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 contribution from VicForests

JULY 2017

Maps in this document were produced by DELWP's Arthur Rylah Institute for Environmental Research and VicForests.

Acronyms

ANU	Australian National University
ARCUE	Australian Research Centre for Urban Ecology
ARI	Arthur Rylah Institute for Environmental Research
DELWP	Department of Environment, Land, Water and Planning
DEPI	Department of Environment and Primary Industries (former title of DELWP)
DSE	Department of Sustainability and Environment (former title of DELWP)
FMA	Forest Management Area
FMZ	Forest Management Zone
GMZ	General Management Zone
GPS	Global Positioning System
LBP	Leadbeater's Possum
LiDAR	Light Detection And Ranging
LMU	Leadbeater's Possum Management Unit
LPAG	Leadbeater's Possum Advisory Group
OHS	Occupational Health and Safety
PVA	Population Viability Analysis
RFA	Regional Forest Agreement
SMZ	Special Management Zone
SPZ	Special Protection Zone
THEZ	Timber Harvesting Exclusion Zone
TRP	Timber Release Plan
TSSC	Threatened Species Scientific Committee
VBA	Victorian Biodiversity Atlas
VEAC	Victorian Environmental Assessment Council

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Executive Summary

Leadbeater's Possum *Gymnobelideus leadbeateri* is a small, nocturnal, arboreal possum that is endemic to Victoria, and restricted to an area of approximately 70 x 80 km in the Central Highlands northeast of Melbourne. Most of the population occurs in montane ash forests, which are some of the most productive and valuable timber producing forests in Australia. A substantial portion of this habitat was severely impacted by bushfires over the past two decades, particularly the Black Saturday bushfires of 2009.

The Leadbeater's Possum Advisory Group (LPAG) was established in 2013 to develop recommendations to support the recovery of Leadbeater's Possum while maintaining a sustainable timber industry. A key focus was to protect colonies where they occurred and they recommended the establishment of a 200 m radius timber harvesting exclusion zone (THEZ) around verified records of Leadbeater's Possum. LPAG also recommended that a review be undertaken after the completion of two years of intensive surveying, or once 200 new colonies were verified in areas of State forest available for timber harvesting. Both these milestones were met in June 2016.

The specific objectives of this review are:

1. to document the extent of additional protection for Leadbeater's Possum colonies based on this action, and assess the effectiveness of this additional protection in supporting the recovery of Leadbeater's Possum;
2. to document the impact on the timber industry of these timber harvesting exclusion zones; and
3. to explore possible alternative options for protecting Leadbeater's Possum colonies and habitat, and compare their potential effectiveness for the possum's recovery and impact on the timber industry.

The review has been undertaken by the Department of Environment, Land, Water and Planning (DELWP), with contributions from VicForests on the costs to the timber industry. Other relevant data and analyses were sourced from the Victorian Environmental Assessment Council (VEAC) Fibre and Wood Supply assessment report.

Key findings

Benefits to Leadbeater's Possum from the THEZs

The review of the 200 m THEZ shows the action is contributing to the conservation of Leadbeater's Possum. The addition of the THEZs around each verified colony has resulted in the protection of 436 additional Leadbeater's Possum colonies (including new records since 2014, and existing records from the previous 15 years), with an additional 4,046 hectares of State forest reserved in Special Protection Zones (SPZ). Without this protection, many of these possum colonies may have been at risk from timber harvesting.

Establishment of the THEZs has resulted in the formal reserve system for Leadbeater's Possum in the Central Highlands increasing in area from 30,520 ha to 34,566 ha (an increase of ~13% in terms of

area). While the Leadbeater's Possum remains at a high risk of extinction until 2050-70[1], that risk has been reduced within the Leadbeater's Possum reserve by ~34%,[2] thus demonstrating the effectiveness and efficiency of this action in contributing to Leadbeater's Possum conservation outcomes.

The THEZs in combination with other components of the parks and reserve system have resulted in a good representation of protection across the geographic range of the species. This is likely to promote longer-term conservation through a more dispersed set of protected sites that helps spread the risk of loss due to any single future catastrophic event (such as a major bushfire).

Clustering of THEZs has also created potential 'neighbourhoods' of possum colonies. This is likely to increase the resilience and long-term viability of these sub-populations, and hence the likelihood of persistence of colonies within the THEZs.

The effectiveness of THEZs contributes to achieving the LPAG aim of slowing the projected decline in population numbers in the Central Highlands, so that there are sufficient individuals for the species to recover in the future. However, the species remains at risk of extinction, especially when considering the likelihood of future bushfires, and so the establishment of the current THEZs has not achieved complete recovery of the species and continued efforts to provide protection will be required.

New knowledge

The review has also served to highlight the important role of science and modelling, and use of innovative survey techniques and technology in locating Leadbeater's Possum colonies, in contributing new knowledge to its ecology and management.

The increased number of 340 confirmed colonies located from March 2014 to 30 January 2017 reflects a significantly greater sampling effort and the use of new, efficient survey techniques. The majority (66%) of these new colonies have been located during government surveys using sophisticated spatial models and ecological knowledge to determine where colonies are most likely to occur. These surveys have also provided important new information about the species' distribution and habitat requirements.

Importantly, a significant proportion (30%) of the new colony detections have come from community groups or members of the public, with 99% of the submitted reports from community groups being successfully verified by DELWP. This has provided a great example of the role that citizen science can play in biodiversity protection, as highlighted in the recently released *Protecting Victoria's Environment – Biodiversity 2037*.

[1] It is predicted that the Leadbeater's Possum will decline in the near term with a high risk of extinction until the 1939 regrowth develops hollows, predicted to occur during the period 2050-70.
[2] this is based on a future scenario of 200 years without bushfire. This is highly unlikely but the figure is useful to demonstrate the relative effectiveness of protection of colonies from timber harvesting.

Information gaps

Notwithstanding the considerable survey effort from the Victorian Government and the community since 2014, there remain some important information gaps that make it challenging to estimate the overall effectiveness of the THEZs in conserving Leadbeater's Possum.

Only about 6-10% of the possum's potential, or most likely occupied, habitat in the Central Highlands has been surveyed. Much of this additional survey effort occurred in State forest available for timber harvesting. ARI surveys, as recommended by LPAG, were initially targeted to areas of State forest more likely to contain the possum in the first two years of sampling (2014/15 and 2015/16) with the third year of sampling (2016/2017) surveying sites across State forests and the formal parks and reserve system. As such, there is only limited data on the distribution and extent of Leadbeater's Possum colonies and habitat in National Parks and reserves.

The small area surveyed and the targeted nature of surveys limits these data's applicability across the whole range of the species. Therefore it is not possible at this stage to update estimates of the total population size, and further work is required to provide more robust estimates. There is also uncertainty about the number of colonies each THEZ may protect and therefore the overall number of possums protected by the THEZs as a proportion of the total population. The persistence of colonies within THEZs is also uncertain both now and into the future.

Long-term persistence will depend on there being suitable habitat in the future and the extent to which the THEZs will provide this is unknown. There is likely to be ample foraging habitat, due to approximately half of the THEZ area being regrowth forest less than 40 years old. In contrast, the on-going loss of hollow-bearing trees reduces nesting habitat for Leadbeater's Possum. It could be expected that the suitability of the habitat protected within a THEZ will be similarly impacted by this decline – particularly so for dead hollow-bearing trees – and hence will be generally less suitable for Leadbeater's Possum in the future than at present.

Further surveys across all land tenures and habitat quality are required to improve estimates of the overall population and the long-term effectiveness of THEZs.

Impact on timber industry

The benefits to Leadbeater's Possum from the THEZs have come at a cost to the timber industry.

The direct impact of the establishment of the THEZs on the timber industry is the reduction in the total area and volume of timber available and suitable for harvesting once other existing planning and regulatory controls already in place are taken into account - such as existing SPZs, steep slopes and riparian buffers. The result of this is that the additional 436 colonies protected by a 200 m THEZ reduce the area available and suitable for timber harvesting by 3,134 ha. Of this, 37% or 1,171 ha is 1930 – 1939 regrowth, which is the predominant age class currently being harvested.

VicForests estimates that the THEZs established up until January 2017 will result in a loss of revenue from sawlog harvesting to 2030 of $14.77 million (Net Present Value).

The establishment of the THEZs has also created additional roading costs to VicForests, where road construction is more complex and costly due to the creation of THEZs. The additional roading costs for coupes on the current harvest plan are estimated to be $5.574 million.

Using a different method of analysis, VicForests estimates that the direct impact of current and predicted future THEZs has reduced sustainable sawlog harvest levels by 11% from the level forecast in 2013. This includes 7,000 m^3 per year from THEZs established up to November 2015 and 18,000 m^3 per year from THEZs projected as being established from November 2015 into the future.

THEZs established by November 2015 also contribute to a further reduction of 10,000 m^3 per year due to indirect impacts resultant from access constraints associated with the THEZs.

Overall, VicForests advises that the largest impact on its estimates of future volumes is resource isolation, including as forest areas adjacent to the THEZs become more difficult and, in some cases, uneconomic to access.

Other indirect impacts, not quantified by VicForests include:

- management costs – these are planning costs to undertake field assessments, plan road construction, field marking, site preparation and infrastructure construction; and
- planning costs to reschedule coupes.

This analysis identifies that the implementation of the THEZ prescription up to 30 January 2017 has resulted in costs to industry, with a significant proportion of impacts resulting from loss of access to timber outside the THEZs and increased roading costs.

Alternative options and findings

The report explores a range of alternative options to the current prescription in terms of their benefits to Leadbeater's Possum and impact on industry, including consideration of:

- size and shape of the THEZs;
- activities permitted within THEZ;
- THEZ location in relation to existing protected areas; and
- continuation or discontinuation of the current prescription and longer term strategic options.

The current 200 m THEZ prescription was recommended by LPAG as a compromise between the two objectives of supporting the recovery of Leadbeater's Possum while maintaining a sustainable timber industry.

The review has shown that the THEZs currently protect suitable habitat for Leadbeater's Possums and this action has been effective in protecting locations where the species is known to occur, and is providing the species with a greater chance of persisting into the future. The review also indicates that there are opportunities to reduce the unintended indirect impacts of the prescription while managing any detrimental impacts on Leadbeater's Possum colonies and habitat through the way it is applied, particularly in relation to access and road construction.

However, the THEZ process can result in small and generally isolated protected areas that individually and collectively may not provide the optimal long-term conservation benefits to the species. The creation of the THEZs also contributes to uncertainty for the timber industry and increases operational costs to VicForests.

Based on the above findings, this review makes the following recommendations for the continued recovery of the Leadbeater's Possum while maintaining a sustainable timber industry.

Recommendations

Recommendation 1: Continue the 200 m Timber Harvesting Exclusion Zone prescription around verified Leadbeater's Possum colonies.

The current THEZ prescription has been effective in providing protection to Leadbeater's Possum colonies and remains an appropriate compromise between the two objectives, noting that further efforts are required to protect the species and reduce costs to industry.

Recommendation 2: Review how the THEZ is applied to reduce unnecessary indirect impacts on the timber industry while ensuring adequate protection for Leadbeater's Possum.

The *Code of Practice for Timber Production 2014* provides for VicForests to apply for approval to construct roads through THEZs.

DELWP should update processes for assessing proposals for exemptions to construct roads through SPZs, ensuring that risks to the Leadbeater's Possum continue to be mitigated. This will provide greater clarity for industry on the circumstances in which road construction is appropriate and can be approved. It should include developing guidelines for the application of mitigation measures and be based on the information gathered in this report and further advice from biodiversity experts and operational foresters.

DELWP should also commit to processing individual applications within a specified timeframe, once a completed application is received.

Recommendation 3: Undertake further field studies to improve knowledge of Leadbeater's Possum.

DELWP should undertake a program of field surveys across parks, reserves and timber harvesting areas to further identify Leadbeater's Possum's distribution and abundance across the Central Highlands. VicForests should continue to conduct pre-harvest surveys in proposed coupes in State forests.

Collecting more information about the distribution and abundance of Leadbeater's Possum colonies will help to reduce uncertainty around the population estimate and provide additional knowledge about habitat requirements and distribution to help guide future actions to support recovery of the species.

Recommendation 4: Further develop species models as the basis for improved forest management planning and conservation management.

DELWP should continue to develop improved models that better predict the current and future distribution of Leadbeater's Possum populations and habitat and that enable the assessment of the species' likely persistence across State forests, parks and reserves in consideration of a range of threats and actions to mitigate these including bushfire.

Recommendation 5: Review THEZs and other existing SPZs in the Central Highlands to optimise for timber availability, protection for Leadbeater's Possum, threatened species and other forest values.

Following additional surveying and improvements to models, the department should review the Central Highlands State forest zoning scheme (including the THEZ) to take into account new information and changes in the forest since the Leadbeater's Possum reserve system was established in 2008.

In the review, efficiencies should be sought across protections for all threatened species and other values such as recreation and water supply. Consideration should be given to whether the revised zoning scheme provides effective protections for the Leadbeater's Possum and therefore whether the 200 m THEZ rule should be discontinued. The effectiveness of zoning protections should also be compared to a broader suite of current and potential Leadbeater's Possum measures, including on ground actions.

Recommendation 6: Transition to landscape-scale planning for threatened species management.

A strategic landscape-scale planning and management approach is more likely to deliver a greater benefit to the conservation and recovery of Leadbeater's Possum than the ongoing detection-based THEZ prescriptions. A landscape scale approach that moves away from the use of detection-based prescriptions will also provide greater certainty and reduced costs to industry.

In line with *Protecting Victoria's Environment - Biodiversity 2037,* Victoria is moving away from prioritising actions for individual species to an approach that considers all species and all threats and possible actions together to inform priority actions that efficiently deliver the maximum benefit for the most species. This requires a transition to a landscape scale, multiple threatened species planning and management approach that aims to deliver the maximum benefit for the highest number of threatened forest-dependent species.

1. Introduction

Leadbeater's Possum *Gymnobelideus leadbeateri* is a small, nocturnal, arboreal possum that is endemic to Victoria, and is Victoria's faunal emblem. Its distribution is restricted to an area of approximately 70 x 80 km in the Central Highlands northeast of Melbourne (Lindenmayer *et al.* 1989, Menkhorst and Lumsden 1995). Leadbeater's Possum is listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988* and critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

With the exception of a small, genetically distinct population that occurs in lowland floodplain forest in the Yellingbo Nature Conservation Reserve (Harley 2002, Harley *et al*. 2005), most of the population occurs in montane ash forest, dominated by Mountain Ash (*Eucalyptus regnans*), Alpine Ash (*E. delegatensis*) and Shining Gum (*E. nitens*). It also occurs in sub-alpine woodland dominated by Snow Gum (*E. pauciflora*) (Harley 2016). Within its range, the species is patchily distributed, occurring in areas of suitable habitat, largely influenced by previous disturbance history.

The key habitat requirements of Leadbeater's Possum across these forest types are:

1. hollow-bearing trees for nesting, breeding and shelter;
2. predominance of smooth-barked eucalypts with exfoliating bark to provide shelter for insect prey and material for nests;
3. a structurally dense interlocking canopy or mid-storey to facilitate movement; and
4. a wattle understorey to provide food (Smith and Lindenmayer 1988).

The first of these key habitat requirements is associated with old trees, with Leadbeater's Possum typically selecting hollow-bearing trees that are older than 190 years (Smith and Lindenmayer 1988, Lindenmayer *et al.* 2015). In contrast, areas with a dense mid-storey including wattles typically occur in young regenerating forests. Therefore, the optimal habitat for Leadbeater's Possum is multi-aged forest where the large trees, dead or live, provide hollows for nesting, while the regenerating vegetation provides foraging habitat and movement pathways (Lindenmayer *et al.* 1990b). Young regeneration typically occurs after disturbance, either from fire or timber harvesting, and while Leadbeater's Possums are often recorded within regenerating forest, this typically represents just their foraging habitat. Young regeneration can only be used if there are nearby hollow-bearing trees to provide nesting sites.

The montane ash forests of the Central Highlands are some of the most productive and valuable timber producing forests in Australia (LPAG 2014b). Approximately 70% of VicForests' annual ash timber supply is sourced from within the range of Leadbeater's Possum. Approximately 63,000 ha of ash forest within the Central Highlands (31% of potential habitat for Leadbeater's Possum) is projected to be harvested and then actively regenerated over the length of a harvesting rotation (around 80 years) (LPAG 2014b).

The Leadbeater's Possum Advisory Group (LPAG) was established in 2013 to develop recommendations to support the recovery of Leadbeater's Possum while maintaining a sustainable timber industry (LPAG 2014a). LPAG recognised the increasing concerns about the conservation of the species after the 2009 bushfires and due to the ongoing loss of hollow-bearing trees. LPAG also acknowledged the value of the area for timber harvesting, and highlighted the importance of managing the forests in a way that would provide habitat for Leadbeater's Possum into the future.

LPAG's focus was to recommend actions that could slow the projected decline in population numbers in the Central Highlands to help ensure there would be sufficient individuals for the species to recover. Therefore it was important to protect colonies where they currently occurred. One of the key recommendations was to reduce the likelihood of colonies and their habitat being lost during harvesting operations, through the establishment of a 200 m radius timber harvesting exclusion zone (THEZ). Prior to the introduction of this action there had been no forestry prescriptions based on the detection of individuals, only on the identification of high quality habitat. Partly this was due to Leadbeater's Possums historically being considered cryptic and difficult to detect. In recent years however, additional, effective survey techniques have been developed which now enable the species to be more readily located (Harley *et al*. 2014, Harley 2016, Lumsden *et al*. 2013, Nelson *et al*. 2015, Nelson *et al.* in press).

The acceptance of all LPAG recommendations by government in 2014 resulted in THEZs being applied to Leadbeater's Possum colonies recorded since 1998, and all new verified colonies reported since February 2014 (LPAG 2014b). All THEZs are re-zoned as Special Protection Zones (SPZs) in State forest, which excludes all timber harvesting operations from within a 200 m radius of the record. This prescription is listed in the *Management Standards and Procedures for Timber Harvesting in Victoria's State Forests 2014* (DEPI 2014a), which is an appendix to the *Code of Practice for Timber Production 2014* (DEPI 2014b). Timber harvesting is permitted in the General Management Zone (GMZ) and Special Management Zone (SMZ) within State forest, subject to compliance with the regulatory framework outlined in the Code (DEPI 2014b).

