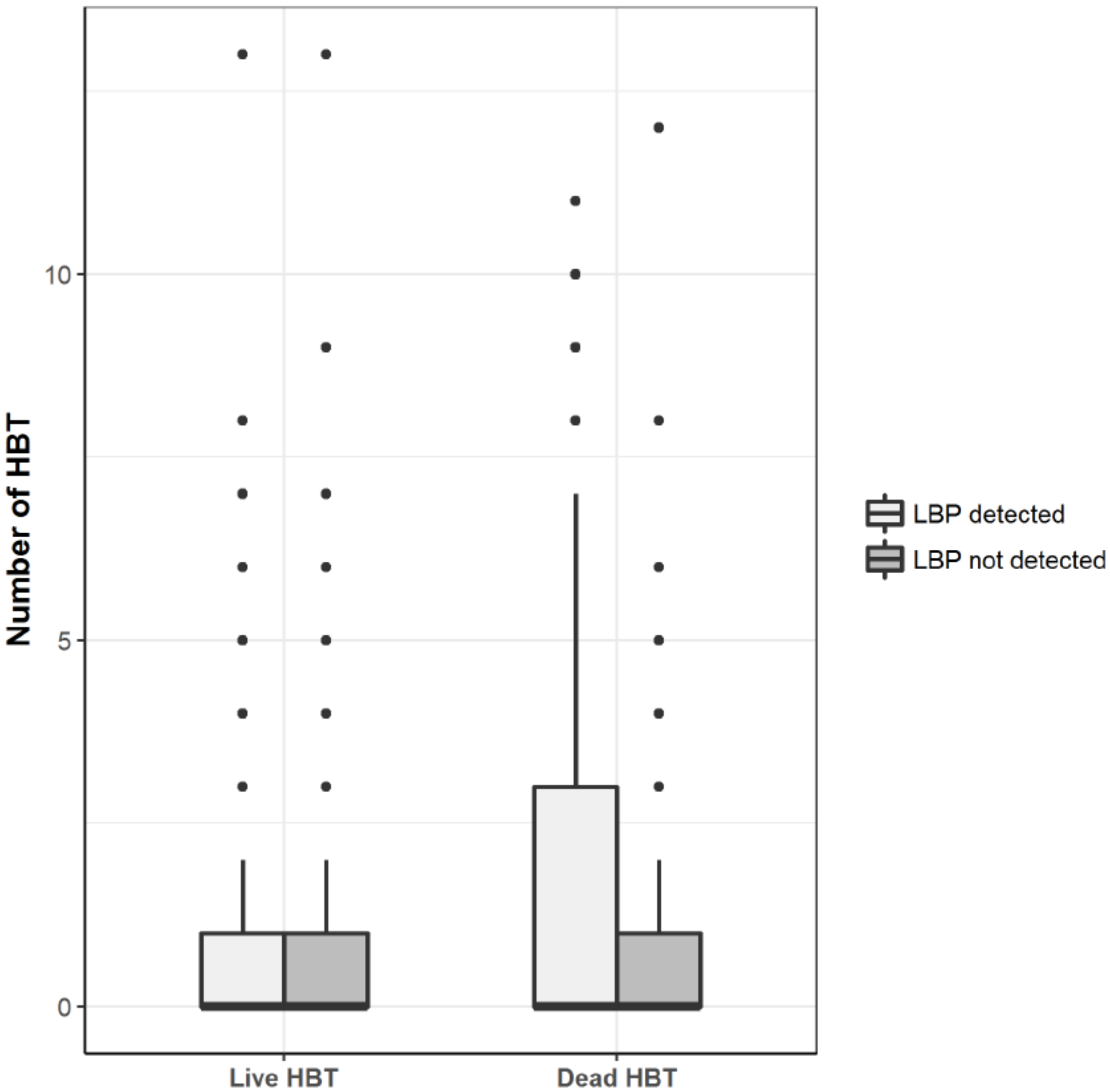

Figure 6. Boxplot of the number of live and dead hollow-bearing trees (HBT) counted on 1 ha plots at sites where Leadbeater's Possum (LBP) was (light grey) and was not (dark grey) detected.
The bottom and top of each 'box' indicates the 25th and 75th percentiles respectively, with the black horizontal line indicating the median value. Black dots are outliers representing sites with large numbers of hollow-bearing trees, compared to the majority of other sites.

Comparison of other habitat variables measured at sites where Leadbeater's Possums were and were not detected over the two years of the survey found that the basal area of live wattles was 30% higher on sites where the possums were detected, and this difference was significant (*W* = 8713, *P* = 0.03; Figure 7). However, there was no significant difference in the basal area of dead wattles (*W* = 1050, *P* = 0.76), live eucalypts (W = 1098, P = 0.32) or dead eucalypts (W = 1027, P = 0.98) on sites where Leadbeater's Possums were or were not detected.

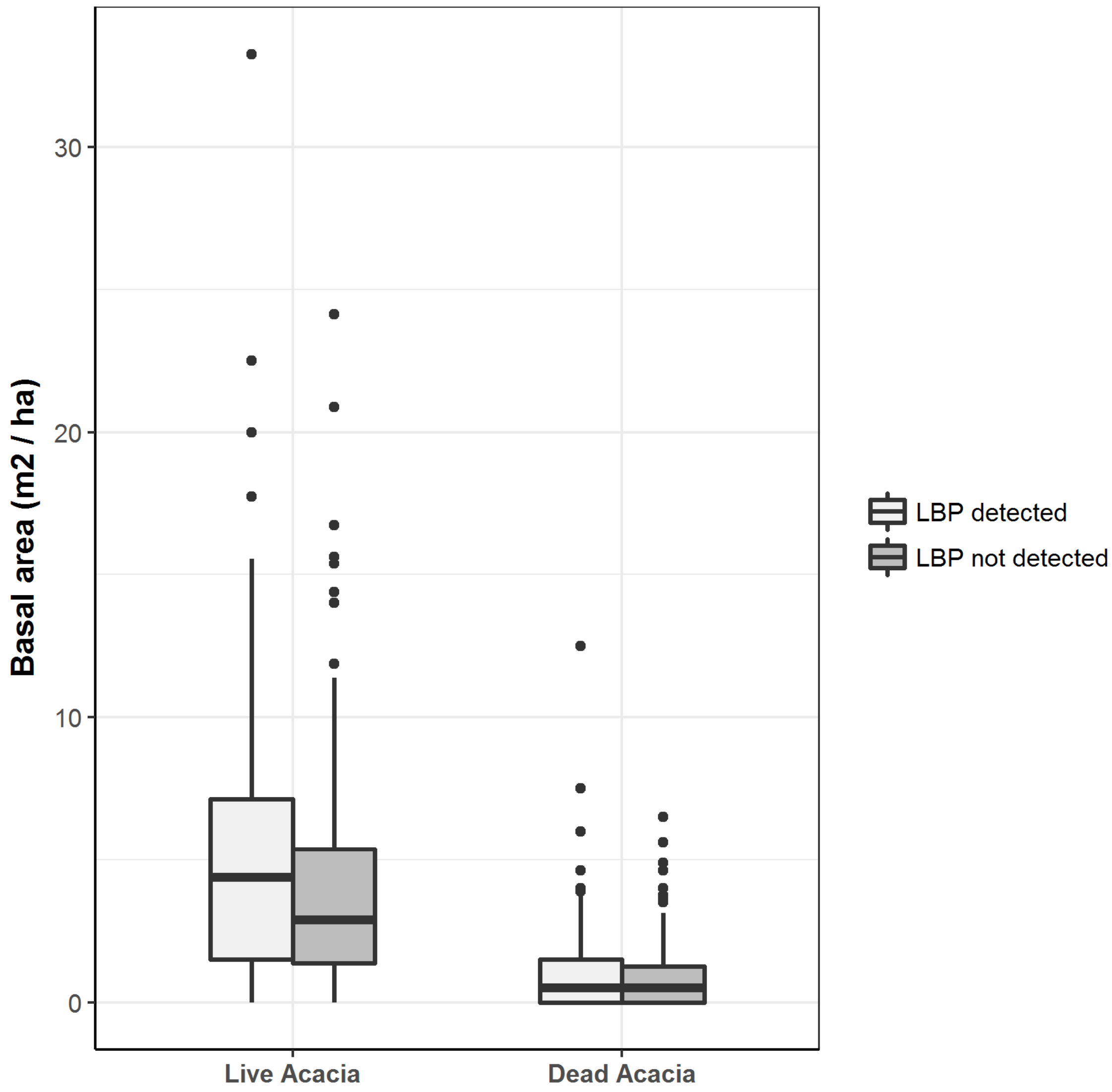

Figure 7. Boxplot of the basal area (mean m^{2}ha^{-1}) of live and dead wattles (*Acacia* spp.) collected from survey sites with (light grey) and without (dark grey) Leadbeater's Possum (LBP) detections.
The bottom and top of each 'box' indicates the 25th and 75th percentiles respectively, with the black horizontal line indicating the median value. Black dots are outliers representing sites with large numbers of hollow-bearing trees, compared to the majority of other sites. The basal area of live wattles is significantly higher at sites where Leadbeater's Possums were detected compared to sites with no Leadbeater's Possum detections.

The midstorey connectivity scores were also significantly higher on sites where Leadbeater's Possums were detected (W = 7383, P <0.0001; Figure 8). There was no significant difference in connectivity scores at the understorey (W = 9404, P = 0.21) or canopy layers (W = 10896, P = 0.38) on sites where the possums were detected, compared with sites where there were no possums detected.