In 2014, as there were a range of uncertainties around the impact of THEZs on the timber industry, LPAG recommended that a review be undertaken on the effectiveness and impact of this action after the completion of two years of surveying, or once 200 new colonies were located where the THEZ impacted a General Management Zone (GMZ) or Special Management Zone (SMZ). In June 2016, both of these milestones were met. Since this time, records of Leadbeater's Possums have continued to be reported to the Department of Environment, Land, Water and Planning (DELWP), and therefore to more fully assess the effectiveness and impact of this action, all verified records reported to DELWP up until 30 January 2017 have been included in this review. Data on the benefits and impacts have been extracted for three timeframes to detect any variability between the reporting time periods:

1. the existing records from 1998 to February 2014 ('existing');
2. the 200 new records (February 2014 to June 2016) ('towards 200'); and
3. additional records up to 30 January 2017 ('beyond 200').

The existing category includes all Leadbeater's Possum records from within the Central Highlands during the 15 years prior to the commencement of the LPAG recommendations (i.e. from 1998), excluding areas that were burnt with a high severity in the 2009 bushfires. Surveys in areas burnt in 2009 had not detected any Leadbeater's Possums (Lindenmayer *et al.* 2013a, Lumsden *et al.* 2013) and so it was assumed that in 2014, colonies did not survive where the bushfire was of high fire severity. THEZs were established around colonies verified during the past 15 years in unburnt areas on the basis that colonies were likely to persist over this period and based on the assumption that Leadbeater's Possums will still be present (Lindenmayer *et al*. 2013b).

LPAG recognised that only a relatively small proportion of the total population had been located in the previous 15 years, and so they recommended extensive surveys to locate additional colonies for

protection under the timber harvesting exclusion zone action. This included a 3-year targeted survey program throughout the species' range to be undertaken by DELWP's Arthur Rylah Institute for Environmental Research (ARI) (Nelson *et al*. 2015, Nelson *et al.* in press). In addition, LPAG recommended the provision of specialised technical survey equipment for loan by community groups to facilitate citizen science surveys with the aim of obtaining high quality supporting evidence so that the reports could be verified by DELWP. VicForests are also undertaking pre-harvest surveys of high priority coupes on the Timber Release Plan (TRP).

The Leadbeater's Possum Implementation Program Evaluation Plan v2.7 (December 2014) outlines a range of performance indicators for assessing benefits and impacts of this action, compared to if the action had not been implemented. These metrics have been used as the basis for this review.

The specific objectives of this review are:

1. to document the extent of additional protection for Leadbeater's Possum colonies based on this action, and assess the effectiveness of this additional protection in supporting the recovery of Leadbeater's Possum;
2. to document the impact on the timber industry of the additional timber harvesting exclusion zones; and
3. to explore possible alternative options for protecting Leadbeater's Possum colonies and habitat, and compare their potential effectiveness for the possum's recovery and impact on the timber industry.

2. Evaluating the benefits to Leadbeater's Possum

Prepared by the Arthur Rylah Institute for Environmental Research, DELWP

2.1 Documenting the extent of additional protection for Leadbeater's Possum colonies

2.1.1 Scope of the review

The approach taken in this review is to document the extent to which the establishment of THEZs around known colonies has increased protection for those colonies, as this may lead to better long-term persistence of the species at these sites. However, some influences on long-term persistence are unknown, and cannot be assessed with existing data. This includes whether a 200 m radius exclusion zone is of sufficient size to guarantee protection of colonies into the future, and how many buffered colonies are required to ensure the recovery of the species. Further studies would be required to answer these questions, and these are outside the scope of this review.

In assessing the benefits of the new THEZs there are a range of assumptions that have been necessary. These are outlined in the text below and summarised in Appendix 1. Appendix 1 also provides detail on the methodology used to derive the results presented.

2.1.2 The number of newly located colonies

The time period covered by this review is 1 January 1998 to 30 January 2017, during which 820 verified records of Leadbeater's Possum were reported to DELWP. Two hundred and eighty-three of these were from the 'Existing' time period (1 January 1998 to 28 February 2014) with a further 537 reported and verified between 1 March 2014 to 30 January 2017.

For the purpose of establishing timber harvesting exclusion zones, LPAG defined a colony as 'any confirmed record of a Leadbeater's Possum, based on the premise that an individual is part of a colony' (LPAG 2014b). As Leadbeater's Possums are colonial and territorial (Smith 1984b), the vast majority of their time is spent within their territory boundary, with only the occasional (maybe once in an animal's life time) longer distance dispersal movements outside of this territory (Smith 1984b).

Within the 820 verified records, there are multiple reports from the same detection site on different dates, and records that are close to each other and hence may represent individuals from the same colony. In reporting the number of new colonies receiving THEZs, any new record that falls within an existing THEZ is considered a duplicate record (LPAG 2014b) and is not included in the tally (Figure 1). Therefore, although more than one colony may occur within a THEZ, for counting purposes, one THEZ equates to one colony.

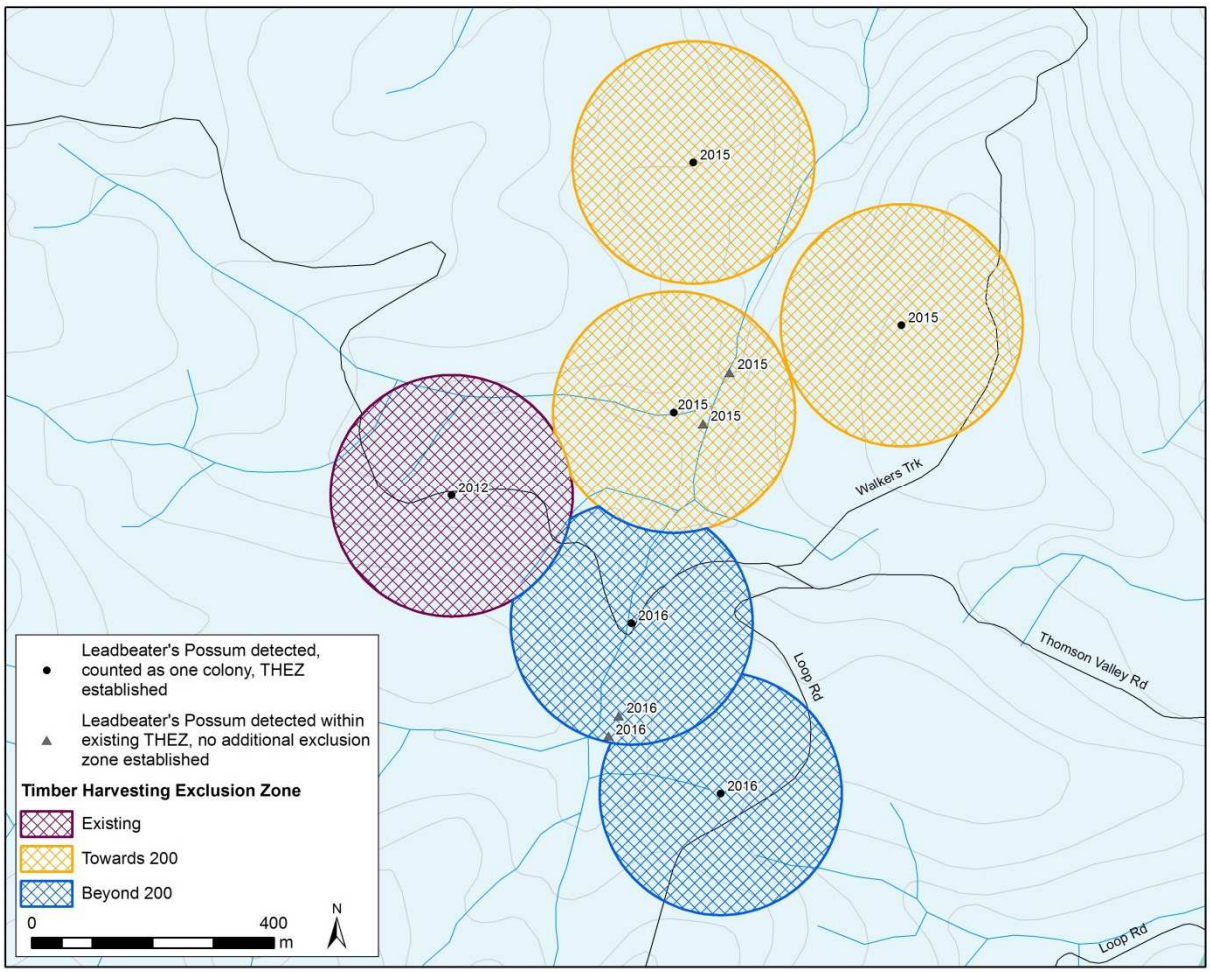


Figure 1. Example of Timber Harvest Exclusion Zones (THEZ) established around Leadbeater's Possum detection sites, Thomson State forest. Grey triangles show records within an existing THEZ, and are considered duplicate records of colonies accounted for by black dots. Labels indicate year of detection.

To enable clear and consistent reporting on the number of new colonies, public land is represented in three categories:

- State forest – General Management Zone (GMZ) and Special Management Zone (SMZ), where timber harvesting is permitted;
- State forest – Special Protection Zone (SPZ), areas managed for conservation with timber harvesting not permitted; and
- parks and reserves managed by Parks Victoria (with the term 'park' used in this report to avoid confusion as the term 'reserve' is used for both SPZs and reserves managed by Parks Victoria).

In total, 495 new colonies were located and reported to DELWP since 1998 (Table 1). One hundred and forty-nine of these are considered 'existing records,' i.e. within the 15 years prior to the implementation of the LPAG recommendations (excluding records that were subsequently burnt by high severity bushfire, as animals were almost certainly extinguished from these areas; Lindenmayer *et al*. 2013a, Lumsden *et al*. 2013). LPAG recommended a review of the THEZ action after two years of intensive surveying (from 2014) or once 200 new colonies had been located (LPAG 2014a). Both of these milestones were met at roughly the same time in June 2016. Since then new colonies have

continued to be found with an additional 140 colonies located in GMZ/SMZ between June 2016 and January 2017. The majority of the newly located colonies are either within State forest GMZ/SMZ, or part of the THEZ impacts on GMZ/SMZ (88%), with 3% wholly within existing SPZs, and 9% wholly in parks. There are some additional records from within parks that have not as yet been submitted to the DELWP databases (DELWP 2016).

Table 1. The number of Leadbeater's Possum colonies located within State forest and parks in the Central Highlands. 'Existing' – 1 January 1998 to 28 February 2014; 'Towards 200' – 1 March 2014 to 6 June 2016; 'Beyond 200' – 7 June 2016 to 30 January 2017.

	Existing	Towards 200	Beyond 200	Total
State forest – GMZ/SMZ	96	200	140	436
State forest – SPZ	9	1	3	13
Parks	44	1	1	46
Total	**149**	**202**	**144**	**495**

All of these newly located, verified colonies were immediately protected from timber harvesting by the establishment of a THEZ, with timber harvesting ceasing if it had already commenced. These newly located colonies are spread across the whole of the known range of the species. A large proportion of the records were from the southern part of the species' range from Warburton, Powelltown, Noojee, Toorongo Plateau and either side of Baw Baw National Park (Figure 2).

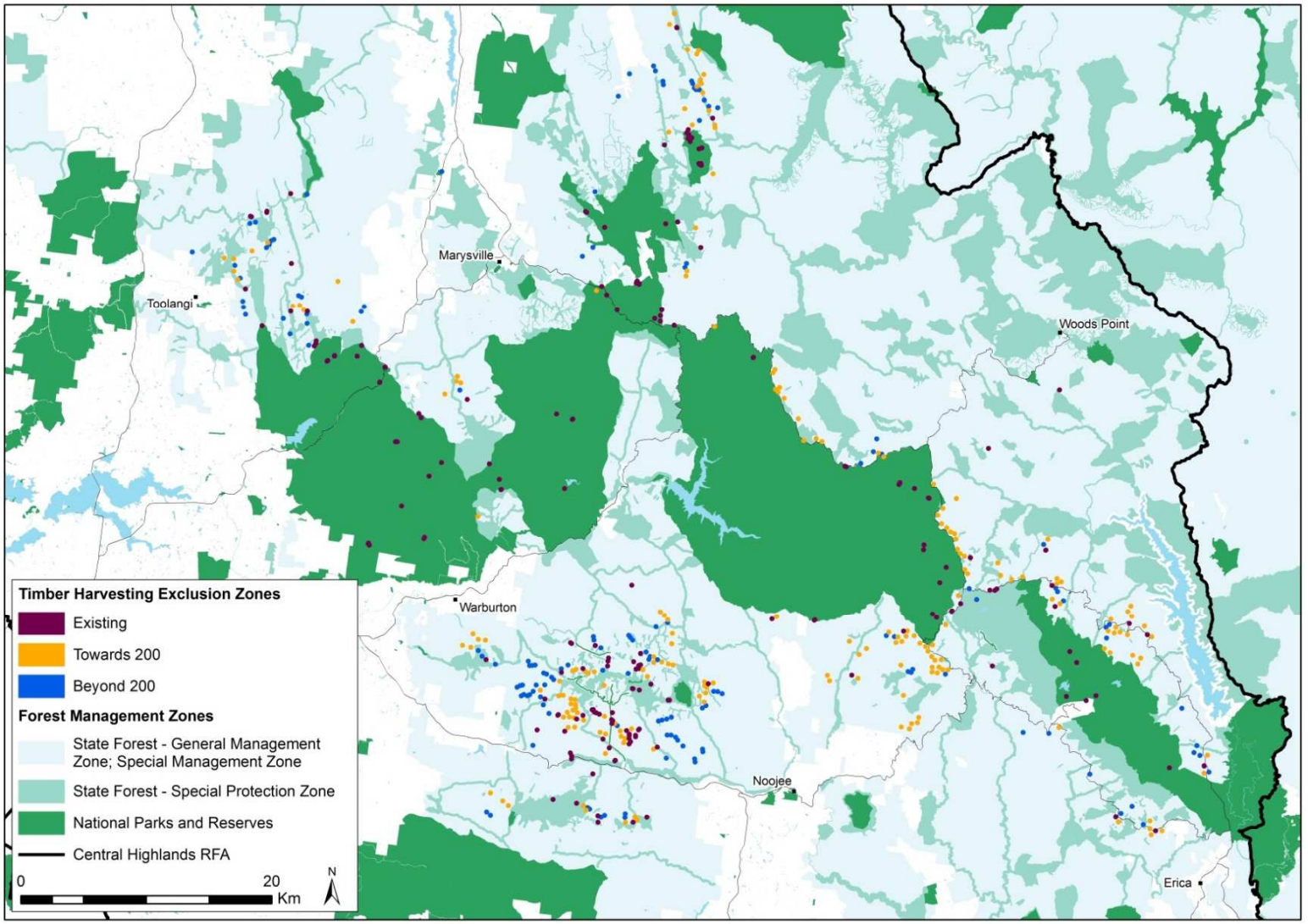


Figure 2. The locations of the timber harvesting exclusion zones (actual size) around Leadbeater's Possum colonies, shown in three time periods. 'Existing' – 1 January 1998 to 28 February 2014; 'Towards 200' – 1 March 2014 to 6 June 2016; 'Beyond 200' – 7 June 2016 to 30 January 2017.

2.1.3 Sampling effort and rate of increase of reported records

Since Leadbeater's Possums were rediscovered in the Central Highlands in 1961 (Wilkinson 1961) the number of records submitted to departmental databases (most recently the Victorian Biodiversity Atlas) has continued to increase. Figure 3 shows the yearly average number of records submitted per decade from the 1960s to the 2000s, with 10-20 records typically submitted per year during this period. These sightings were from a range of organisations, including the Australian National University (ANU) where a subset of 161 long-term monitoring sites are sampled each year (Lindenmayer *et al.* 2003), plus Project Possum, Zoos Victoria and field naturalists surveys (Harley 2016). In 2012, the Arthur Rylah Institute for Environmental Research, DELWP (ARI) undertook a broad-scale survey for the species across its range, with an associated spike in records that year (Lumsden *et al*. 2013). Following this, ARI commenced targeted surveys, implementing the LPAG recommendations, which commenced late in 2014. In contrast to the earlier surveys where sites were selected randomly, these were very targeted to areas considered most likely to contain Leadbeater's Possum, to enable rapid location of colonies for protection from timber harvesting. These surveys have been undertaken using remote cameras installed high in trees by arborists (Nelson *et al*. 2015, Nelson *et al*. in press). Animals are attracted to the cameras by a bait (creamed honey), which is likely to be detected from less than 100 m. Hence these records represent animals foraging within their approximately 3 ha territory (Smith 1984b), rather than drawing them in from outside this area. During this program 289 survey sites were sampled, in the 2014/15 and 2015/16 sampling years, with Leadbeater's Possum detected at 148 sites (51%) (Nelson *et al*. 2015, Nelson *et al*. in press). VicForests commenced pre-harvest surveys during this time which has resulted in additional records. In addition, dedicated community surveys greatly increased in late 2015 and 2016. All these surveys have used new or refined survey techniques, which are proving to be highly effective (Nelson *et al*. 2015, Nelson *et al*. in press).

The dramatic increase in the number of records submitted to the Victorian Biodiversity Atlas (VBA) in recent years (Figure 3), reflects the significant increase in sampling effort and the use of new, effective survey techniques in recent years.

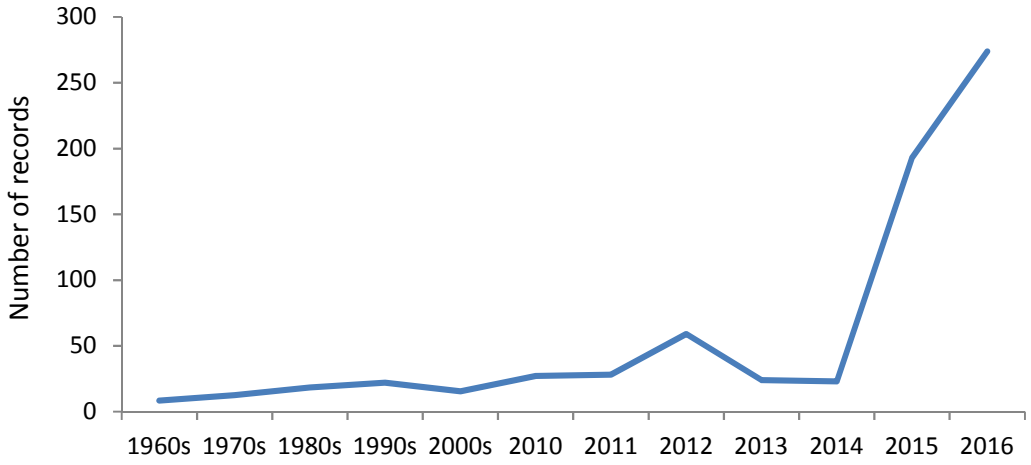


Figure 3. The number of Leadbeater's Possum records submitted to the Victorian Biodiversity Atlas since the 1960s, with the average shown per year for the decades up until the 2000s, and then each year since 2010. Peaks in numbers correspond to increased survey effort.

Note that the figures presented in Figure 3 are based on the number of records submitted to the VBA up until 30/12/2016. The number of colonies this represents will be lower (removing some individual records that may be from the same colony). In addition, not all recent records of Leadbeater's Possum, especially from within parks, have been submitted as yet to the VBA.

Since the commencement of implementing the LPAG recommendations in 2014, 66% of records have come from surveys by government agencies, including ARI, DELWP, Zoos Victoria, Parks Victoria, and VicForests (Table 2).

Table 2. The source of new Leadbeater's Possum colony records since the commencement of the implementation of the LPAG recommendations in March 2014.

Source of colony record	Number of colonies	Percentage
Government agencies	229	66.2%
Community groups / general public	102	29.5%
Universities	15	4.3%
Total	346	100%

A significant proportion of the new records have come from community groups or members of the general public (29.5%) (Table 2). The LPAG recommendations encouraged submission of records from community groups. To help facilitate this, kits of specialised survey equipment were made available on loan to interested groups. There has been a high level of uptake in borrowing this equipment, with the three kits in almost constant use. Survey standards were developed to outline the evidence required for records to be accepted as verified (DELWP 2015). A record could be accepted, based on desktop verification, if sufficient evidence was provided, such as video footage clearly showing the identity of the animal, with continuous footage panning down to a GPS to provide evidence of the location. If the observation could not be verified from the information provided, but there was sufficient evidence to suggest that the sighting may have been a Leadbeater's Possum, or where it was definitely a Leadbeater's Possum but the location could not be unequivocally confirmed, a field-based verification survey was undertaken by ARI.

Since March 2014, 118 reported sightings of Leadbeater's Possum were submitted to DELWP by community groups or members of the general public. Of these, 99% were verified, with the majority (82%) able to be verified via desktop verification due to the high quality of the evidence provided. The remaining 22 required field verification, with all except one successfully verified.

The provision of the specialised survey equipment (thermal imaging cameras, infrared video cameras and still cameras, infrared illuminators, megaphones and mp3 players, GPSs, bright torches etc.) greatly enhanced the ability of these groups to provide the high quality evidence required for desktop verification, and this has been an effective way to locate additional Leadbeater's Possum colonies for protection.

2.1.4 Proportion of potential habitat surveyed

An examination of the coverage of the recent intensive sampling undertaken since the commencement of the LPAG recommendations in 2014 will assist in the interpretation of the likely proportion of the total population that has been located and subsequently included in THEZs. Survey effort (i.e. the total number of sites sampled for Leadbeater's Possums, including sites where the

species was not recorded) is available for some but not all groups undertaking surveys. Where survey effort is available, the total number of sampling locations is used (i.e. from the ARI targeted surveys (357 sites, represented by 956 sampling locations (cameras)) and the VicForests pre-harvest surveys (138 sites, represented by 413 sampling locations (cameras))). Where this is not available (for the community group records and the existing records), just the locations where sampling is known to have occurred (i.e. where the species was detected) are used. Despite these limitations, it does provide an indication of the magnitude of this sampling.

Overlaying a 400 m x 400 m grid (approximately equivalent to a 200 m radius THEZ but with complete coverage) on the distribution of the species within potential habitat in State forest (all montane ash forest and snow gum woodland within the range of the species – refer glossary) resulted in a total of 10,602 grid cells (Figure 4). A grid cell was considered to contain potential habitat if there was at least 3 ha of montane ash forest or snow gum within the cell. To assess the extent of sampling coverage in areas where the species is more likely to occur, a similar grid was overlayed on the area predicted to have a greater than 30% probability of occurrence (from the ARI occupancy model, Lumsden *et al.* 2013) resulting in 4,587 grid cells. Areas predicted to have a greater than 30% probability of occurrence have a higher recorded occupancy rate than those with less than 30% probability of occurrence (Nelson *et al.* 2015).

Overall, 6.2% (654) of grid cells mapped as potential habitat in State forest have been surveyed since the commencement of the implementation of LPAG recommendations. A slightly higher proportion of areas with a greater than 30% likelihood of occurrence have been surveyed (458 – 9.9%).

The lack of inclusion of the full sampling effort from some groups will have underestimated the proportion of the area surveyed, as the number and location of sites surveyed where Leadbeater's Possum were not detected has not been documented. However, using a grid cell of 400 m x 400 m and classifying a cell as surveyed even if only a small part of it had been sampled, will to some extent balance this out as this will overestimate the sampling effort. Despite these limitations, it is apparent that only a relatively small proportion of the total potential distribution of Leadbeater's Possum has been sampled to date, despite the extensive sampling effort in recent years. Not all of this area is likely to be occupied, and not all of it will be likely to be sampled in the future as much of it is inaccessible.

There has been less sampling in parks and reserves in recent years than in State forest, as the LPAG recommendations explicitly stated that the targeted surveys were to sample areas of State forest to enable Leadbeater's Possum colonies to be located and protected from timber harvesting. Some work however has continued in parks throughout this period, especially by Project Possum (a collaborative project between Parks Victoria, Zoos Victoria and Friends of Leadbeater's Possum) (Harley 2016), and at the subset of the ANU long-term monitoring sites that are within parks.

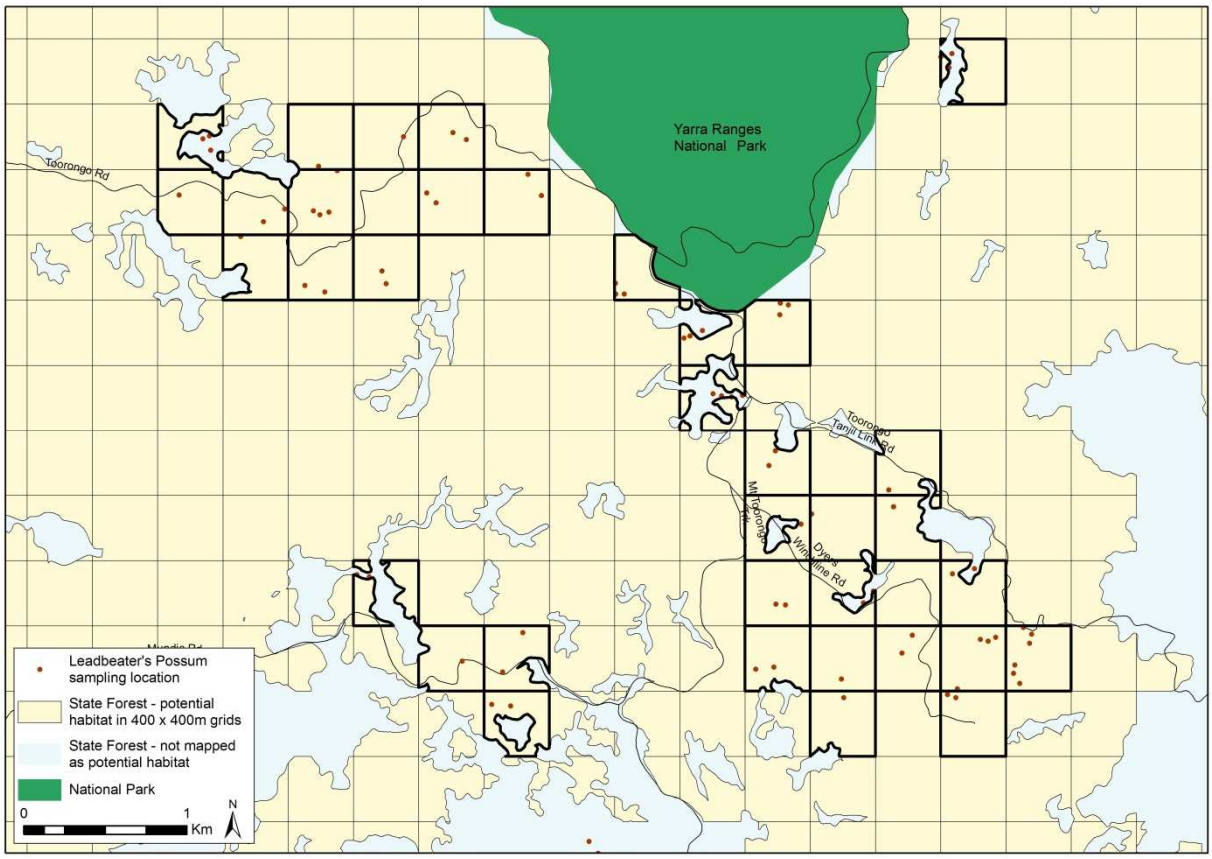


Figure 4. An example of the 400 m x 400 m grid cell overlay on potential habitat in the Toorongo Plateau area, showing sampling effort. Mapped potential habitat is shown only in State forest and not in National Park.

2.1.5 Number of records and sampling effort in the > 65% moratorium area

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

The ARI targeted surveys aimed to sample as much as possible of the greater than 65% probability area within GMZ or SMZ during the moratorium period. Not all areas were accessible (a limit of 400 m from tracks was set for OHS reasons), or suitable for sampling, such as logging regrowth less than 10 years old. Other areas were not sampled because they were included in adjacent THEZs, or were small fragments (<5 ha). Of the 65 sites that were considered available and suitable to survey, 48 were surveyed (74%) during the ARI targeted surveys.

During the timber harvesting moratorium, 42 new colonies were located in areas with a predicted probability of occupancy of greater than 65%. This was 21% of the 200 new colonies located during this period.

2.1.6 Area protected in Leadbeater's Possum timber harvesting exclusion zones

A total of 4,046 ha of State forest that was previously GMZ/SMZ (minus areas excluded from timber harvesting under the Code of Forest Practice for Timber Production) is now protected within THEZs as a result of this action (Table 3). Nineteen percent of this area (772 ha) resulted from Existing colonies recorded during the 15 years prior to 2014 (i.e. 1 January 1998 – 28 February 2014). The first 200 records submitted and verified after 1 March 2014 led to an additional 1,969 ha being protected (49%). Since June 2016, the additional 140 colonies located and verified have resulted in a further 1,305 ha of GMZ/SMZ being protected (Table 3). For many of the new THEZs, a proportion of the 12.6 ha exclusion zone was already within an SPZ, Code of Forest Practice exclusions or park. The average area of State forest GMZ/SMZ impacted per THEZ was 8.0 ha for Existing colonies, 9.8 ha for Towards 200, and 9.3 ha for Beyond 200, with an overall average of 9.3 ha.

Where records were located within SPZs or parts of the THEZ from records in GMZ/SMZ overlapped with SPZ, this resulted in 651 ha within equivalent 200 m radius buffers, and 529 ha within Code of Practice for Timber Production (DEPI 2014b) exclusions. For comparison, delineating 200 m radius buffers around colonies located in parks equates to 803 ha (Table 3).

Table 3. The area protected by the Leadbeater's Possum timber harvesting exclusion zones within State forest in the Central Highlands. Equivalent sized buffers around colonies in SPZs and parks is provided for comparison. 'Existing' – 1 January 1998 to 28 February 2014; 'Towards 200' – 1 March 2014 – 6 June 2016; 'Beyond 200' – 7 June 2016 – 30 January 2017.

	Existing (ha)	Towards 200 (ha)	Beyond 200 (ha)	Total (ha)
State forest – GMZ/SMZ	772	1,969	1,305	4,046
State forest – Code of Forest Practice exclusions	95	287	147	529
State forest – SPZ	310	170	172	652
Parks	744	46	13	803
Total	**1921**	**2472**	**1637**	**6030**

The area within THEZs represents 2.6% (5,156 ha, Table 4) of the total area of potential habitat (all montane ash forest and snow gum woodland within the range of the species – refer glossary). Of the areas predicted to have a greater than 30% probability of occurrence (from Lumsden *et al.* 2013), 3.0% (3,506 ha) is protected within THEZs. These figures include all land tenures, not just areas of GMZ/SMZ protected by this action. The area of GMZ/SMZ within THEZs represents just 1.9% (3,911 ha) of potential habitat and 2.4% (2,819) (Table 4), of the total area of predicted greater than 30% probability of occurrence.

When the area of GMZ/SMZ within newly protected THEZs is combined with the area already protected in parks or SPZs, the total area of potential habitat protected is 46.3% (Table 5) and the area of predicted greater than 30% probability of occurrence is 40.8%. Therefore the THEZs have only marginally increased the protection of potential habitat or areas with predicted greater than 30% probability of occurrence, with a greater proportion already protected in parks or by SPZs. Collectively, however, the THEZs and existing reserves encompass less than 50% of both the potential habitat and the areas with a higher probability of the species occurring (>30% probability) with a lower proportion of the latter protected (41%, Table 5).

Table 4. The percentage of the area of potential Leadbeater's Possum habitat and areas predicted to have a greater than 30% probability of occurrence included in THEZs. These figures include all land tenures. Potential habitat is all montane ash and snow gum within the range of the species in the Central Highlands. The > 30% probability area is based on occupancy model in Lumsden *et al*. (2013).

	THEZ (ha)	Total (ha)*	%
Potential habitat	5,156	198,491	2.6
Area predicted to have > 30% probability of occurrence	3,506	115,174	3.0

Table 5. Areas of potential Leadbeater's Possum habitat and areas predicted to have a greater than 30% probability of occurrence protected in existing parks and SPZs, and the additional area in THEZs.

	Parks & SPZs (ha)	Additional area in THEZs (ha)	Total protected (ha)
Potential habitat	88,071	3,911	91,982 (46.3%)
Area predicted to have > 30% probability of occurrence	44,196	2,819	47,016 (40.8%)

The figures presented above represent the area of GMZ/SMZ protected by this action that would not have been protected under the policies in place prior to LPAG. Not all of this area, however, is operationally available or suitable for timber harvesting. VicForests has developed a GIS layer to represent areas considered available and suitable for harvesting, which is called the 'Available Resource' (Figure 5). This layer comprises all areas of GMZ/SMZ, excluding areas modelled as exclusions under the Code of Forest Practice for Timber Production (DEPI 2014b), such as steep slopes and riparian buffers, and other unavailable or unsuitable areas, and hence represents the area that could potentially be harvested any time into the future, including young regrowth forest that may not be suitable for harvesting for many decades.

The total area available and suitable for harvesting (i.e. the Available Resource) protected by the THEZs is 3,134 ha (Table 6). The majority (91%) of this is montane ash forest, as would be expected since this is the primary habitat type occupied by Leadbeater's Possum. Some adjacent areas of mixed species forest are also included within THEZs. The area within the THEZs represents 2.5% of the total Available Resource area within the Central Highlands, or 4.1% of the ash forest within the Available Resource area.

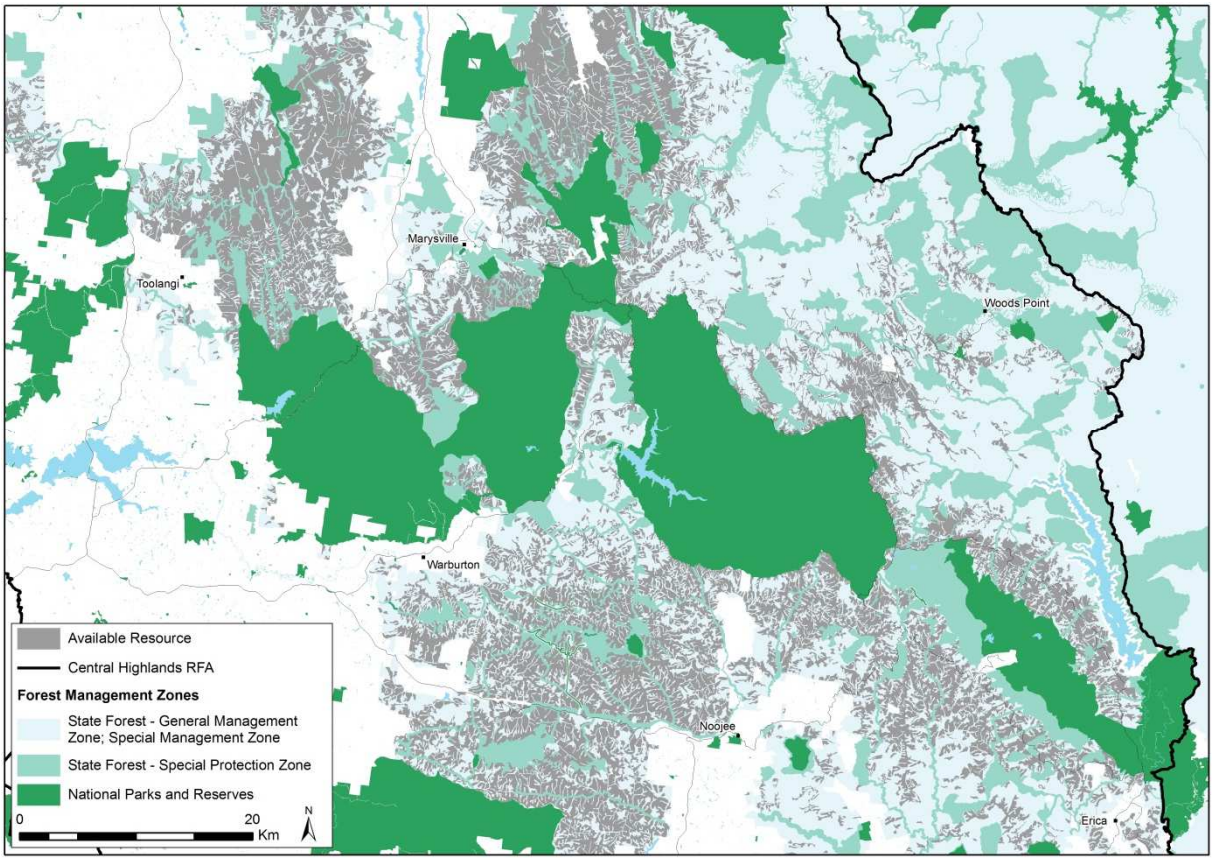


Figure 5. The total Available Resource of timber which can be harvested at any point into the future, within the range of Leadbeater's Possum, Central Highlands RFA. Available timber resource is displayed regardless of rotation stage, i.e. even if recently harvested, and is shown based on the 2013 status prior to the implementation of the THEZ recommendation.