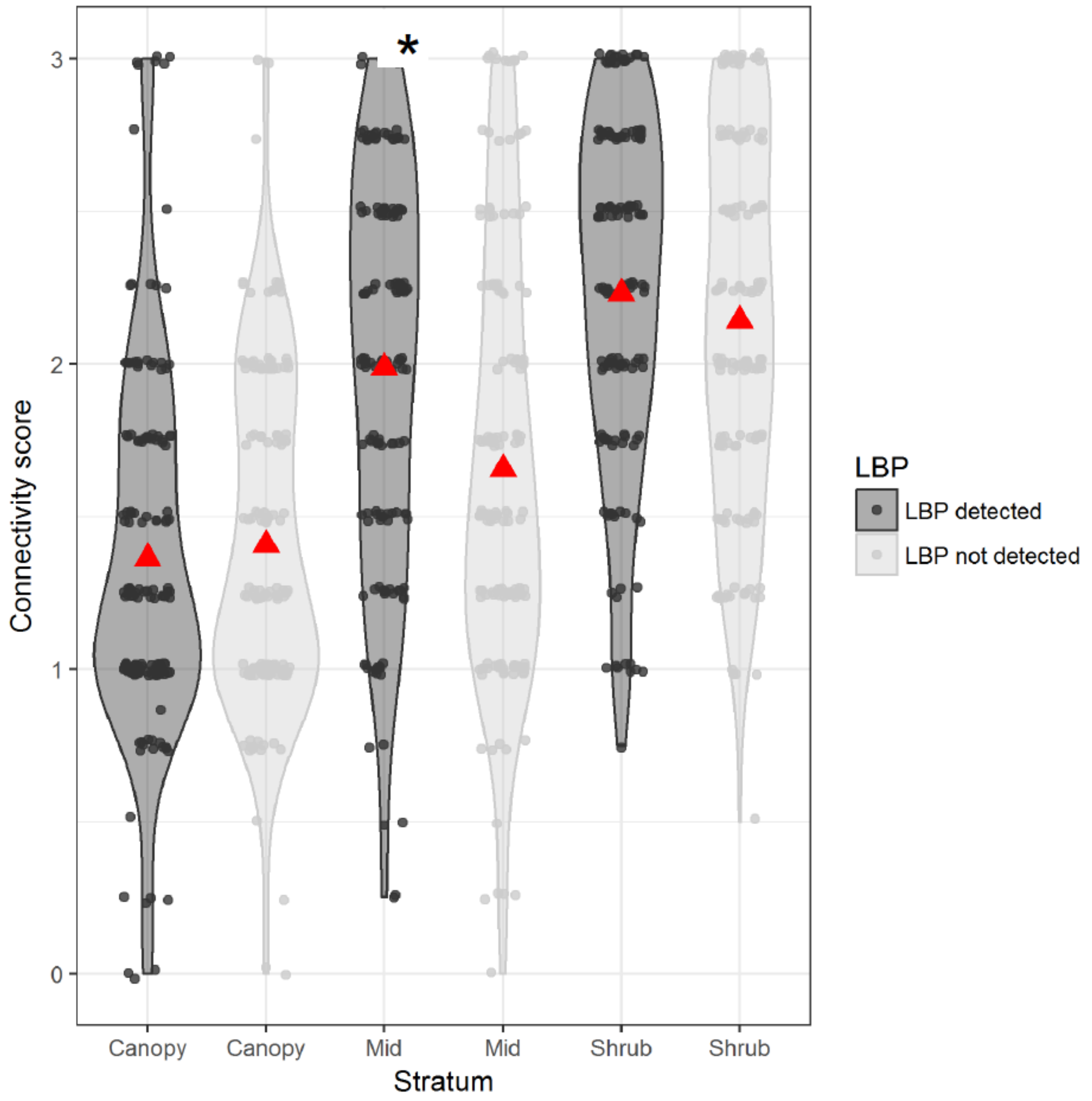

Figure 8. Mean connectivity scores (red triangles) for the Canopy, Midstorey (Mid) and Shrub layers, collected from survey sites with and without Leadbeater's Possum (LBP) detections.
The raw data is displayed for sites with Leadbeater's Possum detections (dark grey) and sites where Leadbeater's Possums were not detected (light grey). The violin-plots give the estimated distribution of the data. Midstorey connectivity scores are significantly higher at sites where Leadbeater's Possums were detected compared to sites with no Leadbeater's Possum detections (indicated by an *).

3.5 Probability of detection using arboreal camera traps

Exploratory fitting of the detection probability models revealed that the additional covariates associated with camera and tree height, whether the camera and bait were on the same tree or on different trees, and date of deployment (to detect any seasonal patterns) had a negligible influence on detectability. Accordingly, the quantitative results presented here are restricted to estimates of detection probability derived from the initial, simple model that only included the effect of camera trap model on the probabilities of detection. Estimates of the probabilities of detection for deployments using one, two or three cameras at a single site, deployed for a period of three or four weeks are given in Figure 9. In general, the detection probabilities associated with the three camera trap models were similar (Figure 9). There was some indication that the probability of detection for camera traps of model PC900 was slightly lower than those for models HC500 and HC600, although the credible intervals of the estimates overlapped somewhat, suggesting that any difference was quite small. After 21 days of sampling with a single camera trap, the expected probabilities of detection for the three models were in the range 0.37–0.54, while deployments of two or three cameras (the usual operational approach) resulted in overall probabilities of detection of 0.61–0.79, and 0.75–0.90 respectively. After 4 weeks of sampling, detection probabilities were slightly higher with two or three camera traps at 0.75–0.87, and 0.87–0.95 respectively. It is therefore concluded that deployment of three camera traps for periods of at least 3 weeks should result in a very high probability of detecting Leadbeater's Possums at sites where the species is present.

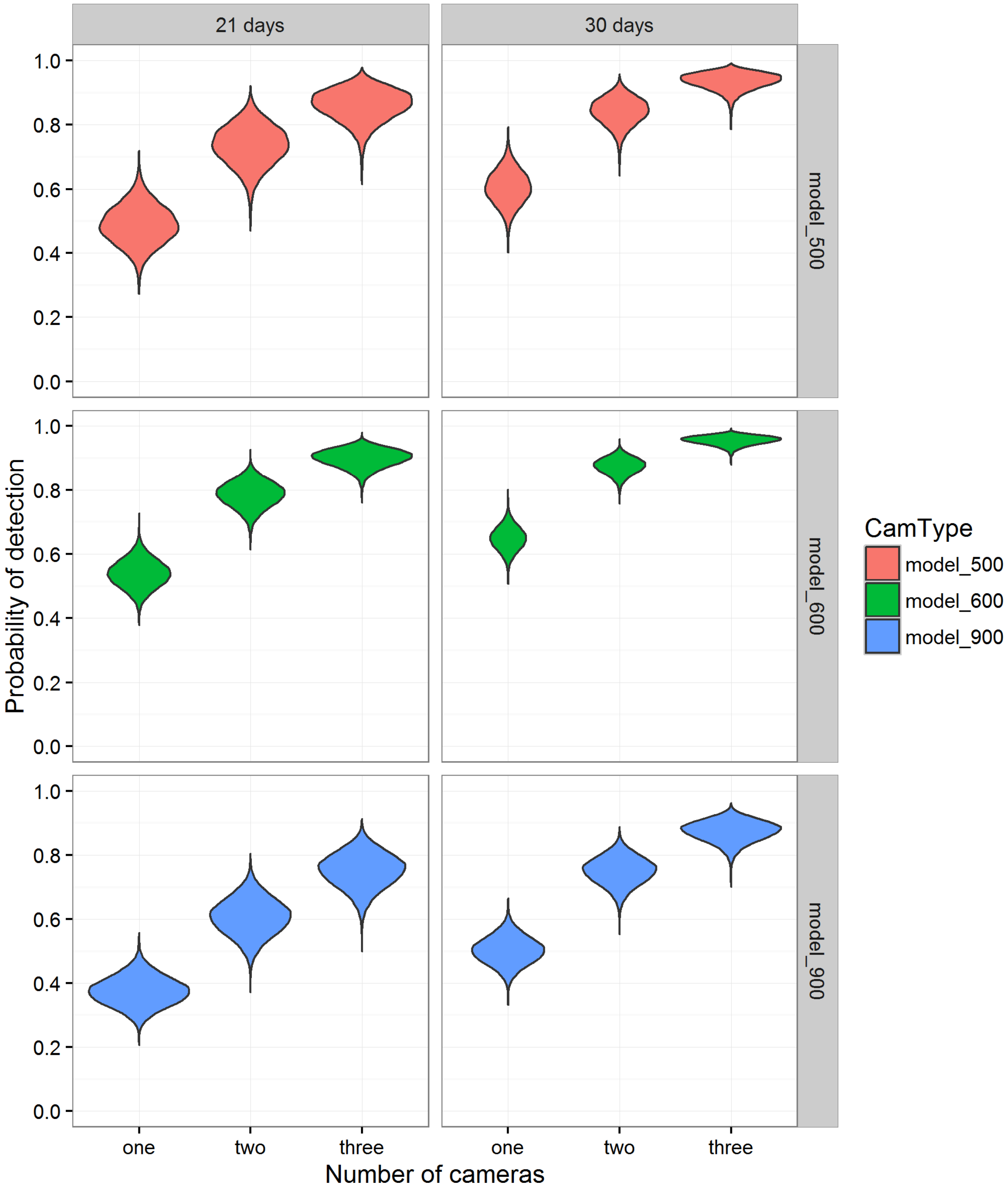

Figure 9. Estimates of the probability of detecting Leadbeater's Possum using one, two or three camera traps with three different models of Reconyx survey cameras after 21 and 30 days of sampling.
Model_500 = HC500, model_600 = HC600, model_900 = PC900. The violin-plot gives the estimated posterior distribution of the detection probabilities, and are derived from the MCMC samples of the parameters generated during the fitting process (see Methods section 2.5.2).

3.6 Assessment of model performance

ROC curves were computed from the modelled predicted probabilities of occupancy by Leadbeater's Possum and the observed presence/absences at the 2014–16 camera trapping sites for the two models developed from the survey data collected in 2012 as outlined in Lumsden *et al.* (2013) and the observed presence/absences at the 2014–16 camera trapping sites. For each model, sensitivity (the proportion of true positives at the 2014–16 camera trapping sites actually predicted) was plotted against 1-specificity (proportion of true negatives at the 2014–16 camera trapping sites actually predicted), and the area under the ROC curve (AUC) was calculated. For reference, a diagonal line, indicating an AUC of 0.5, and thus predictive performance no better than random was superimposed. These curves are presented in Figure 10.

For the model based solely on mapped GIS variables fitted to data collected in 2012 (Lumsden *et al.* 2013), the ROC analysis revealed a very poor predictive capacity (AUC = 0.524), where an AUC of 0.5 implies a model with very poor predictive capacity. The bootstrap 95% confidence interval for the AUC included 0.5, meaning the GIS-based occupancy model was no better than random at predicting occupancy at the sites surveyed in 2014–16 (Figure 10). Conversely, the model that incorporated habitat variables measured on-site had moderately good, but still imperfect predictive ability (AUC = 0.656). The bootstrap 95% confidence interval on the AUC for this model did not include 0.5, indicating that the predictive ability of the model for the sites sampled in 2014–16 was significantly better than random (Figure 10).

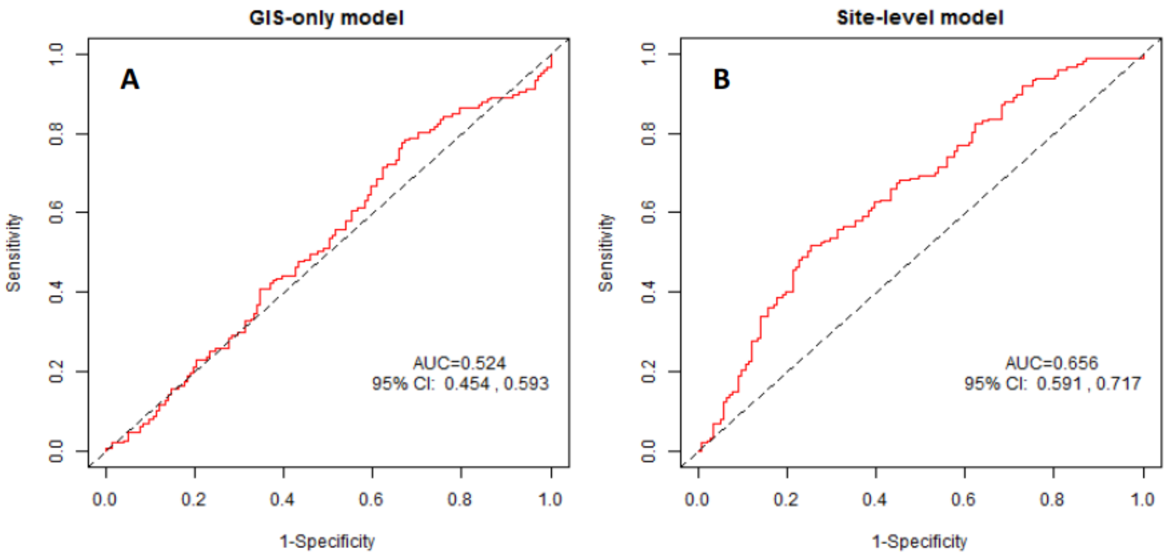

Figure 10. Receiver Operating Characteristic (ROC) curves showing the estimated predictive performance of the two occupancy models for Leadbeater's Possum fitted to the 2012 survey data (Lumsden *et al.* 2013) at the sites surveyed during the current camera trapping surveys. A. the occupancy model based only on available GIS data. B. The model that also included on-site habitat assessment data.

The area under the curve (AUC) statistic for each model is overlaid on each plot at bottom right. The larger the AUC, and the greater the deviation of the red line from the dotted line (indicating an AUC of 0.5), the greater the predictive performance of the model – models with an AUC of 0.5 have a very poor predictive performance.

4 Discussion

4.1 Survey results

In the second year of the Leadbeater’s Possum targeted surveys, the species was detected at 99 of the 176 sites surveyed (56%) between September 2015 and April 2016. Since the targeted surveys commenced in 2014, we have detected Leadbeater’s Possums at 149 of the 289 sites surveyed (52%). In 2015–16, detections were spread throughout the species’ range with the highest detection rates from the south and south-east of the range. Timber harvesting exclusion zones have been established around these 99 records, protecting at least 1,200 ha of forest habitat. Since the targeted surveys commenced in 2014, approximately 1,800 ha has been protected in timber harvesting exclusion zones. Forty-four percent of the 2015–16 records formed part of a cluster of exclusion zones. Overall, 35 colony clusters have been developed over the two years of targeted surveys. The multiple contiguous timber harvesting exclusion zones established around each of the colonies within these clusters increases the prospect for long-term persistence of the species by protecting ‘neighbourhoods’ rather than just individual colonies. These neighbourhoods support more colonies, so are less prone to loss of genetic diversity and extinction than a series of smaller, isolated buffered colonies of the same total area (Lande 1988, Lindenmayer and Lacy 1995, Lindenmayer 2000).

Timber harvesting exclusion zones were established around the 38 colonies located in 2015–16 surveys in coupes designated for harvesting under the 2013–2016 Timber Release Plan (TRP). Over the two years of the targeted surveys, the rate of detecting Leadbeater's Possums in coupes on the TRP was similar to that of sites outside the TRP, with the species detected on 55% of sites surveyed in TRP and 50% of sites surveyed outside the TRP. This result highlights the importance of pre-harvest surveys for Leadbeater’s Possum so that protective measures can be implemented prior to harvesting in areas where the species occurs.

4.2 Influence of forest age on Leadbeater's Possum occurrence

While the majority of sites surveyed over the two years were single-age stands, 27% were multi-aged consisting of two age-classes of forest. Leadbeater’s Possums were detected across all age-classes of forest surveyed, with the highest proportion of records from multi-aged sites with 1939 bushfire regrowth (77 years old) and 13 – 38-year-old timber harvesting regrowth, and from 1983 fire regrowth (69% and 58% of surveyed sites respectively). Ecotones between older and younger forest stands were often targeted during the surveys as these stands provided a mixture of older, unharvested forest that may contain den sites in the form of remnant large, old trees, and younger forest which provided the dense structure required by the possums for movement and wattle for foraging (Smith 1984a, Smith and Lindenmayer 1992). These critical resources are also present in the stands regenerating after the 1983 fires, with fire-killed stags providing den sites and a dense midstorey including wattle providing movement pathways and foraging habitat.

In contrast, our lowest detection rates were in single-aged stands of 39–57-year-old timber harvesting regrowth and in 1939 bushfire regrowth. In some of the single-age stands regenerating after the 1939 bushfire, many fire-killed stags that remained standing after the fire have now collapsed (Lindenmayer *et al*. 1990, Lindenmayer *et al.* 2012) and the density of the wattle has started to decline (Adams and Attiwill 1984). The decline of wattle opens the midstorey, reducing vegetation connectivity and the availability of wattle gum for food and, together with the loss of large stags, reduces the suitability of these stands for the possums (Smith and Lindenmayer 1992, Lindenmayer and Possingham 1995). In single-aged timber harvesting regrowth, the number of older hollow-bearing trees that were retained in the harvested area as wildlife habitat is also likely to have declined as these trees often have limited longevity, with accelerated rates of collapse due to exposure and the impact of the high-intensity regeneration burns applied after harvesting (Lindenmayer *et al.* 1990, Gibbons and Lindenmayer 1996). As in the 1939 regrowth, the wattle present in older timber harvesting regrowth may also have declined, further reducing the suitability of these stands for the possums. Despite this, we detected Leadbeater's Possums on approximately 40% of the sites we surveyed in these single-aged stands, indicating that some still provide suitable habitat and support colonies of the possums. However, it is important to note that we deliberately targeted forest stands containing what we assessed as suitable habitat for the species, particularly dense midstorey vegetation. Our detection rates in different aged forest stands should therefore be interpreted with caution as they may not be indicative of the habitat suitability of these stands more generally.

4.3 Influence of habitat variables on Leadbeater's Possum occurrence

The abundance of hollow-bearing trees (using both the ecological and survey standard definitions) across all sites surveyed during the two years of targeted surveys varied from zero to 21, with an average of 2.5 per 1 ha site. No hollow-bearing trees were recorded on almost 40% of sites and two or fewer hollow-bearing trees on 64% of sites. In comparison, Lindenmayer *et al.* (2016) reported two or fewer hollow-bearing trees on approximately 50% of their 166, 1 ha long-term monitoring sites within the montane ash forests of the Central Highlands, with an average of five hollow-bearing trees per site. Hollow-bearing trees are a critical resource for Leadbeater's Possum, providing shelter and breeding sites (Lindenmayer *et al.* 1991a, Smith and Lindenmayer 1988). While the sites surveyed by Lindenmayer *et al.* (2016) were spread across land tenures, all our survey sites were located in State forest available for timber harvesting, which may indicate a difference in hollow availability across tenures. However, as neither our sites nor the Lindenmayer *et al.* (2016) sites were randomly selected, it is not valid to extrapolate more broadly.