Table 6. The area of Available Resource protected by Leadbeater's Possum timber harvesting exclusion zones in the Central Highlands.

	Area of Available Resource (ha)
Montane ash forest	2848 (91%)
Mixed species forest	286 (9%)
Total Available Resource	3134

Of the area of Available Resource that has been included in the THEZs, 37% is regrowth from 1930-1939, which is predominantly 1939 bushfire regrowth (1,171 ha) (Table 7). This represents 0.9% of the total Available Resource in Central Highlands, or 1.7% of the 69,785 ha of ash forest within the Available Resource (prior to the commencement of the LPAG recommendation implementation). The remaining 63% of the forest within the THEZs is younger regrowth forest resulting from more recent bushfires (1983 and 2009 bushfires) and timber harvesting regrowth with 41% represented by regrowth forest 18-37 years old (Table 7). A visual representation of this pattern is provided in Figure 6.

Table 7. The area of Available Resource that has been protected in THEZs within different disturbance histories.

Age class and disturbance history	Current age of stand (years)	Area (ha)	%
1900-1909, older forest	108-117	21	0.7%
1930-1939, predominantly 1939 bushfire regrowth	78-87	1,171	37.4%
1940-1979, regrowth forest predominantly from selective harvesting	38-77	276	8.8%
1980-1999, regrowth forest from 1983 bushfires and clearfell timber harvesting	18-37	1,277	40.7%
2000-2017, regrowth forest from clearfell timber harvesting and 2009 bushfires	1-17	361	11.5%
Other		29	0.9%
Total Available Resource within THEZs		3,134	100%

These figures align with the results from the ARI targeted surveys (Nelson *et al*. in press), where Leadbeater's Possum were recorded from a high proportion of sites sampled within young regrowth, and this habitat can provide suitable foraging habitat as long as there are hollow-bearing trees within a site or nearby to provide the nesting habitat. During these surveys, the success rate was highest (61%) at sites where young regrowth was adjacent to 1939 regrowth. These areas are likely to provide both the key habitat requirements: dense vegetation structure for movement and wattle for foraging, and fire-killed stags remaining in the 1939 regrowth which are used as nesting sites (Smith 1984a, Smith and Lindenmayer 1992). The success rate in pure 1939 regrowth, while still relatively high with Leadbeater's Possums recorded at 44% of the sites sampled, was lower than when there was adjacent younger forest. In 1939 regrowth, the wattles are senescing and dying (Adams and Attiwill 1984), which opens the mid-storey layer, reducing vegetation connectivity and the availability of wattle gum for food. Within the 1983 bushfire regrowth, both critical habitat requirements are present together, and Leadbeater's Possum were detected at 59% of sites sampled within this age-class (Nelson *et al*. in press). A key factor in interpreting these results is that most of the recent surveying uses techniques that detect the animals in areas where they are foraging and so overemphasises the importance of foraging habitat, and provides little information on critical nesting resources.

Although timber harvesting regrowth can be used by Leadbeater's Possum for foraging, this only occurs once the regenerating forest is old enough to provide sufficient food resources. Immediately following harvesting, any Leadbeater's Possums that may have been on site would most likely die (Lindenmayer *et al.* 2015). If the harvested area was surrounded by suitable habitat that remained occupied, animals could expand into these regenerating areas once the forest stands were old enough, at approximately 10 years of age. However, most regenerating areas have no or few hollow-bearing trees, so they can only provide half of the habitat requirements, with retained older forest required to provide the nesting sites. Therefore, the result that Leadbeater's Possum can use timber harvesting regrowth should not be interpreted as them being able to survive purely within these age-classes. Without nearby hollow-bearing trees, they would be unable to use the regrowth stands.

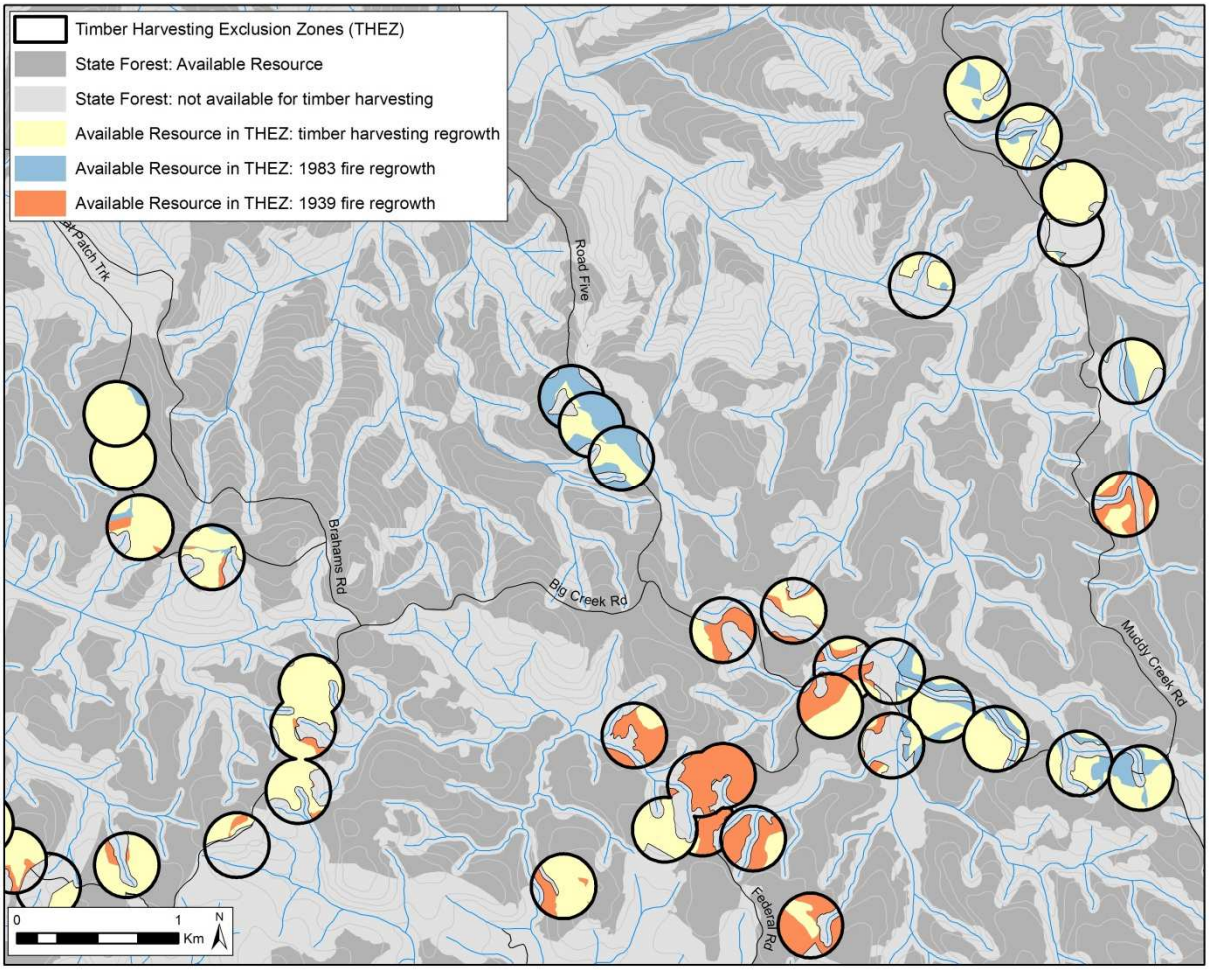


Figure 6. An example of disturbance histories represented within the THEZ, displayed within the Available Resource area, La Trobe and Yarra State forests, Powelltown area. Dark grey shading shows State forest available for timber harvesting (Available Resource), with light grey areas unavailable for harvesting through SPZs or modelled exclusions under the Code of Forest Practice. This example shows areas within THEZs that are 1939 bushfire regrowth (orange), 1983 bushfire regrowth (blue) and timber harvesting regrowth (yellow).

2.1.7 Comparison of the area protected as a result of the timber harvesting exclusion zone action vs habitat prescriptions

Prior to the adoption of the LPAG recommendations, the only site-based prescription for Leadbeater's Possum was through identifying high quality habitat in the form of Zone 1A or 1B. LPAG recommended the definition of Zone 1A be reduced from 12 to 10 live, mature or senescent hollow-bearing ash trees per three hectare patch (LPAG 2014a). Zone 1B remained unchanged at 12 or more live or dead hollow-bearing trees, with a high density of wattle understorey. Zone 1A and 1B are more fully described in the Leadbeater's Possum survey standards (DELWP 2015). The main focus of these habitat prescriptions is nesting habitat, in the form of hollow-bearing trees. At the time it was recognised that these zones did not include all potentially suitable habitat for the species, and that colonies were likely to be found outside these areas (LPAG 2014b). This is because it represents only the highest quality nesting habitat with colonies also located in medium and lower quality habitat, although potentially at lower densities. In addition, where nesting and foraging habitat are geographically separated, animals may be located within foraging habitat which may not meet the Zone 1 criteria.

There is no comprehensive map of areas protected under the Zone 1A or 1B prescriptions. Areas of Zone 1 habitat are identified by VicForests as they are located during ground truthing of coupes scheduled for harvesting, and mapped where no other prescriptions, such as THEZs, apply. As a result the mapped area of Zone 1 habitat will be an underestimate, but it does provide an approximation of the relative size of areas that have been protected in recent years under the two prescriptions.

Within State forest in areas of GMZ or SMZ, 3,274 ha have been protected by THEZs since February 2014. In comparison, 193 ha have been protected using the Zone 1A habitat prescription from October 2012 to June 2016. This suggests that the THEZ action has been more effective than the habitat prescription in protecting areas currently occupied by Leadbeater's Possums.

Habitat assessments undertaken at the ARI targeted survey sites support these figures (Nelson *et al*. in press). All hollow-bearing trees were assessed over a 1 ha area at 287 sites sampled for Leadbeater's Possums. A total of 201 hollow-bearing trees met the survey standard definition (DELWP 2015), with an average of 0.7 live hollow-bearing trees per ha. Only 3% of sites contained three or more such hollow-bearing trees. Although it is not possible to extrapolate from this data to determine the number of sites that would have met Zone 1A definitions (due to the habitat assessments being measured over 1 ha, not the 3 ha required for Zone 1A, and the additional requirement in the survey standards for the hollow-bearing trees to be less than 100 m apart), it does suggest that little of the GMZ/SMZ meets the current Zone 1A definition.

2.1.8 Indirect benefits of the timber harvesting exclusion zone

There will be indirect benefits to Leadbeater's Possum from nearby THEZs, through some areas being effectively, although not formally, protected where there are small fragments of habitat that are unviable to harvest or areas that are inaccessible (Figure 7). VicForests classifies fragments as areas less than 5 ha in size that are more than 40 m from viable, accessible timber stands (refer to Section 4.2.2.4 for further detail). VicForests has estimated that there are 203 ha of fragments no longer available for harvesting. Although it is not known if these additional areas are occupied by Leadbeater's Possums, many of them may be as 74% are within the area predicted to have a greater than 30% likelihood of being occupied. In addition, surveys have found that areas adjacent to known colonies are often occupied (Nelson *et al*. 2015, Nelson *et al.* in press). There are also benefits from an increase in the size of the protected area, by providing a larger buffer around the colony and by increasing connectivity to adjacent colonies, with such increases likely to enhance the persistence of the colonies (Lindenmayer *et al.* 1993, Lindenmayer and Possingham 1995a). As these areas are not formally zoned as protected, their status could change in the future and so they have not been included in the area of protected forest in Section 2.1.6.

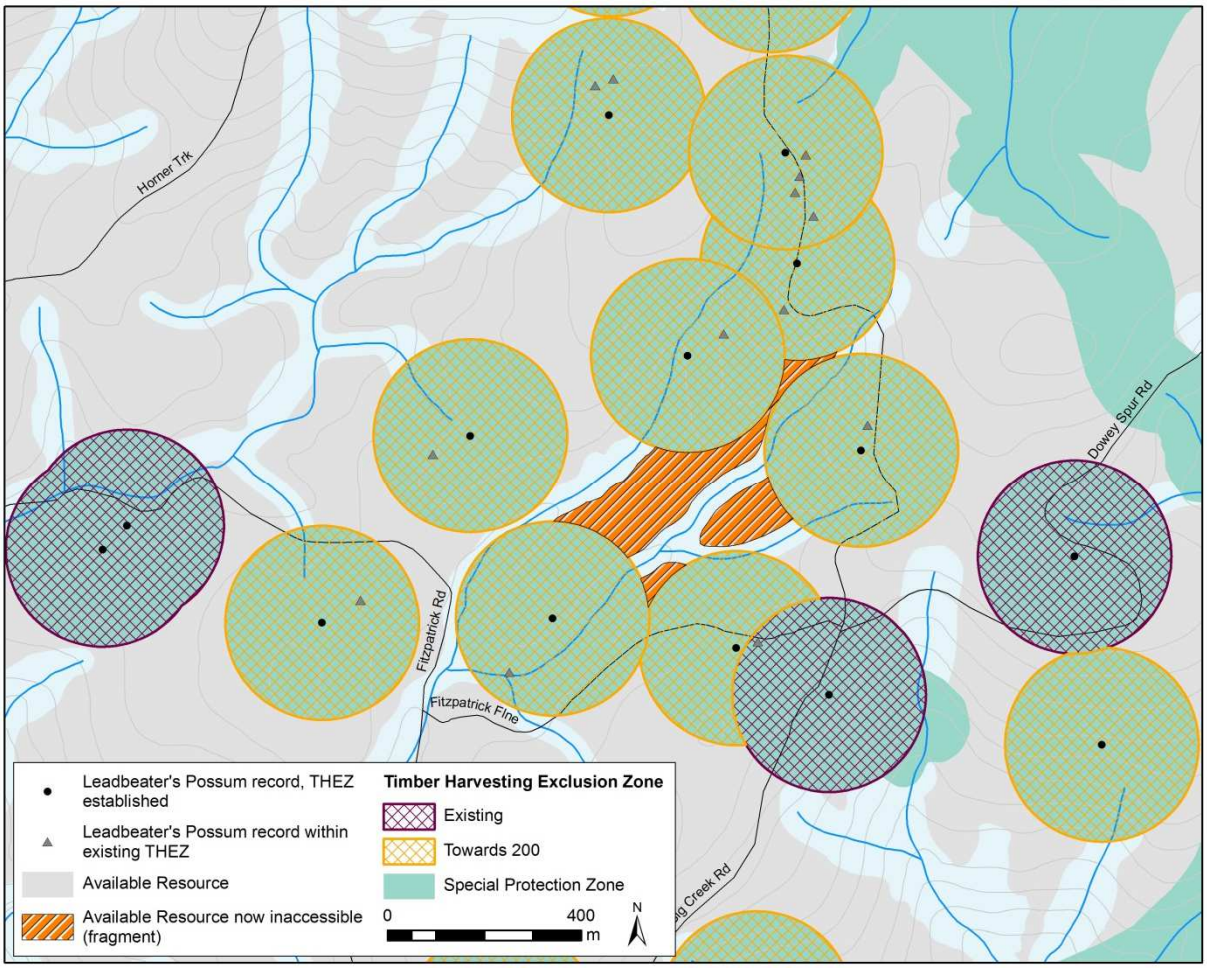


Figure 7. An example of areas classified as 'fragments' around THEZs which are now considered unavailable for harvesting and hence indirectly protected for Leadbeater's Possums.

2.1.9 Summary of the extent of additional protection provided by the timber harvesting exclusion zones

- There has been an increase in the number of records of Leadbeater's Possum in recent years, with 820 verified records received since 1998. This reflects a significantly greater sampling effort, particularly since 2014, and the use of new, efficient survey techniques.
- Despite this increase in sampling effort, only 6% of all potential habitat in the Central Highlands has been surveyed for Leadbeater's Possum, and less than 10% of habitat modelled to have a higher likelihood of occupancy.
- The 820 records correspond to 495 new colonies once duplicate records that may represent the same colony are removed (using the LPAG definition for establishing THEZs). A total of 436 of these are from within State forest in GMZ/SMZ.
- The majority (66%) of these new colonies have been located during government surveys. A significant proportion (30%) have come from community groups or members of the public. Ninety-nine percent of the submitted reports from community groups have been successfully verified, the majority by desktop examination of the high-quality evidence submitted. This has been facilitated by the loan by DELWP of specialised survey equipment to community groups.

- The establishment of THEZs around the 436 new colonies located in GMZ/SMZ resulted in the additional protection of 4,046 ha, of which 3,134 ha was considered available and suitable for timber harvesting now or at some time in the future. Of this, 1,171 ha (37%) was regrowth from the 1930s, predominantly from the 1939 bushfires, with 63% younger regrowth resulting from bushfires in 1983 and 2009, and from timber harvesting.
- Young regrowth from either bushfire or timber harvesting can provide the dense mid-storey connectivity and food supply needed for foraging by Leadbeater's Possum, as long as there are hollow-bearing trees either within or nearby, to provide nesting sites. Timber harvesting or bushfire regrowth with no retained or nearby hollow-bearing trees is unlikely to support Leadbeater's Possums.
- The approach of establishing timber harvesting exclusion zones around existing and all newly located Leadbeater's Possum colonies has therefore been effective in protecting locations where the species is known to occur. Based on the data available, it appears to have been more effective than the prescription that protects high quality Leadbeater's Possum habitat (Zone 1A and 1B habitat), which, over a slightly longer time period (since October 2012), is mapped as protecting only 193 ha, although the full extent of Zone 1A habitat is not known.
- The long-term persistence of colonies within these 200 m radius THEZs, however, is unknown.
- As surveys have only sampled a small proportion of the likely range and population of Leadbeater's Possums, the new protection mechanisms have also only protected a relatively small proportion of the area suitable for Leadbeater's Possums: 2.6% of the total area of potential habitat and 3.0% of the area predicted to have a greater likelihood of the species occurring (>30% probability).
- Although these are useful metrics, the variation among all the metrics used in this evaluation shows that there is no single answer to the question of how much the protection for Leadbeater's Possum has improved, and that this is nuanced.