Most (72%) of the hollow-bearing trees we measured did not meet the criteria for a hollow-bearing tree as defined by the Leadbeater's Possum survey standards (DELWP 2015). High quality habitat for Leadbeater's Possum (Zone 1A) is defined as areas where there are more than 10 live mature or senescent hollow-bearing ash trees per 3 ha, in patches greater than 3 ha (DELWP 2015). Although our habitat measurements were only taken over 1 ha, extrapolating our results out to 3 ha revealed that only 2.8% of all surveyed sites would have met the criteria for Zone 1A habitat (and probably lower once the requirement for trees to be less than 100 m apart is incorporated). In addition, only 3.4% of the 149 sites where Leadbeater's Possums were detected would have qualified for protection as Zone 1A habitat. Together, these results suggest that there are now only very limited areas that qualify as Zone 1A habitat within the State forest General Management Zone and that the possums are occupying many areas that would not qualify for protection under this management prescription for reserving habitat for the species.

Sites where Leadbeater's Possums were detected had a higher basal area of live wattles, and higher midstorey connectivity scores than sites where the species was not detected. This is consistent with the known habitat requirements of Leadbeater's Possum; gum produced by wattles is an important component of the possum's diet, and structurally well-connected vegetation provides a dense layer for these small non-gliding possums to move through (Smith 1984a, Lindenmayer *et al*. 1991b, Smith and Lindenmayer 1992). Several other studies have similarly found a strong positive relationship between the basal area of wattles, degree of connectivity in the understorey and the presence and abundance of Leadbeater's Possum (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b, Smith and Lindenmayer 1992). There is also a well-established positive relationship between the presence and abundance of Leadbeater's Possum and the number of hollow-bearing trees (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991a, Lindenmayer *et al.* 2013a). In contrast, while sites where we detected Leadbeater's Possums had higher numbers of hollow-bearing trees than sites where there were no detections, particularly dead hollow-bearing trees, this difference was not significant. Furthermore, 25% of sites with possum detections had no hollow-bearing trees. Leadbeater's Possum colonies occupy home ranges of 1–3 ha (Smith 1984b), so it is likely that our 1 ha habitat sampling plots only sampled part of the resident possums' home ranges and, because the camera trapping survey technique detects animals while they are moving through the forest and foraging, were focused on foraging areas. As a result, the den trees of the possums we recorded were presumably outside of our 1 ha sampling plot. Despite this, our results indicate that even in areas occupied by the possums, hollow-bearing trees are far from abundant. In addition, approximately 60% of the hollow-bearing trees on occupied sites were dead. These dead trees are more susceptible to collapse than live trees, further limiting the available denning resource in the future (Lindenmayer and Possingham 1995, Lindenmayer *et al.* 2012).

High rates of death and collapse of large, old hollow-bearing trees is currently occurring in the Central Highlands, with projections that the number of these trees will have declined from 5.1 per hectare in 1998 to ~0.6 per hectare by 2067 (Lindenmayer *et al.* 2013b). We recorded an average of 2.8 hollow-bearing trees on our 1 ha plots at sites where we detected possums, almost half of the number reported by Lindenmayer *et al.* (2013b) as being present across their sites in 1998. The remaining large, old trees in the Central Highlands will be critical for providing denning habitat for Leadbeater's Possum into the future. Given that the predominant oldest age-class of live trees is 77-year-old regrowth originating from bushfires in 1939, hollows will be in short supply until these trees begin to form natural hollows, which is predicted to occur after 120 years of age (Lindenmayer *et al*. 1991a). This will lead to a bottleneck in hollow availability in the next 50 years and an associated higher extinction risk (Todd *et al.* 2016). Alternative approaches to provide den sites to supplement existing hollows, such as creating artificial hollows and the targeted use of nest boxes, are currently being trialled and implemented to support the persistence of Leadbeater's Possum colonies in the coming decades until more natural hollows become available (Leadbeater's Possum Advisory Group 2014a, Commonwealth of Australia 2016, Harley 2016).

4.4 Probability of detection using arboreal camera traps

The analysis showed that surveys for Leadbeater's Possums using three camera traps deployed per site for 3–4 weeks should result in a high overall probability of detecting Leadbeater's Possum, regardless of the model of Reconyx survey camera deployed (Figure 9). Although detection probabilities for surveys in 2014–15 when two camera traps were deployed at each site were relatively high, the higher detection probabilities associated with using three cameras at each site as in 2015–16, reduced the likelihood of failing to detect possums on occupied sites (i.e. false negative results). Longer deployments also increased the probability of detection. Although Leadbeater's Possums were mostly detected by at least one of the cameras at a survey site by the end of the second week of deployment, in a small number of cases, possums were not detected until the fourth week of deployment. At these sites, a 3–week deployment would have resulted in false negative errors. As a consequence, no timber harvesting exclusion zones would have been implemented and these sites would have remained available for timber harvesting.

The apparent lack of a seasonal effect on the probability of detection suggests that any seasonal variation in foraging behaviour of Leadbeater's Possum does not translate into meaningful variation in the possums' propensity to encounter and be detected by the camera traps. This result gives a measure of flexibility when planning camera trapping surveys, as the seasonal timing of field work should have little impact on probabilities of detection. Nevertheless, it is recommended that as additional camera trapping data for Leadbeater's Possum is accumulated, further modelling of seasonal, weather and other possible survey-level causes of variation in detection probability is undertaken as a part of any analysis of survey results, in case there are some subtle effects that were not uncovered during the current analysis. It is also important to note that this lack of a seasonal effect only applies to those months during which the camera trap data were actually collected (September – May). Extrapolation of these results to winter, when no sampling was undertaken during the current study, would not be appropriate.

The analysis also showed no meaningful effects of camera position on the probability of detection. Adding camera height, tree height and whether or not the camera was on the same or an adjacent tree to the bait led to no improvement in the model, suggesting that these factors had little influence on detectability. However, as cameras were placed in locations judged to be the most likely to yield detections of possums, a more rigorous experimental design, would be required to confirm these findings.

As the camera trapping method used in this study was found to yield high probabilities of detection, we can be confident that future camera trapping surveys conducted using the same approach should be able to detect the presence of Leadbeater's Possum on sites with high confidence. The results therefore confirm the findings of a previous study that suggested that camera traps were potentially an effective survey tool for Leadbeater's Possum (Harley *et al.* 2014).

4.5 Assessment of the performance of the existing occupancy model

The collection of new survey data on Leadbeater's Possum enabled an examination of the predictive accuracy of the existing occupancy models developed in 2012 (Lumsden *et al*. 2013). The ROC analysis of the predictive performance of the GIS-based spatial occupancy model found that this model performed poorly at predicting the presence or absence of Leadbeater's Possum at the sites that were surveyed using camera trapping during the current study. The occupancy model that included site structural and habitat variables had a better predictive performance, indicating the importance of these variables as predictors of habitat quality for Leadbeater's Possum.

The finding that the model based solely on GIS variables had poor predictive performance was perhaps not unexpected for a number of reasons. Firstly, the sites that were surveyed during the current camera trapping surveys were not a random sample of habitats within the geographic range of Leadbeater's Possum, but a highly biased and clustered subset of sites chosen to maximise the likelihood of detecting the species. At the outset, all surveyed sites were considered potentially suitable for occupancy by Leadbeater's Possum, with few if any sites being inherently unsuitable for the species. This included sites that the model predicted were of low habitat quality on the basis of mapped GIS variables, but that were judged by field staff to have attributes that predisposed them to occupancy by the species. In contrast, the sites selected for the 2012 study were randomly selected, and included a wide range of sites of varying suitability. As the sites surveyed during the present study were not drawn from a similar statistical population to the sites on which the model was built, the model might not have been expected to have strong predictive capability.

Secondly, some of the sites that were surveyed using camera traps were selected because they were in close proximity to sites that were already known to be occupied by Leadbeater's Possums. Even if these sites were of low habitat quality, and/or were predicted to have low probabilities of occupancy by the GIS-based model, the presence of extant populations in close proximity would increase the chances that possums would be present, due to their ability to disperse from adjacent, known-to-be-occupied habitats.

Thirdly, several sites that were surveyed during the current study were located within the mapped boundary of the 2009 fires, with mapping suggesting they had been burnt. However, when ground-truthed, these sites were found to be unburnt, or only partially burnt. Given that the existing occupancy models for Leadbeater's Possum included a strong, negative effect of the 2009 bushfire on the probability of occupancy, and other studies confirm a strongly negative impact of this fire on occupancy by Leadbeater's Possum (Lindenmayer *et al.* 2013a) it is unsurprising that the model would make inaccurate predictions about the probability of occupancy for sites that while mapped as burnt, were in reality unburnt or only partially burnt.

Finally, the model based solely on GIS variables did not include any useful information on several habitat attributes known *a priori* to be important in determining habitat quality for Leadbeater's Possum. In particular, the GIS-only model did not include any direct information on the presence or abundance of hollow-bearing trees, important structural attributes of the forest such as mid- and shrub-layer connectivity, or the availability of important food resources such as wattles. That a model that lacked these important attributes performed poorly when used for prediction at new sites is therefore unsurprising.

The improved performance of the model that included site-level structural and habitat variables illustrates the importance of accurate spatial understanding of these components of habitat to accurately predict the distribution of Leadbeater's Possum. Further work to develop GIS layers from remote sensing data (LiDAR - Light Detection and Ranging - and infrared imagery technologies) has the potential to provide measurements of some of these critical aspects of habitat quality for Leadbeater's Possum. Such GIS layers can hopefully lead to the development of improved distribution models with better predictive accuracy. LiDAR in particular is well suited to remotely identifying structural habitat features of importance to arboreal fauna such as midstorey structure and the presence of large, old trees (Vogeler *et al.* 2013, Garabedian *et al.* 2014, Owers *et al.* 2015), so this is a promising area of research that can contribute greatly to the aim of developing better methods for predicting the presence of Leadbeater's Possum for management purposes. Current work to develop LiDAR based structural habitat GIS layers for the Central Highlands is being undertaken at present (DELWP 2016).

Further occupancy surveys of Leadbeater's Possum using the camera trapping survey methodology presented here could contribute to improved occupancy models by providing more data to fit models to. This would have the most benefit if sites were selected using stratified random sampling. This would ensure that sites were included with a wide variety of attributes, representative of the range of habitat within the species' range. The possibility of sampling in habitat types and land tenures that are under-represented in the occupancy data collected to date would also improve the representativeness of the data.

4.5 Future directions

The number and spread of sites where we detected Leadbeater's Possum over the two years of the targeted survey program indicate that the possum is currently widespread across much of the State forest within the Central Highlands, particularly in the southern part of the range. Although we surveyed a wide range of forest age-classes with different disturbance histories throughout the range, our site selection was largely targeted towards areas we assessed as being suitable habitat for the possums or close to existing buffered records. In addition, all sites were located in State forest, with none in conservation reserves, or in areas burnt in the 2009 bushfires. As a result, while detecting possums at 52% of the sites we surveyed is encouraging, this result cannot be used to infer the likely proportion of occupied sites throughout the species' entire range.

In the first two years of targeted surveys, the primary aim was to maximise the number of new Leadbeater's Possum colonies located for protection within State forest. In 2016-17, the final year of the targeted survey program, the survey design will aim to provide information on the distribution, status and habitat requirements of the species across the full range of available habitat throughout the Central Highlands. To maximise improvements to the occupancy model, sampling will follow a stratified, randomised design (as per Lumsden *et al.* 2013), with an estimated 150 new sites to be surveyed. While the majority of sites will be in unburnt State forest to continue locating new colonies for protection, sites will also be surveyed in conservation reserves (i.e. parks and reserves, Special Protection Zones) and in areas burnt in the 2009 bushfires. Key outcomes will be improved capacity to accurately predict where Leadbeater's Possums occur throughout their range in areas that have not been surveyed, and increased understanding of habitat requirements and the current relationship between species presence and the presence and abundance of critical habitat elements.

Camera trapping was found to be an effective method of detecting Leadbeater's Possum and surveys in 2016–17 will continue to use this method. To provide a high level of confidence that the possums will be detected at sites where they occur (i.e. minimise the chance of false negatives), three camera traps will be deployed at each survey site for four weeks.

As outlined in the previous section, a key requirement for improving the predictive performance of occupancy models is to incorporate spatialised habitat data that are currently unavailable. This would ideally include spatial data for the availability of hollow-bearing trees, abundance of wattles, and structural variables indicative of connectivity in various forest strata. If current research efforts to construct such layers from LiDAR and other remote-sensed data sources are successful, then it is anticipated that spatial predictive models with much higher predictive performance than is currently available will be able to be constructed. Once available, such spatial data layers will be incorporated into updated spatial occupancy models, together with the 2016-17 randomised survey data.

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Document 9

From: s22
To:
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]
Date: Monday, 13 November 2017 1:22:19 PM
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Thanks s22

The straightforward corrections of fact or expression I'm doing now, but any that are actual "decisions" (like the population size estimate) I'll wait until it goes to TSSC and see what they have to say.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Sunday, 12 November 2017 2:35 PM
To: s22
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

good to catchup the other day. here are just a few thoughts and comments. Let me know if anything not clear.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E** s22 @delwp.vic.gov.au

www.ari.vic.gov.au

s47C - deliberative material

s47C

From: s22 @delwp.vic.gov.au]
Sent: Thursday, 2 November 2017 12:23 PM
To s22
Cc
Subject: Re: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

Happy to help. I am at the physio at moment as I injured my knee last week. Can give you a ring after 2 pm

Bye

s22

On 2 Nov. 2017, at 11:48 am, s22 @environment.gov.au> wrote:

Thanks very much for this. I am most appreciative of having people who really know the detail and can point out the errors. Most of it I can deal with reasonably well…

The one I struggle with is the recovery post-fire. I think I might have come up with a solution, but if you're in and well-rested now I wouldn't mind running it by you.

If so, let me know what's a good time to call you. I'll be out of the office from 12:15 until 2:00pm, but otherwise available as far as I can tell.

****

s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275s22

****

From: s22 @delwp.vic.gov.au]
Sent: Wednesday, 1 November 2017 11:36 PM
To: s22
Cc s22
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

s22 and I have now gone through the rest of it. More interesting reading! The new comments in this version start at A31 - I have indicated this with a blue highlighted comment. Quite a few more comments to consider - sorry for getting them to you so late in the piece. And I hope the comments make sense - normally I would read over them all again but need to go to bed now and want to get these to you so you have them first thing in the morning. Let me know if things aren't clear.

good luck in the revision. Happy to talk to expand on our comments.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F:** 03 9450 8799 | **E** s22 @delwp.vic.gov.au

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From: s22 @environment.gov.au>
To: s22
Cc:
Date: 01/11/2017 03:08 PM
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi again,

I thought I should just note that I took your advice re the recovery plan so that the newer version of the conservation advice simply has the list of objectives and actions from the draft recovery plan. So please disregard the Conservation Actions section of the version that you have.

If it's helpful I can send the revised CA, but I'm a little nervous of getting them muddled up and potentially overlooking some comment(s). That said, I've addressed most of your changes already so it's reasonably tidy.

And thanks for what you've provided thus far. I'm glad to see I haven't (so far) gotten anything too badly wrong.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275s22
****

From s22 @delwp.vic.gov.au]
Sent: Wednesday, 1 November 2017 11:45 AM
To s22
Cc:
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

sorry for my shorthand! this is the one.

DELWP (2017). A review of the effectiveness and impact of establishing timber harvesting exclusion zones around Leadbeater's Possum colonies. Department of Environment, Land, Water and Planning, with contributions from VicForests.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 **F:** 03 9450 8799 | **E:** s22 @delwp.vic.gov.au

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From: s22 @environment.gov.au>
To: s22
Cc:
Date: 01/11/2017 11:24 AM
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Thanks! Will take me a bit to digest all this.

Just one quick question – when you say the "200 report" which one is that exactly? I *think* know, but would prefer to be sure.

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275s22
****

From: s22 @delwp.vic.gov.au]
Sent: Wednesday, 1 November 2017 12:15 AM
To: s22
Cc:
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

sorry for not getting comments back to you sooner. And sorry but I haven't finished them all - too many urgent deadlines at the moment! I got s22 to read through the background info and make comments and I added a few things here too, then have gone through the first criteria. I have meetings most of the next 2 days so thought I should send through at least what we have got up to so far. I will try and have another go between meetings and get s22 to do some more tomorrow as well and progressively get comments to you, so that you have time to consider them.

and it makes for interesting reading!

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E** s22 @delwp.vic.gov.au

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From: s22 @environment.gov.au>
To: s22
Date: 30/10/2017 04:00 PM
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

A simple answer for that one – I haven't really gotten to it. Just cut and pasted from the old CA for now. My focus has to be getting the assessment right first. I have a little more time to do the actions – I'll also have to see whether there are any restrictions on incorporating those actions, given the plan hasn't been signed off on yet. That shouldn't be an issue, but I will have to check.

I've not shared the *potential* category with s47F yet. It's a bit awkward to know how much/how little is OK to convey to someone who is outside of government. For the moment I've just asked question on specific detail and interpretation so that it's not clouded by any potential bias to lead to a specific outcome. I'll sound out a couple of more senior folk on that before I say too much. Needless to say, everyone will know anyway once it goes to consultation and it might be better to prepare the ground first.

Absolute deadline is probably Thursday afternoon/Friday morning if that's do-able for you. That *might* be allowed to spill over into next week, but if you end up having more extensive comments it'll be hard to work them into a document that I get to the TSSC with enough time for them to consider it properly.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Monday, 30 October 2017 3:53 PM
To: s22
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

just glancing through it now - one quick question - why not use the new recovery plan to outline the conservation actions and priorities at the end- we spent a year of blood, sweat and tears writing it so I would hate to see it be wasted. And it has gone to public consultation so even if the final version wasn't included since it hasn't been released, at least the consultation draft version could be used with the comment to say that it will be updated once the plan is released. The list of actions you have is very out of date now.

when is your absolute deadline for comments

s47C

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

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From: s22 @environment.gov.au>
To: s22
Date: 30/10/2017 03:17 PM
Subject: RE: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

I will take what I can get. I've attached the latest version where I have put it all into the standard format we use. You're welcome to comment on any/all of it, but if you're pressed for time, just skip the bit until the actual criteria. I've largely cut and pasted that from the previous advice, and it really is only the assessment that matters. It's not *much* different to what I sent you, but enough here and there to make it better to comment on this.

I've put a reference once or twice to your telling me that there was a 35% strike rate on the last set of surveys. I've highlighted it in each case, so that you can see whether it's a reasonable thing to say at this point or not. Do feel free to just ask me to delete if it's not appropriate there.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division

Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Monday, 30 October 2017 2:02 PM
To: s22
Subject: Re: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

sorry for not looking at these last week - I always think I can get more done than I can!! I can look at it this afo if that is not too late - have you got a revised version or will I look at the one from 20 Oct?