2.2 Evaluating the effectiveness of the additional protection in supporting the recovery of Leadbeater's Possum

Evaluating the effectiveness of the additional protection in supporting the recovery of Leadbeater's Possum is a more complex and less tractable question than documenting the extent of the additional protection. There is no definitive answer to the extent to which these THEZs can support the recovery of Leadbeater's Possum. This is because, although this is one of the most-studied threatened species in Australia, there remain many unknowns, such as the current and past total population size. In addition, there is no single metric to address this issue as there are a range of factors that influence extinction risk, including both current and future disturbance regimes. Given these uncertainties, a range of complementary measures are used to assist in the evaluation of the benefits of the THEZs in reducing extinction risk and supporting population recovery.

2.2.1 Proportion of the total estimated population protected by the exclusion zones

There are no definitive assessments of the total population size for Leadbeater's Possum, however a number of population estimates have been attempted (summarised in Threatened Species Scientific Committee (TSSC) 2015). All estimates include a range of assumptions, which often differ between approaches. The most recent estimates include 3,125 individuals (equivalent to 1,250 colonies) (Lindenmayer *et al*. pers. comm., in TSSC 2015) and 3,945-10,960 individuals (1,578-3,484 colonies)

(LPAG 2014a). The Lindenmayer *et al*. figures (in TSSC 2015) are based on an assessment of the availability of suitable habitat and long-term data on mean abundance of animals per hectare of suitable forest. The LPAG (2014a) figures are an extrapolation from the number of Leadbeater's Possum detections at 180 randomly selected sites surveyed throughout the species' range in 2012 (Lumsden *et al*. 2013), factoring in different detection rates in State forest and national parks, and in areas burnt and not burnt in the 2009 bushfires, imperfect detectability resulting in the species not being detected at some sites where they actually occur, and differing estimates of the effective survey area, i.e. the distance from which animals were drawn into the call playback technique used in these surveys. The large number of uncertainties and assumptions resulted in the wide range in these population estimates.

It is not possible to reassess population numbers from the recent increased number of new records of Leadbeater's Possums, as the targeted nature of the sampling that yielded these new records precludes extrapolation across the whole range. An additional confounding factor is that current colony sizes are also unknown. In the past, colony sizes have been reported to be between 2 and 12 individuals (Smith 1984b, Lindenmayer and Meggs 1996, Harley 2005); however, in recent years, colony sizes appear to have reduced (D. Lindenmayer, pers. comm.; DELWP unpublished data). Another unknown is how many colonies are likely to be protected by a single THEZ. If territory sizes are on average 3 ha, potentially up to four territories could be present in a single 12.6 ha THEZ. However, the actual number of colonies will depend on the size, shape and density of colonies and whether there are unoccupied areas between them, for which there is only limited information.

Nevertheless, the recent increased number of located colonies, while only a small proportion of the potential habitat has been surveyed, casts doubt over the accuracy of earlier population estimates, and further work is required to provide more robust estimates. This is needed before it is possible to estimate the proportion of the total population protected by the THEZs. Further randomised surveys across the whole of the species' range, and a clearer understanding of the effective survey area of the technique used in the surveys, along with information on home range configurations, are required.

2.2.2 Reduction in extinction risk based on Population Viability Analysis modelling

Population Viability Analysis (PVA) can be used to inform conservation decisions by estimating the probability of extinction of a species based on the range of threats to its survival. A PVA was developed in 2012 for Leadbeater's Possum to evaluate if the specific Leadbeater's Possum reserve system was sufficient to support the long-term conservation of the species, or if additional strategies were required (Lumsden *et al.* 2013, Todd *et al*. 2016). The PVA modelled significant fluctuations in population numbers over time due to past fires, especially the extensive bushfires in 1939 and 2009. The species' range was divided into six regional metapopulations (see Figure 11), to factor in the differential impact of these fires. Appendix 1 provides more detail on the approach taken in developing the PVA and its underlying assumptions.

The Leadbeater's Possum reserve system was established in 2008, protecting 30,500 ha of high-quality Leadbeater's Possum habitat. A total of 127 patches, greater than 50 ha in size, and containing (at that time) predominantly old growth ash forest were selected for inclusion (Smith and Morey 2001). Areas of old growth were primarily selected as these were likely to provide suitable nesting habitat into the future, compared to areas of 1939 regrowth where dead hollow-bearing trees killed in the 1939 fires were collapsing. Following the establishment of the dedicated

Leadbeater's Possum reserve system, 45% was burnt in the 2009 bushfires, significantly reducing the extent of old growth forest in the reserve.

To quantify the risk of extinction, the probability that the number of adult females within the Leadbeater's Possum reserve would fall below 500 individuals within a 200 year time frame was calculated (Lumsden *et al.* 2013, Todd *et al*. 2016). Typically, once populations fall below these levels they are more susceptible to extinction due to a loss of genetic variation, population changes resulting from unfavourable environmental conditions and catastrophic events such as wildfires (Lacy 2000). As Leadbeater's Possum colonies are dominated by a single breeding female (Smith 1984b) the number of adult females was used as the basis for the PVA estimates. This is therefore comparable to the number of colonies protected by THEZs, under the assumption that one THEZ is equivalent to one colony.

A risk analysis was undertaken by estimating the minimum number of adult females under a range of scenarios and graphing probabilities of minimum numbers as a risk curve (Lumsden *et al*. 2013, Todd *et al*. 2016). These represent the likelihood, or risk, that the modelled population will fall to a given population size within a 200 year time period, below which the long-term persistence of a species cannot be ensured (quasi-extinction). Within these risk curves, the closer the curve is to zero the greater the risk that a population will go extinct. Additionally, risk curves can be readily compared and assessed in terms of increasing or decreasing risk by a shift to the left or right, respectively. An example is shown in Figure 8 to illustrate the interpretation of these risk curves. Using the risk curve on the left, there is a 73% chance (shown as 0.73 probability) of the population falling below 500 adult females within a 200 year timeframe (point c* on the graph). At a 5% probability level, the predicted population size is well below the required 500 adult females (point a*). To have less than a 5% chance of the population not falling below 500 adult females at any time over the next 200 years, the curve would need to pass through (or be to the right of) point b on the graph (i.e. represented by the risk curve on the right). The area of the polygon bounded by the points a*, b, and c* represents how the scenario performs with respect to reaching the desired goal of no more than 5% probability of the population falling below 500 adult females in 200 years. In this example, the risk curve to the left is indicative of an ineffective reserve system (Figure 8). The area of the polygon under the curve is the 'measure of effectiveness', which decreases as a scenario approaches effectiveness and is zero when the desired goal is achieved. For example, the area of the polygon bounded by points a, b, and c (the middle risk curve), is less than the area of the polygon of the curve on the left (a*, b, c*). The middle risk curve therefore represents a decreased risk of extinction, although some risk still remains.

The original PVA model (Todd *et al*. 2016) indicated that there was a severe reduction in the Leadbeater's Possum population following the 2009 bushfires, and this decline was predicted to continue into the future as habitat deteriorates further due to the continuing collapse of dead hollow-bearing trees. The model predicted that areas will become increasingly unsuitable over the next 50-120 years, until the 1939 regrowth matures sufficiently to produce suitable hollows. Increased rates of tree fall and future fires will exacerbate this situation, with models predicting the population in the reserve could fall to critically low levels (Lumsden *et al*. 2013, Todd *et al*. 2016).

This PVA model has been used to help evaluate the effectiveness of the new THEZs, by assessing the reduction in extinction risk through the addition of these areas (which are specifically reserved for the species) to the Leadbeater's Possum reserve system, also specifically reserved for Leadbeater's Possums.

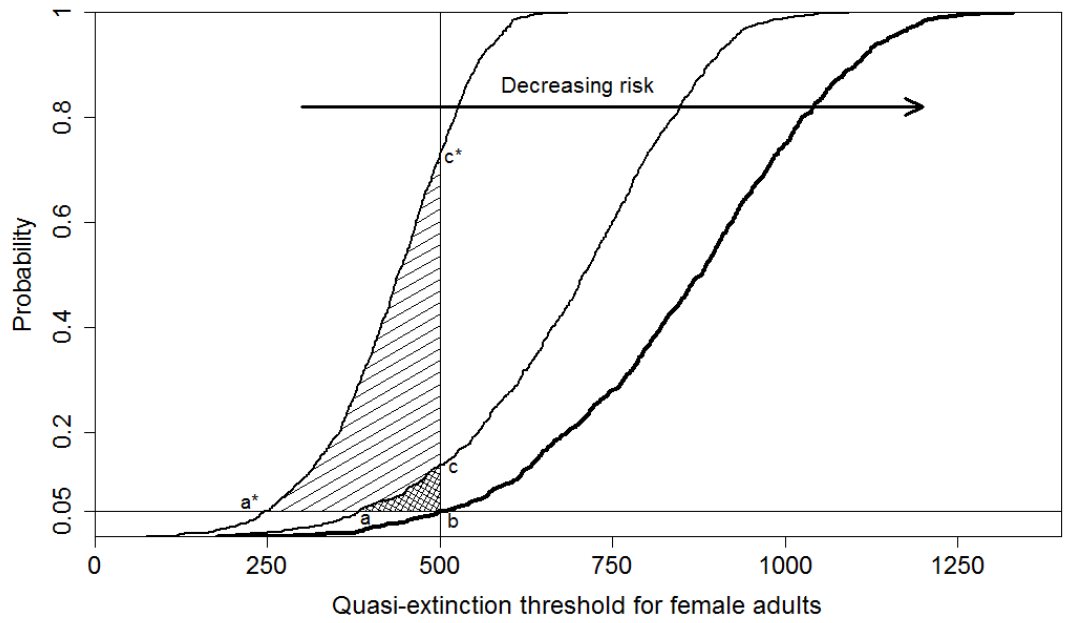


Figure 8. An example of different risk curves, progressing from a situation where the reserve is not effective (left) in reducing the risk of extinction, to improved effectiveness (middle), to achieving desired goal of a less than 5% chance of falling below 500 adult females within the Leadbeater's Possum reserve within the next 200 years (right). The area under the curves (shaded) declines as risk decreases and is a measure of the effectiveness of each scenario.

The addition of the 4,046 ha of GMZ/SMZ (Table 3) which is now in THEZs, to the 30,520 ha of the existing Leadbeater's Possum reserve system resulted in a 13.2% increase in size. This increase produced an increase in the expected value of the minimum population size of adult females from 432.5 to 508.7, an increase of 17.6% (Table 8). The 5% probability quasi-extinction threshold increased from 245 to 293, an increase of 19.6% and the probability for the quasi-extinction threshold of 500 adult females decreased from 0.73 to 0.45, a decrease of 38% (Figure 9). The area under the curve, representing the measure of effectiveness, decreased from 142.5 to 93.3, a 34% improvement towards the desired goal of less than a 5% chance of falling below 500 adult females in the area reserved specifically for Leadbeater's Possum in the next 200 years (Table 8). This indicates that the approach of applying THEZs around known colonies is a useful tool in improving the effectiveness of the reserve system for Leadbeater's Possum, and for reducing the overall extinction risk. While this outcome represents an improvement, it also indicates that there is still a substantial remaining risk of extinction for this species.

Table 8. A summary of the change in measures of extinction risk reduction by the addition of the THEZs to the existing Leadbeater's Possum reserve system.

	Existing reserve	Existing reserve + THEZs	% change
Expected value for minimum population size	432.54 ± 100.59	508.65 ± 118.31	17.6
Range in expected value	74 - 684	84 - 789	–
Quasi-extinction threshold at 0.05 probability	245	293	19.6
Probability at quasi-extinction threshold of 500 adult females	0.73	0.45	38.4
Measure of effectiveness	142.47	93.31	34.5

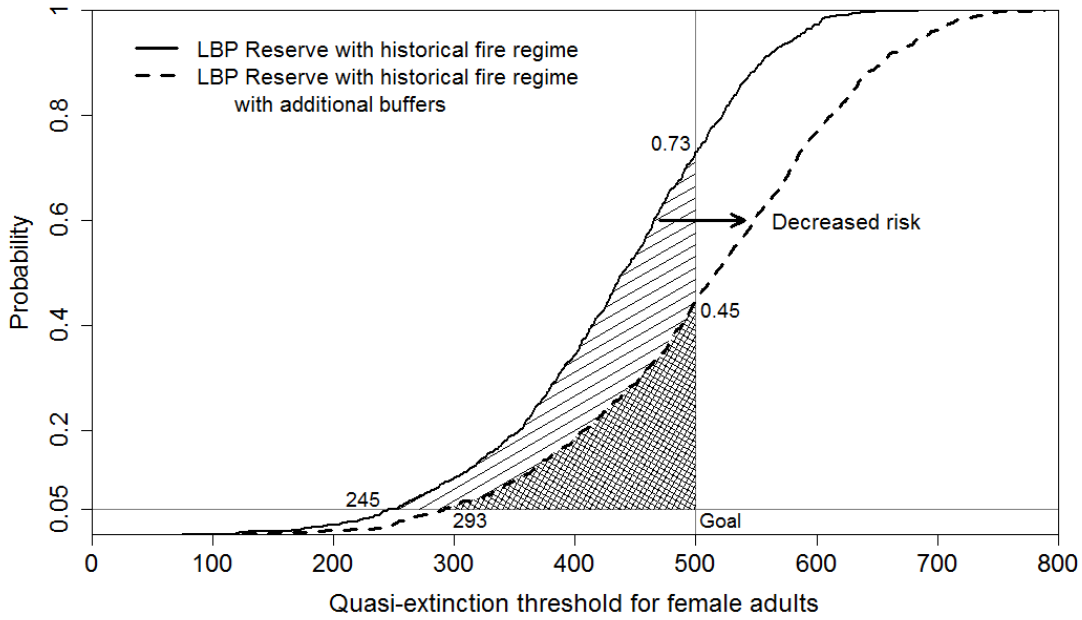


Figure 9. Risk curves showing the reduction in extinction risk from the addition of the THEZs to the existing Leadbeater's Possum reserve. The solid line represents the risk curve for the existing Leadbeater's Possum reserve system, with the dashed line showing the reduction of risk with the addition of the THEZs. The cross hatched areas show the change in effectiveness of the new additional area. These curves include the influence of historic fires, but do not include predictions based on future fires.

This analysis factors in the influence of past fires, but does not include predictions of the impact of future fires. Fire is an integral part of the Australian landscape, and it is highly likely that wildfires will affect Leadbeater's Possum and its habitat sometime in the future. Since 1900 there has been a wildfire within the Central Highlands on average every 10 years, and this frequency is likely to continue (Lumsden *et al*. 2013). However, it is unknown when the next major fire may occur or the extent of its impact. To assess how future fires may impact the effectiveness of the new THEZs, the effect of future fires in 2020 or 2040, with an impact on 12.5% and 25% of the total area of the reserve were modelled. Any future fire increases the extinction risk of Leadbeater's Possum, with larger fires having a greater impact and fires in the near future having more impact than fires further

into the future (Figure 10). With future fire scenarios, the THEZs decrease the extinction risk, but these risks remain higher than is the case without fire.

Using the existing PVA allows a numerically explicit and repeatable assessment of the extent to which the THEZs reduce extinction risk, but it is clear that the model does not provide a single definitive answer, as there are many possible future scenarios.

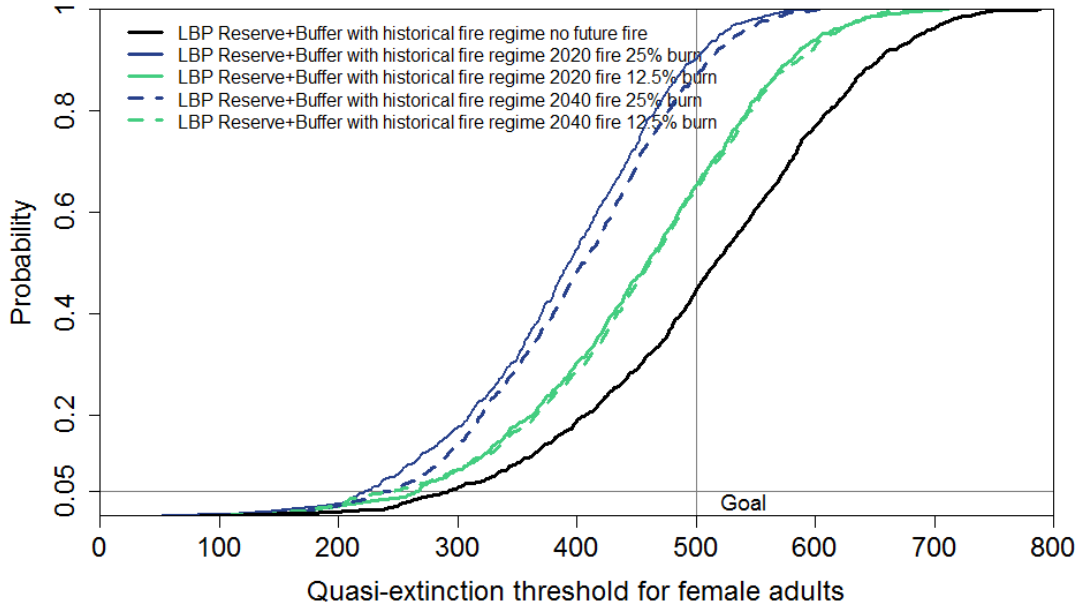


Figure 10. Risk curves from modelling future fire impacts on the combined Leadbeater's Possum reserve and THEZs. The solid black line is no future fire (equivalent to the dashed line in Figure 9). The green lines indicate a future fire impacting 12.5% of the area, and the blue line 25%.

There are a range of assumptions in the existing PVA model, as outlined in Lumsden *et al*. (2013) and Todd *et al*. (2016) (with some summarised in Appendix 1). It would be useful to update the PVA to incorporate new information collected since it was developed in 2012, and test some of these assumptions. However, it remains the best available PVA and as the comparison is between the existing reserve system and the reserve system plus the new THEZs, and is based on the same assumptions, these do not impact the interpretation of the reduction in extinction risk.

2.2.3 Geographic spread of exclusion zones

The degree of spread of THEZs throughout the range of Leadbeater's Possum will influence the risk of extinction of the species due to widespread disturbances such as large bushfires. If all the newly protected colonies are in a localised area and hence could be impacted by a single bushfire then the risk of extinction will be higher. In contrast, long-term conservation security is likely to be enhanced by a more dispersed set of protected sites as it spreads the risk against catastrophe. A measure of how geographically dispersed the newly protected colonies are is based on their spread across the Leadbeater's Possum Management Units (LMUs), which divide the species' range into 21 units (DEPI 2014; and see glossary), or across the six metapopulations used in the PVA modelling (described in Lumsden *et al.* 2013 and Todd *et al.* 2016) (Figure 11).

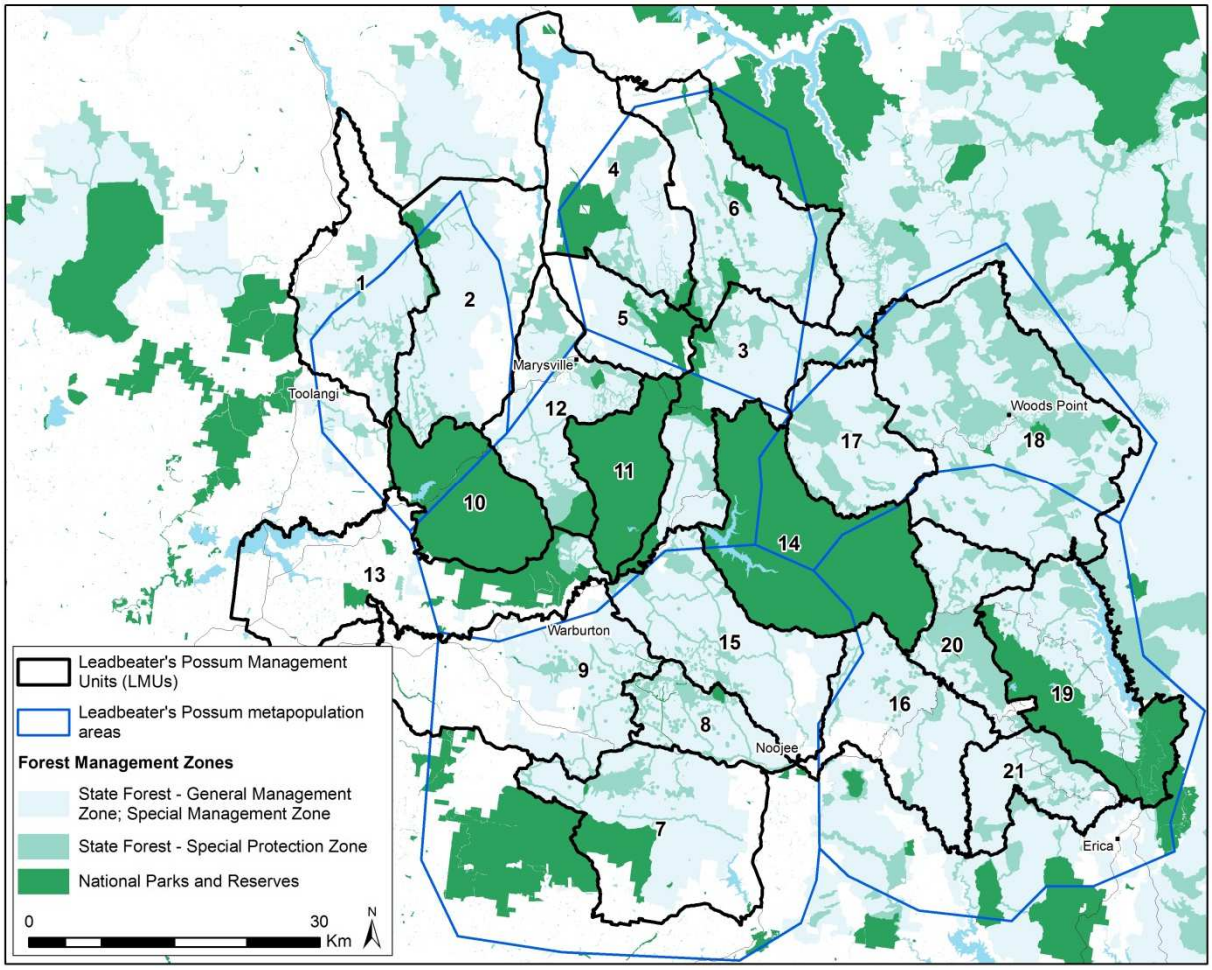


Figure 11. The 21 Leadbeater's Possum Management Units and six metapopulation areas. The metapopulations are numbered from 1 in the north-west to 6 in the south-east.

Table 9 shows the breakdown of buffered Leadbeater's Possum colonies (those within THEZs and the equivalent areas within parks and SPZs) across the 21 LMUs, with Table 10 outlining the breakdown across the six metapopulations. While protected colonies are distributed among all the LMUs, there is a wide range in the number of colonies in each, from two to 72. The highest proportion of colonies are in LMUs 8 and 9 (14.5 and 12.5%, respectively) in the Powelltown region, where there is a high concentration of records. Similarly, there is a spread of colonies over the six metapopulations, but two metapopulations (5 and 6) have high numbers of colonies (40.0% and 27.5% respectively), representing the area across the southern part of the species' range from Powelltown to Baw Baw.

Another measure of how geographically spread protected colonies are throughout the Central Highlands is to examine how many LMUs or metapopulations would meet a set threshold (representing an arbitrary adequacy threshold of numbers of THEZs within an area) as increasing numbers of THEZs (or equivalent buffers in parks and SPZs) are added into the landscape. For example, thresholds of five THEZs or 20 THEZs can be compared and their accumulation curves examined to see if they have reached a plateau, which would suggest the threshold number of THEZs in each specified area (LMU or metapopulation) has been achieved.

Table 9. The number of Leadbeater's Possum colonies and the proportion of the total colonies located within each of the Leadbeater's Possum Management Units (LMUs). LMUs 10, 11 and 14 are contained entirely within national park.

LMU	No. of colonies	% of colonies
1	22	4.4
2	21	4.2
3	17	3.4
4	2	0.4
5	7	1.4
6	40	8.1
7	21	4.2
8	72	14.5
9	62	12.5
10	13	2.6
11	6	1.2
12	9	1.8
13	4	0.8
14	17	3.4
15	37	7.5
16	41	8.3
17	14	2.8
18	2	0.4
19	44	8.9
20	33	6.7
21	11	2.2
Total	**495**	**100**

Table 10. The number of Leadbeater's Possum colonies and the proportion of the total colonies located within each of six Leadbeater's Possum metapopulations from Todd *et al*. (2016).

Metapopulation	No. of colonies	% of colonies
1. Toolangi	50	10.1
2. Marysville	57	11.5
3. Camberville	35	7.1
4. Woods Point	18	3.6
5. Powelltown	198	40.0
6. Baw Baw	136	27.5
Total	**494***	**99.8**

* 1 colony is missing as it was outside all of the metapopulation boundaries.

For the purposes of this review, LMU thresholds have been set at 5, 10, 15 and 20 THEZs and metapopulation thresholds were set at 20, 40, 60 and 80 THEZs (larger figures as these represent greater areas than the LMUs). These arbitrarily assigned thresholds are based on an even division of the Leadbeater's Possum records amongst the number of LMU or metapopulation polygons. The THEZs were randomised (to avoid confounding effects of time and non-random survey effort in certain locations), and then groups of 50 THEZs were drawn from the THEZ pool (495 THEZs) in batches of 50. It is important to note that there is variation between LMUs in land tenure (3 LMUs are contained entirely within national parks) and in the proportion of potential Leadbeater's Possum habitat. This has implications for the accumulation curves as, given that the focus of the survey effort undertaken as part of the LPAG program has been State forest, few newly located colonies have been recorded in national parks.

As the number of THEZs within the landscape increases, the number of LMUs reaching an assigned threshold increases, however the curves vary for the different thresholds set (Figure 12). For example, once there are 100 THEZs within the landscape, almost one third of the LMUs (8/21) have reached a threshold of 5 THEZs, whereas not one LMU has yet reached a threshold of 20 THEZs. By the time there are 450 THEZs within the landscape, 18 of the 21 LMUs (86%) have reached the threshold of 5 THEZs, but only one third of the LMUs (8/21) have reached a threshold of 20 THEZs. This demonstrates the uneven clumping of THEZs across the LMUs, with some LMUs with a higher proportion of THEZs (LMUs 8 and 9, Table 9). None of the curves have plateaued, which indicates additional buffers would be required to reach all of the assigned thresholds. In order to maximise the spread of THEZs across the LMUs to reduce future bushfire risk, any future establishment of Leadbeater's Possum THEZs would require a targeted approach, with directed effort in LMUs containing less than 20 Leadbeater's Possum records.

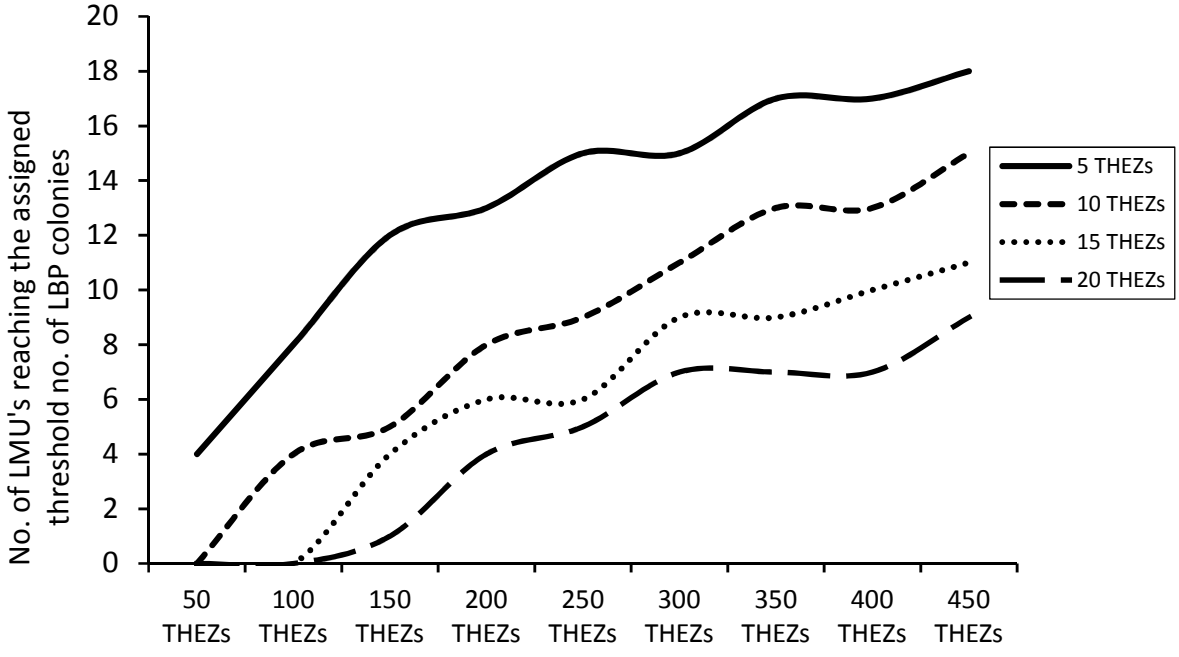


Figure 12. An accumulation curve showing the number of Leadbeater's Possum Management Units (LMUs) reaching an assigned threshold of Leadbeater's Possum colonies as the number of THEZs in the landscape increases. Arbitrary thresholds have been set to 5, 10, 15 and 20 THEZs per LMU, and are shown by the solid or dotted lines.

As the number of THEZs within the landscape increases, the number of metapopulations reaching an assigned threshold increases (Figure 13), however the curves vary to those for the LMUs. For example, once there are 100 THEZs within the landscape, one third of the metapopulations (2/6) have reached a threshold of 20 THEZs, whereas no metapopulation has yet reached a threshold of 80 THEZs. It is not until there are 200 THEZs within the landscape that a metapopulation reaches the assigned threshold of 80 THEZs. By the time there are 450 THEZs within the landscape, all but one of the metapopulations have reached a threshold of 20 THEZs and the curve has begun to plateau. However, only one third of the metapopulations (2/6) have reached a threshold of 80 THEZs. This demonstrates the uneven spread of THEZs across the metapopulations, with some metapopulations having a higher proportion of the THEZs. Two of the curves (thresholds 60 and 80 THEZs) have plateaued, which is due to the large number of THEZs in two of the metapopulations (metapopulations 5 and 6, Table 10). If 80 THEZs was deemed an appropriate threshold for protecting against future bushfire risk, any future establishment of Leadbeater's Possum THEZs would benefit from a more targeted approach, with effort directed to metapopulations 1, 2, 3 and 4, all of which contain less than 80 Leadbeater's Possum colonies. However, the amount of potential Leadbeater's Possum habitat and the area already protected in parks varies between metapopulations (and LMUs), so additional effort would need to be scaled accordingly.

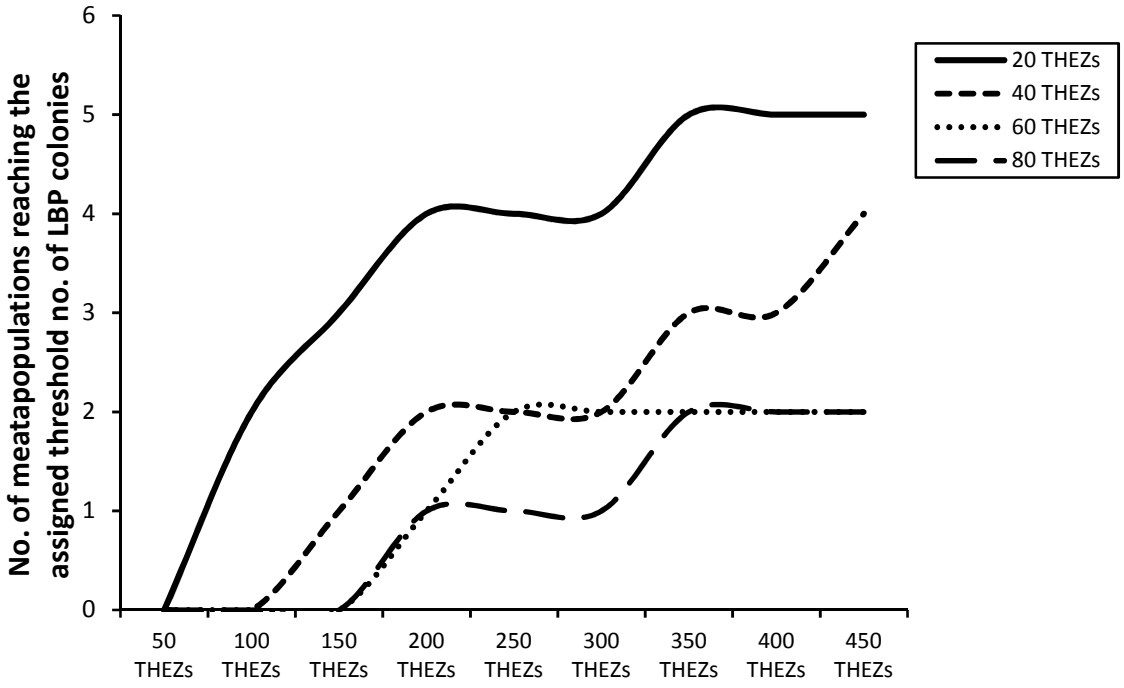


Figure 13. An accumulation curve showing the number of metapopulations reaching an assigned threshold of Leadbeater's Possum colonies as the number of THEZs in the landscape increases. Arbitrary thresholds have been set at 20, 40, 60 and 80 THEZs per metapopulation, and are shown by the solid or dotted lines.

2.2.4 Increase in protected areas within the surrounding landscape

While the THEZs directly protect Leadbeater's Possum colonies and their habitat around Leadbeater's Possum detection sites, the overall amount of habitat now protected in a wider landscape context is also important in evaluating the effectiveness of the THEZ in increasing the resilience and persistence of colonies. Leadbeater's Possum is known to be negatively affected by habitat disturbance in the surrounding landscape, even when local habitat is intact (Lindenmayer *et al.* 1993, 2013b), and

populations are more likely to persist when habitat patches are larger (Lindenmayer and Possingham 1995a). To date, none of the THEZs have had all their surrounding habitat cleared, so it is not possible to assess what effect such disturbance has on resident colonies. However, much of the area outside each THEZ is available for harvest at some point in the future. The greater the area in the surrounding landscape that is protected from timber harvesting operations, the more likely that colonies and their habitat remain intact and connectivity between colonies is maintained. This benefits the population as a whole by facilitating dispersal and gene flow and the maintenance of high levels of genetic diversity and fitness (Lindenmayer and Possingham 1995a, 1996, Hansen *et al.* 2009).

To assess the change in the extent of the protected area in the surrounding landscape of each colony, all colony centroids were buffered to one kilometre, giving a 314 ha landscape around each of the 495 colonies considered in this review. Most colony landscapes overlap with others, such that the THEZ established around each colony contributes to the protected area within one kilometre of its neighbours. The proportion of protected area, both SPZ in State forest and national park within each colony landscape was measured prior to the establishment of any THEZs (28 February 2014), assuming knowledge of all 495 colony locations at that point in time, and then again at the point of this review (30 January 2017). Any change in protected area is due solely to the new Leadbeater's Possum THEZs.