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

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From: s22 @environment.gov.au>
To: s22
Date: 27/10/2017 10:51 AM
Subject: Draft CA comments? [SEC=UNCLASSIFIED]

Hi s22

I thought I'd check in and see if you've had a chance to read over the draft conservation advice material I sent? It's nominally due today, although I have an extension for a few days. Currently I'm just working on the introduction text (general biology etc) so I'm not at a loose end.

I got some comments from s47F too. As expected, I'll need a couple of subtle changes to the text, but more along the lines of qualifying statements here and there rather than profound changes to the substance. So I'll be working on them next (I hope to get to it later today).

Cheers,

s22

****

s22

Assistant Director

Marine and Freshwater Species Conservation Section

Wildlife Heritage and Marine Division

Department of the Environment and Energy

ph 02 6275 s22

****

[attachment "2017 - Gymnobelideus leadbeateri - Consultation CA.docx" deleted by s22

FOI 171109
Document 10

From: s22
To:
Subject: Another quick Qn? [SEC=UNCLASSIFIED]
Date: Tuesday, 17 October 2017 2:32:01 PM

Hi again,

I'm just now looking at Criterion 2, which includes "severely fragmented or Number of locations".

I'm wondering whether the accumulation of new colonies/locations now makes it harder to make a case for severely fragmented given that there are places on the map where the symbols are overlapping over distances of several kilometres. I *think* it still falls in there, because there are a few "pinch" points in the distribution of forest etc, and perhaps more fragmentation at small scales due to logging, roads etc. Do you have any thoughts on that?

And a supplementary question if I may:
I'm looking at the LBP reserve side by side with the sightings in Figure 3 of the survey report that you sent me last week and thinking about the PVA work done by Todd et al.:

- If I read it correctly, the PVA models the populations *only* within the reserve system itself, and groups together the "reserve patches" within each area (such as Baw Baw/Toorongo) such that the sum those patches is the population for that area. If that's correct it raises two key questions for me:
    1. Given that there are distances between patches within an area that can exceed a couple of kilometres, wouldn't each patch be essentially demographically independent (and need to be modelled as such)?
    2. And if not, then there's an implicit assumption that the possums can move back and forth between patches which essentially says that the habitat in between is suitable to some degree. If that's the case (and given your detections are all >40% for occupancy categories) then the populations are potentially much larger than modelled (and thus both potentially more stable, or at least if they still behave the same way, still more likely to stay about the desired threshold). So I guess I'm asking if it's not appropriate to do PVA just for the reserve, or rather to do it in future for the whole of the reserved area (perhaps broken into the same regional areas)?

Just loving how having more data makes this harder.

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 11

From: s22
To:
Cc:
Subject: RE: Total # colonies and Total # new colonies [SEC=UNCLASSIFIED]
Date: Wednesday, 18 October 2017 12:16:52 PM

Hi again,
And just to check – it looks to me like the 84 new colonies within parks and reserves (from 2016 progress report) are not included in Figure 3 of the surveying report. Is that correct? So could I say that there's something like 400+ new colonies been found?
Is it also safe to make the comment that survey efforts continue and new colonies are still being found?
Cheers,
s22

From: s22
Sent: Wednesday, 18 October 2017 12:04 PM
To: s22
Subject: Total # colonies and Total # new colonies [SEC=UNCLASSIFIED]

Hi s22

I'm just doing up another of the assessment criteria (3/C) and I'd like to say something about the total number (overall, and new colonies since 2014) but it's ever-changing and seemingly variably reported:

The 2016 progress report says "as at 30 September 2016, 354 new…." With 270 in state forest and 84 in reserves.
https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0023/27914/Progress-Report-December-2016.pdf

But then the July 2017 Review of Effectiveness etc. says "of 340 confirmed colonies located from March 2014 to 30 January 2017.."

That's lower, but seems not to include the Project Possum sightings (I'm not sure about that).

Anyway, are you able to give me a current figure for:

- Number of new colonies
- Total number of existing colonies.
- Number of each in parks vs state forests (Yes, I will qualify it to note that sampling is very much biased away from parks/reserves thus far).

It doesn't matter exactly as it'll change by the time of the final recommendation, but there's an intension to put it out to consultation probably in early December so I'd like it to be clearly credible at that point.

Thanks!
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275s22
****

FOI 171109
Document 12

From: s22
To:
Subject: RE: Visit re LBP [SEC=UNCLASSIFIED]
Date: Tuesday, 19 September 2017 1:55:43 PM
Attachments: image001.gif
image002.gif
image003.gif
image004.gif
image005.gif
image006.gif
image007.gif

Hi again,

One more specific question has occurred to me. I'm looking at the ANU review and it refers (on p24, Fig 4.3) to the paper by Todd et al "Assessing reserve effectiveness: Application to a threatened species in a dynamic fire prone forest landscape" on which you're an author too. It's hard to read specific population numbers off the graph, but I wonder if we could get the specific modelled population sizes for 2000, 2009, 2017 and 2035? They seem to me to one of the most clear and explicit attempts to demonstrate population trend (noting of course that these may have changed too with your new data?).

Cheers,
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Tuesday, 19 September 2017 12:54 PM
To:
Cc: s22
s22
Subject: RE: Visit re LBP [SEC=UNCLASSIFIED]

HI s22

thanks for sending down the ANU report - very interesting! Some good things in there but also quite a lot that I would question or where their interpretation is different to ours. I will try and have a thorough read before tomorrow but have meetings all afternoon so it might have to be just a skim.

In relation to your questions I would add another one - were the figures worked out correctly in the first place? rather than just has there been any change. And what if it still doesn't match what we are finding? For example s47F says there is only 2000 ha of suitable habitat and yet the new occupied timber harvesting exclusion zones represent 6000 ha and we have only sampled a fraction of the species range and so they are likely to be present in a lot more areas than the 6000 ha. So is it about the definition of 'suitable'?

things to discuss tomorrow I guess.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E**: s22@delwp.vic.gov.au

www.ari.vic.gov.au

From: s22
To:
Cc:
s22
Date: 19/09/2017 11:25 AM
Subject: RE: Visit re LBP [SEC=UNCLASSIFIED]

Hi s22,

Review attached. It is an all round review, but certainly addresses re-assessment (or rather, offers a rejoinder to the need). We only found it because one of the TSSC members provided it. I can’t actually find anywhere online where it’s available(?).

I think we’re in the same position as you, with the key issue for us being how to we look at decline in habitat quality, particularly given your comment that “ANU decline in hollow-bearing trees doesn't really match where we have now found them.”

While the conservation advice from 2015 is long (53pp) the only criterion where the species was eligible for Critically Endangered was Criterion 1 so the key question we have to ask in doing the reassessment is whether any of the new information changes that.

So to me that breaks down to two questions to address tomorrow (which will no doubt lead to several more related questions):

1. Is there anything in the new data that suggests that the rate of decay of hollow bearing trees (as the key

component of suitable habitat) is different than the estimates provided by Lindenmayer et al.?
2. Is there anything to suggest that the reliance of LBP on hollow bearing trees is less fundamental than assumed in the previous assessment? Are they persisting in areas where they are clearly *not* nesting in tree hollows (and if so, are the numbers doing so sufficient to affect the decline estimates for the population overall)?
3. And another I've just thought of – you've found a couple of instances of LBP outside the Central RFA area. Are there large numbers of them, and is the habitat any more/less secure than found with the original area of interest.

If I think of anything more detailed I'll let you know.

Cheers,
s22
[redacted]

Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

From: s22 @delwp.vic.gov.au]
Sent: Tuesday, 19 September 2017 10:10 AM
To: s22
Cc:
s22
Subject: RE: Visit re LBP [SEC=UNCLASSIFIED]

Hi s22

s22 - material irrelevant to scope

can you send me the ANU summary you mentioned - not sure I have seen this so it would be good to read it over before tomorrow. Is it a general summary or specific to a reassessment? A key thing for tomorrow is to decide on how to assess decline in habitat quality, given the previous approach used that was based on ANU decline in hollow-bearing trees doesn't really match where we have now found them. I am still not sure how to deal with this so am keen to get your thoughts on this.

s22

s22

s22

s22

FOI 171109
Document 13

s22 - material irrelevant to scope

From: s22
Sent: Friday, 20 October 2017 9:25 AM
To: s22

s22

Subject: Review of status of LBP: coordination b/w TSSC and Vic SAC [SEC=UNCLASSIFIED]

Hello s22 (and I've copied s22 in too),

Following our conversation on Wednesday afternoon, we've coming up with the following proposed schedule for ensuring that the Vic SAC are comfortable with our assessment of the LBP. I hope this is satisfactory for you. Please let me know if you have any concerns or suggested amendments.

You'll note that it's a tight schedule, which is unavoidable due to the tight deadline put on the assessment by the minister and the EPBC Act's requirement to allow 30 business days of consultation. You might note that I've added on a little because the consultation will unavoidably be over Christmas.

Hope this suits.

s22 I've noted below that we'd start sending things to you from Monday, but I can send individual criteria from today if that suits you better. Note that I'm working from home today, so if you want to discuss anything, my mobile number is s22 .

Cheers,

s22

23/10/17 Consultation with DELWP/ARI (Early exposure drafts etc.)

3/11/2017 – Consultation draft due for TSSC meeting.

- Same draft that goes to TSSC is provided to Vic SAC

13/11/2017 – Return of comments from Vic SAC

20/11/2017 – TSSC meeting

27/11/2017 – Circulate revised draft to Vic SAC - with **rapid** turn around for release to consultation

4/12/2017 – Release draft for consultation – add extra time to allow for Christmas break.

29/1/2018 – End consultation

5/2/2018 – Post-consultation out of session discussion with TSSC

8/2/2018 – Circulate revised draft to Vic SAC

15/2/2018 – Return of comments from Vic SAC

19/2/2018 – Final draft to TSSC

27/2/2018 – TSSC meeting – Recommendation due

****

s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22

****

FOI 171109
Document 14

From: s22
To:
Subject: LBP advice drafts [SEC=UNCLASSIFIED]
Date: Friday, 20 October 2017 4:05:50 PM
Attachments: Criterion 5 rough draft v1.docx
Criterion 1 rough draft v3.docx
Criterion 4 rough draft v1.docx
Criterion 2 rough draft v1.docx
Criterion 3 rough draft v1.docx
image001.gif
image002.gif
image003.gif
image004.gif
image005.gif
image006.gif
image007.gif

Hi s22

Here they are in their unpolished glory.

Note that I'm waiting on some responses to questions from s22 relating to criterion 1 in particular. I *think* I know roughly what they'll be so I don't expect too much change. But then I'm trying not to be too naively optimistic.

I only just finished Criterion 5 a few minutes ago. My grasp of the whole PVA is a little tenuous so I'm unsure on that one.

Anyway, I'll very much look forward to your thoughts.

I've said very little about Yellingbo yet. Largely because I've been in a hurry, but also because in terms of numbers it really has little effect (not that it's unimportant overall).

Cheers,
s22
****

s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22

****

From: s22 delwp.vic.gov.au]
Sent: Friday, 20 October 2017 10:35 AM
To: s22
Subject: Re: Total # colonies and Total # new colonies [SEC=UNCLASSIFIED]

Hi s22

the numbers are confusing I am sorry, and some got missed in the 200 report unfortunately. some explanations below in red.

and send me what you have by the end of today as I can have a look over the weekend.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T s22 **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 18/10/2017 12:04 PM
Subject: Total # colonies and Total # new colonies [SEC=UNCLASSIFIED]

Hi s22

I'm just doing up another of the assessment criteria (3/C) and I'd like to say something about the total number (overall, and new colonies since 2014) but it's ever-changing and seemingly variably reported:

The 2016 progress report says "as at 30 September 2016, 354 new…." With 270 in state forest and 84 in reserves.
https://www.wildlife.vic.gov.au/__data/assets/pdf_file/0023/27914/Progress-Report-December-2016.pdf

But then the July 2017 Review of Effectiveness etc. says "of 340 confirmed colonies located from March 2014 to 30 January 2017.." This is just in State forest - Table 1 shows the full figures which adds a few more from parks and SPZs. however the 84 in reserves (and some in SF) mentioned above are missing because they hadnt been submitted to the DELWP databases but where included in the progress report. We tried to cover this by the following statement in the 200 report just before the Table 1. 'There are some additional records from within parks that have not as yet been submitted to the DELWP databases (DELWP 2016).'

That's lower, but seems not to include the Project Possum sightings (I'm not sure about that). Yes that is correct they were the Project Possum ones - there was confusion in getting them on the system and by the time we all realised the discrepancy it was too late.

Anyway, are you able to give me a current figure for:

- Number of new colonies
- Total number of existing colonies.
- Number of each in parks vs state forests (Yes, I will qualify it to note that sampling is very much biased away from parks/reserves thus far).

I don't have the current figures and would need someone in head office to work them out, so suggest that you just use the figures in the 200 report for now and then put in a request closer to the consultation draft date and we can extract them for you.

It doesn't matter exactly as it'll change by the time of the final recommendation, but there's an intension to put it out to consultation probably in early December so I'd like it to be clearly credible at that point.

And just to check – it looks to me like the 84 new colonies within parks and reserves (from 2016 progress report) are not included in Figure 3 of the surveying report. Is that correct? The targeted survey report is just the ARI records so no the other records don't show up there. The more relevant map is Fig 2 in the 200 report which has everyone's records, but they don't show up there either because we didn't have them in our database.

So could I say that there's something like 400+ new colonies been found? yes that would be OK

Is it also safe to make the comment that survey efforts continue and new colonies are still being found? the DELWP (ie ARI) targeted surveys (which represented about half of the records in the 200 report) are now finished. The community groups are still sending in records and VF is still doing some preharvesting surveys, so surveys are continuing but at a lower intensity.

Thanks!
s22

****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

FOI 171109
Document 15

From: s22@delwp.vic.gov.au
To: s22
Cc:
Subject: Re: LBP [SEC=UNCLASSIFIED]
Date: Wednesday, 4 October 2017 2:00:24 PM
Attachments: ATT00001.gif
ATT00002.gif
ATT00003.gif
ATT00004.gif
ATT00005.gif
ATT00006.gif
ATT00007.gif

Hi s22

really sorry for the delay in reply - too many things on. Great that you are able to do lots of reading and get your head around it all!!

With the occupancy model we have used 4 categories - <30%, 30-50%, 50-65% and> 65% and don't really use the >50% more than we use some of the other categories. And it depends what it is being used for, as it is all just a probability of occupancy, there is no hard and fast rule for saying what is suitable habitat. For example >65% got used for the moratorium. We often use > 30% as there seems to be a difference in detection rates in areas predicted to be more or less than 30%. In the PVA analysis in the report we included both >50% and >30% as the area reserved under two different predicted levels of occupancy.

s22 is just finalising the report - we will get this to you asap.

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E**: s22@delwp.vic.gov.au

www.ari.vic.gov.au

From: s22@environment.gov.au>
To: s22
Date: 28/09/2017 09:50 AM
Subject: LBP [SEC=UNCLASSIFIED]

Hi s22

I thought I should just touch base to let you know I'm still onto the LBP work. I haven't been bothering you much as I'm (still) trying to get on top of all the reading. I've gone through a lot of the ANU work and am now starting back in on the ARI work, like the big "strategic approach to biodiversity…" report.

And it has raised on general question that you might be able to answer, or point me to where I might find it:

I'm not hugely familiar with occupancy modelling, so I'm wondering why both the ANU and ARI work seems to fix on 50% likelihood of presence as being the definition of "suitable" or "occupied" habitat? It seems like just a rule of thumb agreed on by convention some time ago, but it does seem to me that there can be quite a lot of habitat available at lower probability levels. I'm thinking, for example, you could do something like multiply area x probability class to give some estimate of relative numbers within each of the probability classes(?).

I'm finding it quite interesting to do this reading. I'm hoping at some point it gels and a way to approach it becomes clear. At best I have a somewhat hazy overall picture just now. Will be touching base with TSSC members soon to discuss it.

Anyway, I'll keep reading in the meantime. Let me know if/when you get that report for last year's surveys available for reading. I'm sure it'll be quite influential.

Cheers,
s22
****
s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 s22

FOI 171109
Document 16

From: s22 elwp.vic.gov.au
To: s22
Cc:
Subject: Re: Occupancy [SEC=UNCLASSIFIED]
Date: Tuesday, 10 October 2017 9:27:16 AM

Hi s22

That is really interesting. We have often wondered if they can nest in things other than the classic big old dead tree. It would be really interesting to find out more about the two nests in live 1939 trees - were these in hollows in these trees or a fork of the tree? If in a hollow what did the hollow look like - a hole in the main trunk or elsewhere?

Ringtails can make dreys in forks of trees but the description of densely intertwined shredded bark is more LBP like and saying he saw 5 animals in it also is much more LBP than ringtail so that is really interesting too. Have often wondered if they can do this but haven't had any clear evidence. We are hoping that s47F when he gets his GPS tracking going might shed light on alternative nesting sites particularly in young regrowth forest but he hasn't managed to catch any animals yet.

So both reports are intriguing. But how often it happens and so how important it is are unknown. You are right in that if they did this a lot it would change perception of suitable habitat considerably. But would need a lot more data first. Would be fascinating to hear more.

Am in the field at present - will think more on you suitable habitat email and get back to you.

Bye

s22

On 9 Oct. 2017, at 3:52 pm, s22 @environment.gov.au> wrote:

> Oh, and while I'm at it:
>
> I was going back through some of the submissions on the last assessment, and found one containing this:
>
>> I have had verbal reports from forest workers, of sightings prior to 2009, of densely intertwined shredded bark nests, containing Leadbeater's Possums. These nests were observed located in 1939 regrowth Ash. I have seen one myself, containing five possums, that had been constructed in the bifurcated stem of a Eucalyptus delegatensis tree. Another report I received was of at least two nests being observed in 1939 regeneration trees within a single logging coupe. This coupe also contained dead decaying Eucalypt stems of an older age class.
>
> What do you make of it? Is it credible and/or significant? I'm guessing it's not that big a deal unless it turned out to be a common practice, in which case it could change habitat assessment quite a bit (couldn't it?). The contributor seems to at

least have a credible background.

I've just sent the guy an email to ask if he can elaborate so if you're interested I'll pass on his reply.

Cheers,
s22

****

s22
Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22

email chain contained in Document 8

s22 - material irrelevant to scope

s22

s22

FOI 171109
Document 17

From: s22 elwp.vic.gov.au
To: s22

Subject: *Confidential: Re: Confidential - Draft LBP assessment
Date: Sunday, 12 November 2017 2:40:39 PM
Attachments: ATT00001.gif
ATT00002.gif
ATT00003.gif
ATT00004.gif
ATT00005.gif
ATT00006.gif
ATT00007.gif
ATT00008.gif
ATT00009.gif
ATT00010.gif
ATT00011.gif
ATT00012.gif
ATT00013.gif

Hi everyone

thanks for the great discussions on Friday.