In February 2014, prior to the establishment of any THEZs, an average of 88 ha (28%, range 0-314 ha) within 1 km of each colony was protected from timber harvesting by SPZ or national park. By 30 January 2017, the protected area within 1 km had increased to an average of 128 ha (41%, range 12.6-314 ha). An example of this increase in proportional protected area in a landscape context is shown in Figure 14. Note that there is some self-evidence in this approach: placing a THEZ around a previously unreported colony increases the proportion of protected area within a 1 km radius by 4%. However, the mean proportional increase of 13% observed across all colony landscapes suggests additional improvement beyond this default. The overall mean increase is attributable to two factors. Firstly, the close proximity of many THEZs to others means that each contributes to the protected area within 1 km of its neighbours. Secondly, many previously unknown colonies have been located along the boundaries of existing protected areas, for example the eastern and northern boundaries of Yarra Ranges National Park. These colonies have a high proportion of the landscape within 1 km already reserved.

The establishment of THEZs in close proximity to each other has thus led to a beneficial outcome for known colonies, by increasing the mean percentage of reserved area within 1 km radius landscapes. The 'clustering' of colony records was a key sampling strategy in the ARI targeted Leadbeater's Possum surveys since 2014 (Nelson *et al.* 2015, in press). Surveys conducted by community groups also often resulted in the creation of, or addition to, clusters of THEZs. This clustering has resulted in many THEZs that are connected or close to others. Effectively this results in THEZs that are greater than a single isolated 12.6 ha area. Here, a 'cluster' of colonies is defined as a group of at least two THEZs, where the distance between the edges of the exclusion zones is less than 100 m, following Nelson *et al.* (in press). Three hundred out of 495 (61%) colonies assessed in this review are part of a cluster of at least two, and up to 21 THEZ (mean 3.5 THEZ per cluster by 30 January 2017).

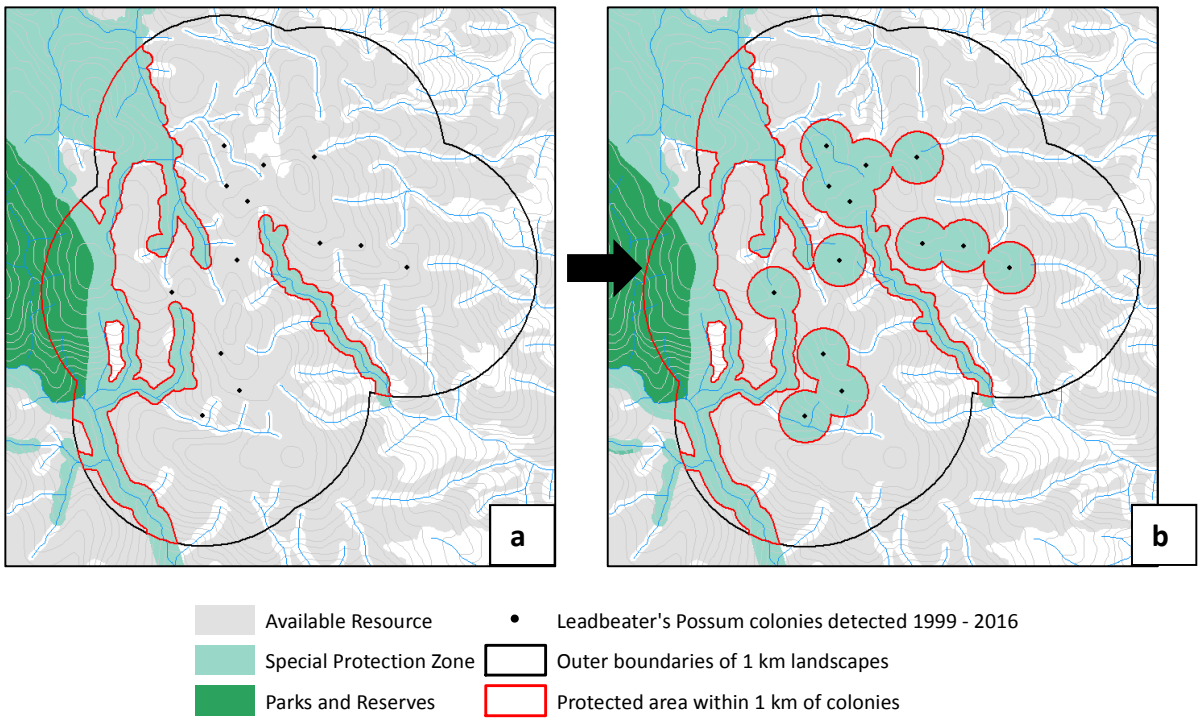


Figure 14. Example of the change in protected area within 1 km landscapes of known colonies, a) prior to the establishment of timber harvesting exclusion zones in February 2014, and b) by 30 January 2017, Noojee and Latrobe State forests. Protected area within 1 km of the 13 colonies shown was individually assessed – internal boundaries of the 1 km radius landscapes are not shown for simplicity. In this example, the proportion of protected area within 1 km of these 13 colonies increases from a mean of 15% in (a) to a mean of 23% in (b).

As the number of known colonies increased with increased survey effort during the 2014 – 2017 period, the area within THEZs within each cluster increased from an average of 33 ha to an average of 41 ha by 30 January 2017 (Figure 15b). The number of clusters over this time increased from 28 to 86 (Figure 15a). While the number of THEZ clusters has tripled (Figure 15a), the average increase in area within clusters has increased by only 20% (Figure 15b). This is because most THEZ clusters were comprised of only two or three colonies, contributing approximately 25 ha and 38 ha, respectively, so the overall increase in area was relatively small. Interpretation of the benefits for Leadbeater's Possum persistence is limited by the fact that most THEZs are currently still surrounded by intact forest. Small-sized reserves may be effective at maintaining colonies in these situations, but may rapidly lose effectiveness if they become surrounded by intensively disturbed areas (Lindenmayer and Possingham 1996).

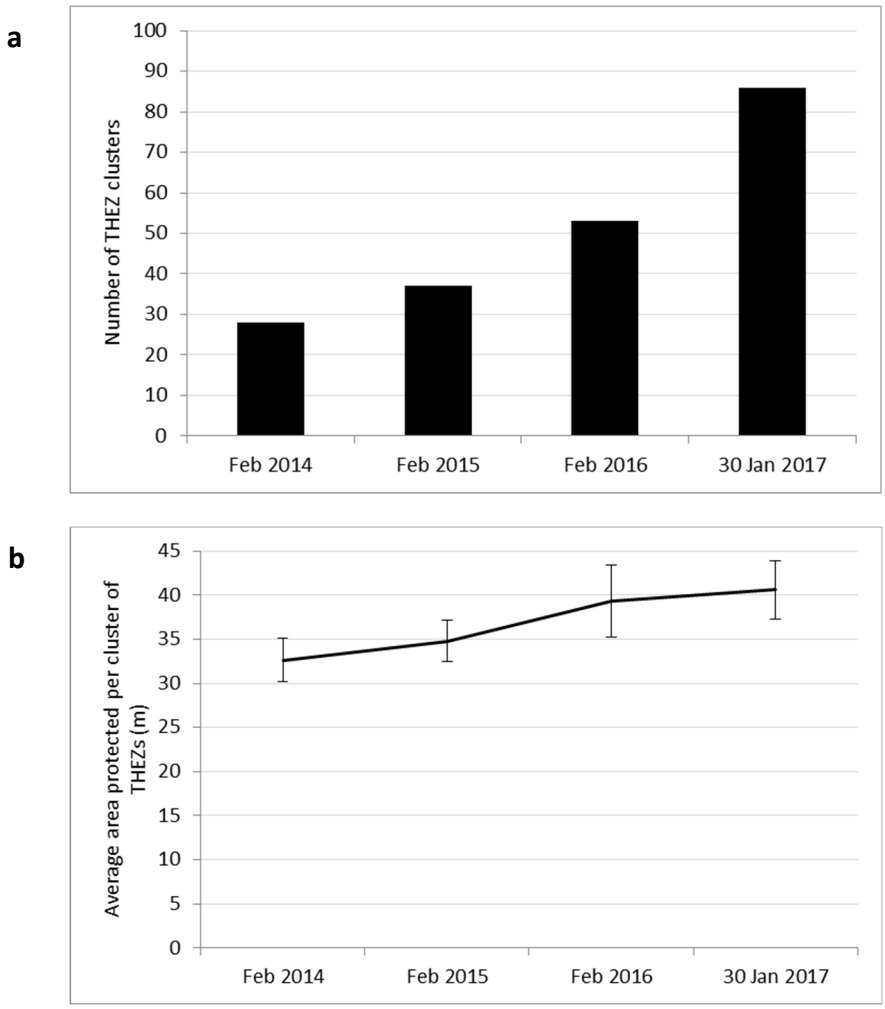


Figure 15. The increase in cluster numbers and area in recent years: a) the cumulative number of timber harvesting exclusion zone 'clusters'; and b) the cumulative area protected (ha) in timber harvesting exclusion zone 'clusters'. Each date on the x-axis reflects the clusters added in the preceding 12 months, with the exception of Feb 2014 which accounts for all 'Existing' THEZ clusters arising from Leadbeater's Possum records 1 January 1998 – 28 February 2014. Error bars are ± 1 SE.

2.2.5 Extent to which the THEZs will provide long-term habitat

The THEZs currently provide suitable habitat for Leadbeater's Possums as they are known to be occupied. However, the long-term survival of the species will depend on there being habitat suitable into the future. The extent to which the current THEZs will be suitable in the future can be assessed through the examination of two of the species' key habitat requirements: the availability of hollow-bearing trees, and wattle density.

Hollow-bearing trees

High rates of death and collapse of large, old hollow-bearing trees are currently occurring in the Central Highlands, with projections that the number of these trees will have declined from 5.1/ha in 1998 to ~0.6/ha by 2067 (Lindenmayer *et al.* 2012). This includes dead trees that remained standing after the 1939 bushfires and that are collapsing due to natural decay (Lindenmayer *et al.* 1990; 1997), and it is predicted that these will be lost completely within coming decades. Once these nesting resources are gone, hollows will be provided mainly by the current live hollow-bearing trees. High densities of wattles, which are used as a direct and indirect food source, are also a key resource (Smith 1984a). Wattles regenerate readily after disturbances, such as bushfire and timber harvesting,

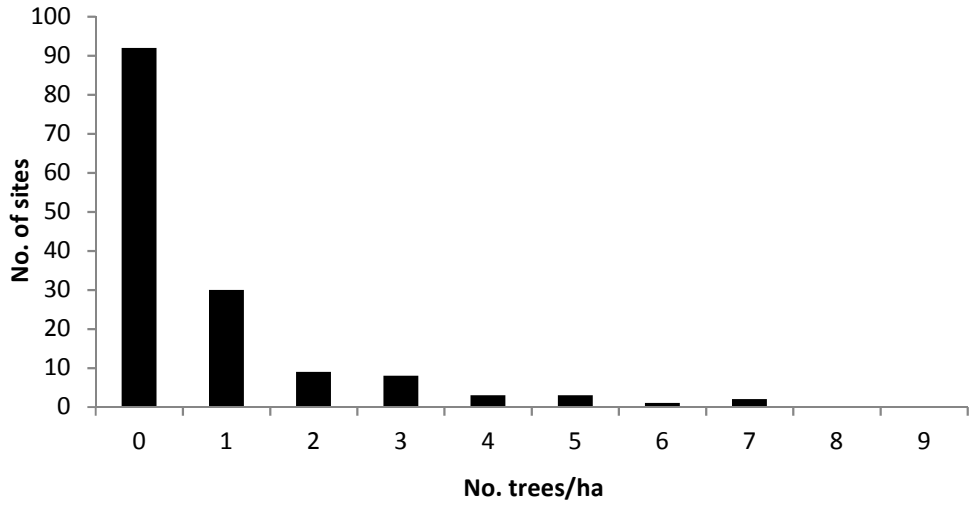
but senesce as they age, which reduces the available foraging resource for Leadbeater's Possum (Smith and Lindenmayer 1992).

Detailed mapping of key habitat requirements across the species' range is lacking (although current LiDAR surveys are attempting to fill this key knowledge gap, DELWP 2016). However, insights can be drawn from the ARI targeted survey sampling where on-ground habitat assessments were made at 287 survey sites (Nelson *et al.* in press). This information provides a basis for assessing the extent to which the THEZs at sites where the species was recorded (n=148 sites) will continue to retain live and dead hollow-bearing trees, and wattle mid-storey. A prediction of future changes in habitat suitability can be made, given that models have been developed that describe the rate of loss of hollow-bearing trees (Lindenmayer and Wood 2010). Calculating the density of live hollow-bearing trees will provide an indication of nesting resources into the future, once all the currently standing dead hollow-bearing trees have collapsed. Although it is not known where the Leadbeater's Possums recorded on the sites would be nesting, with many potentially nesting outside the site, it does however provide a sample of sites that can be used for comparative purposes.

The average density of dead hollow-bearing trees is twice that of live hollow-bearing trees (1.7/ha, range 0-11; and 0.8/ha, range 0-8, respectively) on sites containing Leadbeater's Possums. These figures underestimate to some extent the hollow availability as they only include hollows in eucalypts. Some hollows were also recorded in other tree species such as Myrtle Beech *Nothofagus cunninghamii* although the extent of use of such hollows by Leadbeater's Possum is unknown. For the purpose of this assessment, only the eucalypts are included as this is what the Lindenmayer and Wood (2010) tree decline data is based on.

Thirty-two per cent of sites had no live hollow-bearing trees present on the 1 ha site. Where hollow-bearing trees were present, most sites had just a single live hollow-bearing tree, with fewer sites containing multiple live hollow-bearing trees (Figure 16a). A greater proportion of sites had multiple dead hollow-bearing trees (Figure 16b), however once these trees are lost, the only nesting resource within the site will be in the remaining live trees. Given that the predominant oldest age-class of live trees is 78 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.

a) live hollow-bearing trees



b) dead hollow-bearing trees

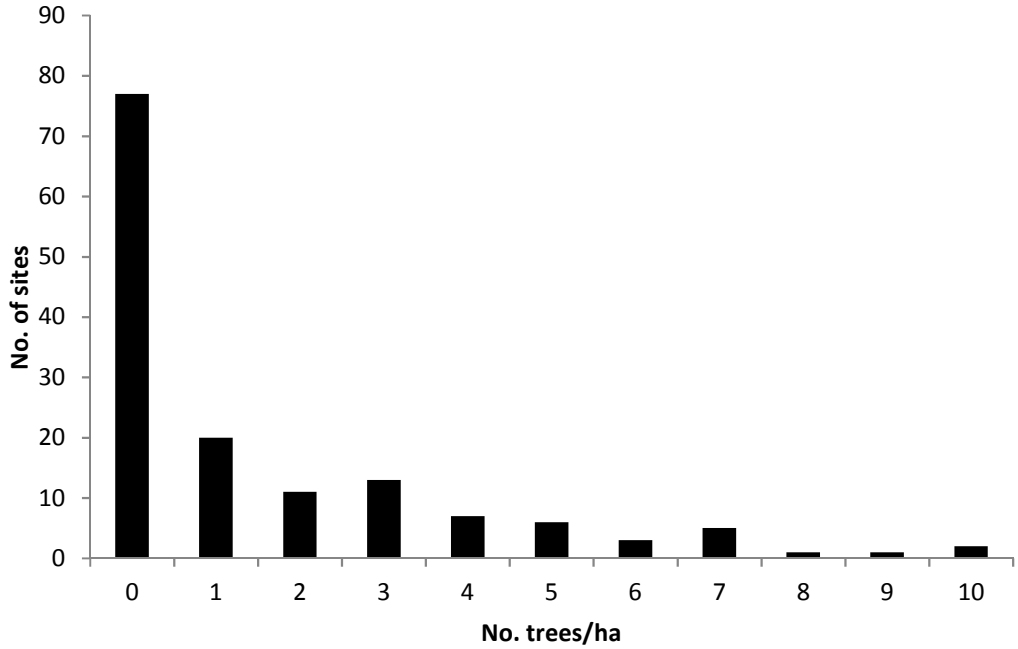


Figure 16. Frequency histograms showing the number of sites containing different numbers of hollow-bearing trees per ha, at locations where Leadbeater's Possum colonies were detected during ARI targeted surveys (n=148 sites): a) live eucalypt hollow-bearing trees; and b) dead eucalypt hollow-bearing trees.

The collapse rates of hollow-bearing trees in ash forests has been quantified by Lindenmayer and Wood (2010). They provide estimated probabilities of tree collapse for eight different tree forms for a 14 year time period (1993-2007). At each ARI targeted survey site, the form of each hollow-bearing tree on a 1 ha grid was recorded using the same 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 trees that were not yet 'mature', using the definition of 'mature' in the Leadbeater's Possum survey standard (DELWP 2015), but that had hollows. The estimates of tree collapse provided by Lindenmayer and Wood (2010) have been used to predict the number of hollow-bearing trees likely to be still standing on ARI targeted survey sites where Leadbeater's Possum was detected, over the next 14 years, i.e. by 2030.

Hollow-bearing trees in all tree form classes are predicted to decline, with the greatest declines occurring in tree forms 6, 7 and 8 (Figure 17). Over half of the form 8 trees will be lost within the 14 year period. Leadbeater's Possums tend to prefer short, large trees with several hollows, which are typically those in the late stages of decay (forms 7-8, Lindenmayer *et al.* 1991a), so the collapse of these tree form classes is likely to have a significant impact on the colonies within these THEZs.

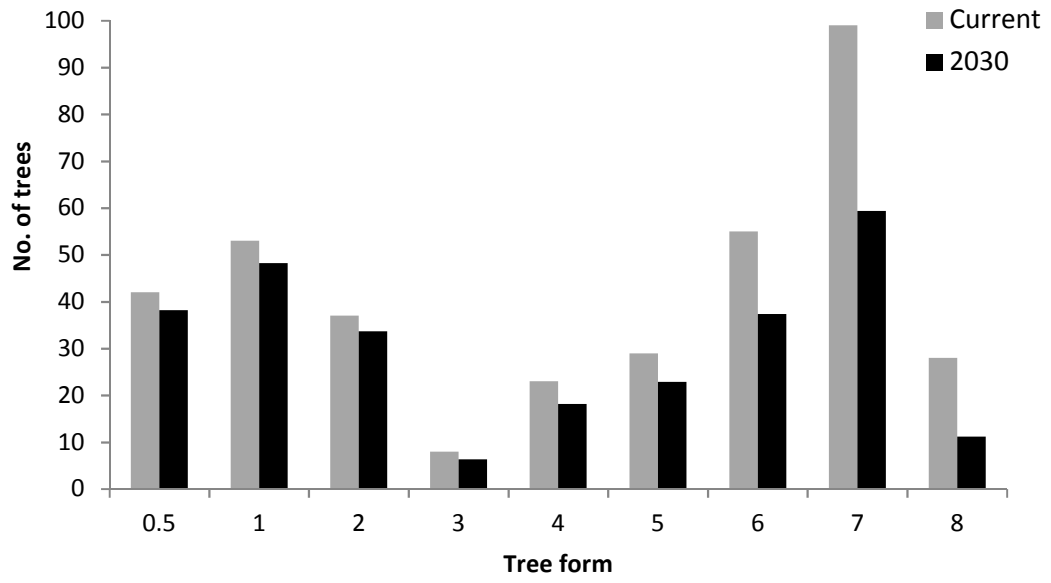


Figure 17. Frequency histogram showing the total number of trees (tree forms 0.5 – 8), at locations where Leadbeater's Possum colonies were detected during ARI targeted surveys (n=148 sites), currently (grey bars) and predicted into the future to 2030. These estimates account for different probabilities of tree collapse rates in different tree form classes (as per Lindenmayer and Wood, 2010).