One thing I said I would check was what proportion of the total potential habitat in the Central Highlands (ie all ash forest and snow gum woodlands) was snow gum. We had a figure that 96% was ash and only 4% was snow gum which seemed a bit low - but it is correct. There are 8,483 ha of snow gum - a bit over 6000 ha in Baw Baw and the rest in Lake Mountain, Mt Bullfight etc. 8,482 ha is 4.2% of the 204,000 total hectares.

bye

s22

s22 | s22 Wildlife Ecology| Arthur Rylah Institute
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St , Heidelberg, Victoria 3084
T s22 | F: 03 9450 8799 | E s22 @delwp vic gov au

www ari vic gov au

From s22
To s22
Cc
s22
Date 06/11/2017 04 20 PM
Subject Confidential - Draft LBP assessment

Dear all

Please find attached the draft conservation advice, including assessment against the IUCN criteria.

We will go through the document in detail on Friday but feel free to raise queries with s22 as per his offer below.

Please treat the draft as strictly confidential.

Regards

s22 s22 Threatened Species Policy | Biodiversity Division
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

Level 2, 8 Nicholson St, East Melbourne, Victoria 3002
T s22 F 03 9637 8451 | E s22 @delwp.vic.gov.au

----- Forwarded by s22 /VICGOV1 on 06/11/2017 03 50 PM -----

From s22
To
Cc
Date 06/11/2017 03 12 PM
Subject RE Update on draft LBP assessment [SEC UNCLASSIFIED]

Hi s22

I ve been to check with s22 and the answer is apparently: now

The draft of the Conservation Advice is attached You may note that it s been once in full to s22 I ve incorporated s22 comments, but not passed them by her again to check I got it spot on

By the way, if any of the members want to ask me questions, or ask me to bring any particular materials to the meeting, I m more than happy for them to drop me a line via phone or email

Cheers,
s22
****
s22

Assistant Director
Marine and Freshwater Species Conservation Section
Wildlife Heritage and Marine Division
Department of the Environment and Energy
ph 02 6275 s22
****

[attachment "TSSC 70 Item 7 4 1 Gymnobelideus leadbeateri - Consultation CA docx" deleted by s22 /VICGOV1]

From: s22 @delwp.vic.gov.au
To: s22
Subject: RE: Phone catch up [SEC=UNCLASSIFIED]
Date: Monday, 17 July 2017 2:23:15 PM
Attachments: ATT00001.gif
ATT00002.gif
ATT00003.gif
ATT00004.gif
ATT00005.gif
ATT00006.gif
ATT00007.gif
ATT00008.gif
ATT00009.gif
ATT00010.gif
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ATT00016.gif
ATT00017.gif
ATT00018.gif
ATT00019.gif
ATT00020.gif
ATT00021.gif
LBP ARI new survey info relevant to IUCN reassessment.docx

---

just checking that you previously got my outline of how the new info related to the IUCN criteria - attached slightly modified

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 17/07/2017 01:58 PM
Subject: RE: Phone catch up [SEC=UNCLASSIFIED]

No probs s22

From: s22 @delwp.vic.gov.au]
Sent: Monday, 17 July 2017 1:57 PM

To: s22
Subject: RE: Phone catch up [SEC=UNCLASSIFIED]

Hi s22

just trying to finish lunch amongst other things that have come up - can we delay until 2.30?

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084
T: s22 **F**: 03 9450 8799 | **E** s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 17/07/2017 01:17 PM
Subject: RE: Phone catch up [SEC=UNCLASSIFIED]

Thanks s22 sounds good.

From: s22 @delwp.vic.gov.au]
Sent: Monday, 17 July 2017 1:05 PM
To: s22
Subject: Re: Phone catch up [SEC=UNCLASSIFIED]

Hi s22

yes happy to chat - how about at 2 pm? I will ring you from a meeting room

bye

s22

s22 | s22 **Wildlife Ecology| Arthur Rylah Institute**
Energy, Environment and Climate Change | Department of Environment, Land, Water and Planning

123 Brown St., Heidelberg, Victoria 3084

T s22 | **F**: 03 9450 8799 | **E**: s22 @delwp.vic.gov.au

www.ari.vic.gov.au

From: s22 @environment.gov.au>
To: s22
Date: 17/07/2017 12:48 PM
Subject: Phone catch up [SEC=UNCLASSIFIED]

Hi s22 are you around this arvo to have a catch up on Leadbeater's possum, I believe s22 has spoken to you. Largely on data availability underpinning your report and the sorts of analyses we might do over the next 6 months as well as the need for further survey effort. We have to make a call on this pretty soon. Any time after 1.30?

Cheers

s22

Director
Terrestrial Species Conservation
Department of the Environment and Energy
GPO Box 787 Canberra ACT 2601
02 6275 s22
s22 @environment.gov.au

FOI 171109
Document 18a

Additional survey requirements for Leadbeater's Possum relevant to a reassessment of conservation status and improved understanding of distribution and habitat requirements

s22, ARI, DELWP, 3/5/2017

Background

In the past 3 years DELWP (ARI) has undertaken extensive surveys for Leadbeater's Possum within the Central Highlands. In addition, community groups have been very actively surveying for the possum. This has resulted in the identification of an additional 346 new colonies located (with a new colony defined as records that are at least 200 m from any other record). This is in addition to the 149 colonies recorded between 1998 and 2014. All these new colonies are now protected with 200 m radius timber harvesting exclusion zones.

Within the first two years of the ARI sampling (2014/15 and 2015/16), 289 sites were surveyed, with Leadbeater's Possum recorded at over 50% of these. This sampling was very targeted at areas more likely to contain Leadbeater's Possums so can not be used to extrapolate to the entire distribution. In the third year of sampling (2016/17) survey sites have been selected using a randomised sampling design so that the data can be used to extrapolate across the species distribution, with 150 sites being sampled. Extensive habitat assessments have been undertaken at all sites which is providing new insights into habitat requirements and extent of use of various disturbance histories and age classes. This information and spatial data of two key habitat requirements (hollow-bearing trees and understory density) which is currently being modelled from LiDAR data, will enable much improved occupancy models to predict where the species is more likely to currently occur. Limited sampling of the area regenerating after the extensive 2009 bushfires, as part of the randomised surveys, show some early recolonisation of parts of these burnt areas, which has occurred sooner than expected. However, more information is needed to determine the extent and pattern of this recolonisation.

Information relevant to a reassessment of IUCN criteria

Leadbeater's Possum was listed as Critically Endangered in 2015 based on a > 80% decline 'in area of occupancy, extent of occurrence and/or habitat quality' over the past 18 years, and also a predicted decline of > 80% over the next 18 years (Criteria 1). The TSSC considered that it met the criteria for Endangered under Criteria 2 which includes extent of occurrence, area of occupancy, severely fragmented population and continuing decline; and Endangered under Criteria 3 which also includes an estimate of population numbers.

The new information that has been collected over the last 3 years, and key remaining knowledge gaps, relevant to these criteria include:

- Extent of Occurrence
  - New information: the recent surveys are unlikely to change this metric as these surveys have been within the existing known range of the species.
  - Knowledge gaps: while there is a possibility that the species occurs outside the Central Highlands and if surveys were undertaken and then located the species, this could increase the size of Extent of Occurrence. However, while it would be really

interesting to undertake such surveys, these would be expensive with no guarantee of success.

- Area of Occupancy
    - New information: results from the recent surveys will increase the size of the Area of Occupancy compared to figures used in the previous assessment.
    - Knowledge gaps: the extent to which Leadbeater's Possum have recolonised the area burnt during 2009 will influence calculations on area of occupancy. In total 34% of the range of the species was burnt, with 43% of the specific Leadbeater's Possum reserve. The species was thought to have disappeared from the majority of this area, and this was factored into the 80% decline figure. However, the species has started recolonising but it is unknown how much of this area is now occupied and hence would influence the area of occupancy estimates from the past 18 years. In addition, there is comparatively less information of the occurrence within formal parks and reserves, than within State forest, with additional surveys in these areas likely to clarify the area of occupancy, and improve the ability to predict where the species occurs.
- Decline in habitat quality
    - New information: there is now more information on habitat suitability and the amount of habitat likely to be occupied across the species range.
    - Knowledge gaps: 2009 fire recolonisation pattern and extent – e.g. proportion of area recolonised, persistence in fire refuges, and influence of fire severity, previous age class, and distance from fire boundary.
- Severely fragmented
    - New information: new survey data will influence an assessment of how fragmented populations are.
    - Knowledge gaps: some of the previously assessed fragmentation was due to the impact of the 2009 bushfires. The extent to which this area has been recolonised will influence this assessment.
- Population numbers
    - New information: the new survey data is influencing the perception of population numbers and can in a limited way be used to inform a re-assessment. Population numbers cannot be estimated from the first two years of the ARI surveys due to the targeted nature of that sampling. However, in the third year (surveys to be completed May 2017) the randomised sampling design will enable a greater level of extrapolation, although still with a relatively high level of uncertainty.
    - Knowledge gaps: A larger number of random sites would improve population estimates, with even sampling in all land tenures and fire histories (current sampling has been weighted to unburnt State forest with less in parks and in areas regenerating after the 2009 bushfires). An additional key unknown is the effective survey area for the remote camera survey technique – i.e. from what distance are animals drawn into the bait and hence what area is considered to have been sampled. This however, will be difficult to determine, and would require detailed studies (e.g. using radiotracking) and so any new population estimates will still have a level of uncertainty.