Note that the figures presented above are based only on the available information for a subset of THEZs (those sampled by ARI, n = 148), and not for any of the other 347 THEZs that have been established. As such, it is unknown how representative they are of all sites where Leadbeater's Possums have been recorded. In addition, habitat assessments were compiled for only a small part of each THEZ (1 ha), so may not be entirely representative of the full 12.6 ha, especially as Leadbeater's Possums were recorded while foraging, and may therefore nest elsewhere. As the success rate from the ARI targeted surveys was highest (61%) at sites where timber harvesting regrowth (13-38 years post-harvest) was adjacent to 1939 regrowth (Nelson *et al*. in press), this suggests that additional remnant large, old hollow-bearing trees would likely have been present outside the areas in which the possums were located and where habitat data were collected. Finally, unpredictable future disturbances (e.g. bushfire) will further change the densities of hollow-bearing trees.

Wattle decline

Densities of Leadbeater's Possums peak when there is a high biomass of wattle (Smith and Lindenmayer 1992). Common species of wattle in montane ash forests include Silver Wattle *Acacia dealbata*, Montane Wattle *Acacia frigescens*, Mountain Hickory Wattle *Acacia obliquinervia* and Blackwood *Acacia melanoxylon*. Wattle regenerates readily after disturbances such as fire and timber harvesting. No clear published data on the timing of wattle senescence could be found, despite well documented descriptive patterns of montane ash forest succession. However, it is well accepted that young regrowth ash forests have dense, interlocking canopies that become more open over time, with a decline in the number and diversity of wattle species as the forest ages (Smith and Lindenmayer 1992; McCarthy and Lindenmayer 1998). Wattle abundance and density is estimated to be greatest somewhere around 30-40 years after disturbance, but has declined to lower levels of

abundance in stands of 1939 fire regrowth, although there is evidence that Blackwood may be longer lived than the other three species (C. Nitschke, University of Melbourne, *pers. comm*.).

Table 7, presented in Section 2.1.6, outlines the area contained within THEZs of different disturbance histories. These data can be used to estimate availability of wattle into the future, and to examine what proportion of the area contained within THEZs currently has a high density of wattle (based on the estimated peak in wattle density 30-40 years post-disturbance), or is declining following this peak. It should be noted that these values were only calculated for areas of 'Available Resource'. Combining the two categories containing forest less than 37 years post-disturbance showed that there is 1,638 ha within THEZs (52%) that could currently be considered to contain a high density of wattle. These areas are likely to continue to provide ample foraging habitat for Leadbeater's Possums for some time into the future, although the abundance of wattle will eventually begin to decline. The remaining categories represent forest stands aged between 38 - 117 years, which cover 48% of the area contained within THEZs. This suggests that about half of the area protected by THEZs will have a lower probability of providing a high density of foraging resources for Leadbeater's Possum into the future. Some of this area may therefore become less suitable for the species. However, these areas may also contain other critical resources, such as hollow-bearing trees, so it is difficult to provide an exact estimate on the extent to which the THEZs will provide long-term habitat. In addition, unpredictable future disturbances (e.g. bushfire) will influence wattle regeneration, and so these areas may be altered in the future.

2.2.6 Summary of the effectiveness of the additional protection within THEZs in supporting the recovery of Leadbeater's Possum

- It is more complex to evaluate the effectiveness of the additional protection in supporting the recovery of the species than it is to document the extent of this additional protection, and there is no single definitive answer to this question. Therefore a range of complementary metrics are used in this evaluation.
- One of the difficulties in assessing the effectiveness is that the total population size, and hence the proportion of the population within the THEZs, is unknown. It has not been possible to update population estimates due to the targeted nature of the recent sampling, however the large number of records, despite only a relatively small proportion of the potential habitat having been surveyed, casts doubt on the previous population estimates. Further work is required to improve the robustness of these population estimates.
- Population Viability Analysis modelling can be used to assess the reduction in extinction risk. Using the most recent PVA model there was a 34% reduction in extinction risk of the population within the Leadbeater's Possum reserve system by the addition of the THEZs, areas also specifically reserved for Leadbeater's Possums. While this suggests an improvement in the effectiveness of the reserve system, it also indicates that there is still a substantial remaining risk of extinction. This is especially the case when future bushfires are considered. These increase the risk of extinction for Leadbeater's Possum, with larger fires having a greater impact and fires in the near future having more impact than more distant fires. Within these scenarios, the THEZs decrease the extinction risk, but do not negate these increased risks.
- The THEZs are spread throughout the full range of the species within the Central Highlands, reducing the risk that a single bushfire could impact the majority of the protected

population. There is a concentration, however, of new protection zones within the southern part of the species' range from Powelltown to Baw Baw regions, and so any future fire within this area would have a disproportional impact.

- Increasing the amount of protected habitat within the landscape surrounding the THEZs is likely to increase the resilience and long-term viability of these subpopulations. Implementing the THEZ action has resulted in a 13% increase in protected habitat within a 1 km radius of the colonies. Developing clusters of colonies has led to the protection of 'neighbourhoods' of colonies, not just of individual colonies, improving long-term resilience.
- The THEZs currently provide suitable habitat for Leadbeater's Possums; however, the persistence of colonies at these locations will depend on there being habitat suitable in the future. There are currently high rates of death and collapse of large, old hollow-bearing trees. This is especially the case for dead stags resulting from the 1939 bushfires, currently a key nesting resource for Leadbeater's Possum. These are predicted to be completely lost within coming decades, and once this occurs, hollows will be restricted to the current live hollow-bearing trees. The density of live hollow-bearing trees on ARI targeted survey sites where Leadbeater's Possum currently occur is just 0.8/ha. This will represent a severe shortage of nesting resources. In contrast, foraging habitat does not appear limited as approximately half of the THEZ area is regrowth forest where wattles are at their peak density. These different age classes represented in the THEZs are likely to be of considerable conservation benefit, as it will mean that THEZs will retain habitat suitability for varying lengths of time, or provide optimum suitability at different times.
- In summary, this evaluation suggests that the THEZs have been relatively effective in reducing the extinction risk of Leadbeater's Possum through preventing the inadvertent destruction of Leadbeater's Possum colonies. As such, they are likely to go some way towards achieving the LPAG aim of slowing the projected decline in population numbers in the Central Highlands, so that there are sufficient individuals for the species to recover in the future. However, there remains a residual risk of extinction, especially when considering the likelihood of future fires, and so the establishment of the current THEZs has not achieved complete recovery of the species.

2.3 Key knowledge gaps

Although Leadbeater's Possum is one of the best studied mammals in Australia, there remain key knowledge gaps relevant to this evaluation of the benefits to Leadbeater's Possum of the THEZs and in assessing the risks and benefits of potential alternative options.

Further information on the following aspects would be beneficial for future deliberations.

- **More accurate population estimates**. There is currently a wide range of figures suggested for the total population of Leadbeater's Possum. None of the studies on which these estimates were based were designed to explicitly address this question, and so all have a wide range of assumptions. While it will never be possible to precisely determine total numbers, developing more accurate estimates would assist in understanding the proportion of the total population protected by the THEZs.
- **Proportion of the total population within existing parks and reserves**. While some surveys have been undertaken within parks and reserves, these areas have been less surveyed than

the State forest, and hence a full understanding of the distribution and population within these protected areas is lacking.

- **How many THEZs or other protected areas are required to fully support the recovery of the species?** An updated and spatialized PVA model across the whole of the species' range would assist in evaluating the area required to significantly reduce the risk of extinction over the next 100 years.
- **What is the long-term survival of colonies within the 200 m radius THEZs, and how does this increase with clusters of colonies?** It is currently unknown if these exclusion zones are of sufficient size to guarantee protection of colonies into the future. A greater understanding of the impacts of nearby disturbances on colonies would be useful.
- **Colony territory sizes**. Earlier studies in high quality habitat suggested territories (home ranges) were 1-3 ha in size. However in lower quality habitat, or where the habitat is comprised of patches of different age classes, resulting in animals potentially nesting and foraging in different areas, territory sizes may be larger. This information is key to assessing the impact of alternative options, and it is an influential variable within the PVA modelling and population estimate calculations.
- **Distribution of critical habitat features mapped throughout the range.** Predictive distribution models could be improved through the inclusion of spatial information on key habitat features, especially hollow-bearing tree and wattle densities, through LiDAR and high resolution aerial photography modelling.
- **Effectiveness of management mitigations**. Further information on the impact of roads of different sizes on nightly foraging patterns and dispersal of individuals and the extent to which rope bridges could mitigate this impact would be beneficial.
- **Dispersal patterns**. Little is known of dispersal patterns in montane ash forests. This information would improve understanding of gene flow and population fragmentation at a landscape-scale, and inform the ability of the species to recolonise habitat disturbed by timber production or fire.
- **Recolonisation of areas burnt during 2009**. The extent to which Leadbeater's Possum can recolonise areas burnt during 2009, and how quickly this may occur, will influence overall population estimates and assessments of extinction risk.

3 Ecology of Leadbeater's Possum relevant to assessment of alternative options

Prepared by the Arthur Rylah Institute for Environmental Research, DELWP

Leadbeater's Possum has been the focus of numerous scientific studies over the past 35 years, and some aspects of its ecology, including its habitat requirements, are well understood. The impacts of forest management on critical habitat features of the possum are also well documented (summarised in Lindenmayer 2009). This provides a basis for assessing the potential risks and benefits to Leadbeater's Possum of proposed alternative options to the current THEZ approach. Other aspects of the species' ecology however, such as the annual patterns of dispersal within and between populations, are not well understood and are key knowledge gaps.

Here we describe the evidence base for aspects of the ecology of Leadbeater's Possum that were used to assess how the species may be impacted by the proposed alternative options in Section 6.

3.1 Leadbeater's Possum ecological considerations

3.1.1 Habitat requirements

Leadbeater's Possum mainly occurs in montane ash forest, dominated by Mountain Ash *Eucalyptus regnans*, Alpine Ash *E. delegatensis* and Shining Gum *E. nitens,* as well as in adjacent areas of Cool Temperate Rainforest and riparian thickets (Lindenmayer *et al.* 1989, Harley 2004). Within its range, the species is patchily distributed, occurring in areas of suitable habitat, largely influenced by previous disturbance history. There are four key habitat elements that influence habitat suitability for Leadbeater's Possum:

1. Hollow-bearing trees for breeding sites and shelter
Hollow-bearing trees, which provide nest sites, are a critical habitat feature for Leadbeater's Possum. Hollows can occur in large, live trees or in large, dead trees, such as those killed during bushfires. Dead hollow-bearing trees appear to be preferred (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991a, b). In ash forests, hollow formation commences at about 120 years. However, hollows suitable for Leadbeater's Possum do not typically form until trees reach around 190 – 220 years of age (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991a). This species requires hollows with large internal dimensions, in the order of 30 cm in diameter, in which to build their nests. Leadbeater's Possums are more likely to occur in areas with higher densities of hollow-bearing trees, such as areas with more than two or three hollow-bearing trees per hectare (Smith and Lindenmayer 1988, 1992, Lindenmayer *et al.* 1990, 1991b). There have been significant losses of hollow-bearing trees in the past decades as the large old trees that were killed in the 1939 bushfires decay and collapse, greatly impacting the availability of den sites for Leadbeater's Possum (Lindenmayer *et al.* 1990, 1997, 2012).

2. A predominance of smooth-barked eucalypts with strips of exfoliating bark is also a critical habitat feature, providing food in the form of surface exudates licked from the eucalypt trunks and branches, and invertebrate prey that shelters in the ribbons of bark (Smith 1984a, Harley 2004). The bark is also shredded and used for building the large communal nests (Smith *et al.* 1982, Smith 1984b).

3. A structurally dense interlocking canopy or secondary tree layer to facilitate movement

Leadbeater's Possum is an arboreal species, that rarely comes to the ground. Unlike some other small possums that can glide between trees, Leadbeater's Possums depend on connecting vegetation to move through their territory. Areas of suitable habitat typically have a dense mid-storey layer with interconnecting lateral branches providing movement pathways (Smith and Lindenmayer 1992, Harley 2004).

4. The presence of gum-producing wattle for food

In montane ash forest, the mid-storey often comprises wattles, which provide food in the form of carbohydrate-rich plant and insect secretions, such as sap, manna and honeydew (Smith 1984a, Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b).

The distribution of these habitat elements across the landscape influences the presence and abundance of Leadbeater's Possum across its range. In montane ash forest, high quality habitat for Leadbeater's Possum is a mixed-aged forest that contains an ample supply of both large, hollow-bearing trees, and a dense mid-storey layer that includes wattles, especially Silver Wattle, Mountain Hickory Wattle and Montane Wattle (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b).

Forest regenerating from disturbances including timber harvesting and bushfire can provide habitat for Leadbeater's Possum; the high stem density of these stands provides the dense structure required by the possums for movement, and the presence of wattle provides gum for foraging (Smith 1984a). However, whether colonies are able to use such stands depends on the presence of hollow-bearing trees that are critical for nesting and diurnal shelter, either within the stand, or nearby (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b, Nelson *et al.* 2015).

3.1.2 Social organisation/territoriality

Leadbeater's Possum typically form social groups of 2-12 individuals (mostly 2-6 individuals) (Smith and Harley 2008, ARI unpublished data). Colonies usually consist of a single breeding pair with one or more generations of their offspring (Smith 1984b, Lindenmayer and Meggs 1996, Harley 2005, Harley and Lill 2007). Colonies are territorial and vigorously defend areas of 1-3 ha from neighbouring colonies and, in the absence of disturbance, have long-term site fidelity (Smith 1984b, Harley 2005, Lindenmayer *et al.* 2013b). Each territory generally contains multiple nest sites which animals move between regularly (Lindenmayer and Meggs 1996, Harley 2004). The size and the shape of each territory is likely to vary depending on the distribution and abundance of nest sites and foraging habitat and on the presence of neighbouring colonies (Figure 18). While territory sizes in areas of high quality habitat may be smaller than 3 ha, in areas where habitat quality is lower or more patchy, such as where den trees and foraging areas are dispersed, territories may be larger. However, home range characteristics in these areas are poorly known and this is a key knowledge gap (Commonwealth of Australia 2016).

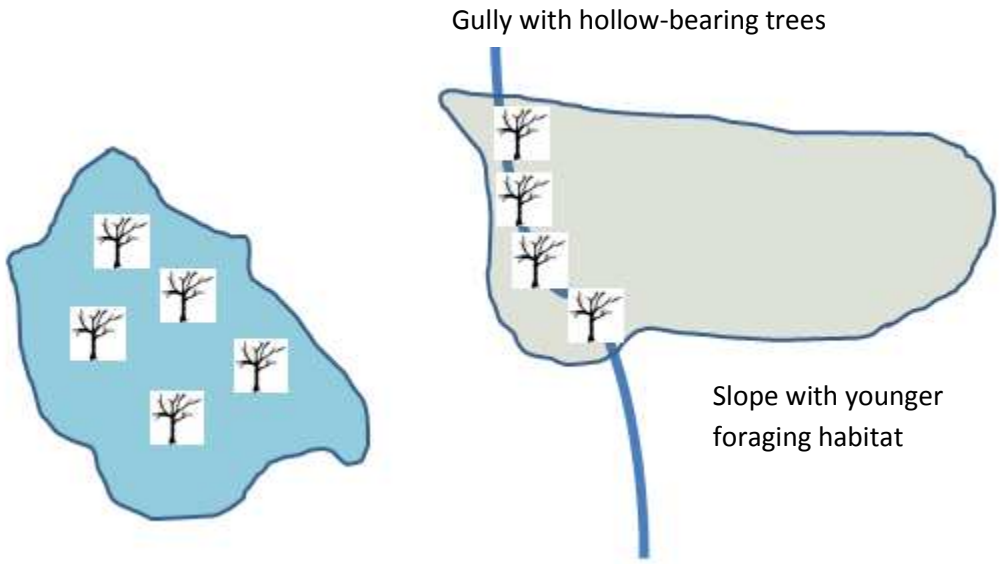


Figure 18. Variations in the size and shape of Leadbeater's Possum territories arising from the distribution of critical habitat features. In the territory on the left, hollow-bearing trees providing nest sites are dispersed amongst foraging habitat, while in the territory on the right nest sites are present along a gully and foraging habitat is upslope in a younger forest stand.

3.1.3 Movement patterns

Nightly movements

Leadbeater's Possums emerge from their nest tree each night and typically forage singly within their territories (Commonwealth of Australia 2016). Animals regularly move between nest trees, with the distance between occupied trees usually exceeding 50 m (Smith 1984b, Lindenmayer and Meggs 2006). Although nesting and foraging habitat may be in different areas of a territory, the high energetic costs of foraging may limit the distances animals can move each night to efficiently harvest food (Smith *et al.* 1982, Lindenmayer *et al.* 1993). The distances across which animals move between foraging and nesting habitat in areas where resources are dispersed is a key knowledge gap. Survey techniques such as camera trapping and call playback detect animals after they have left their nest tree, when they are moving through the forest foraging (Lumsden *et al.* 2013, Nelson *et al.* 2015). Using these techniques, the position where they are detected within the territory, e.g. near the edge or in the centre, is unknown.

Dispersal

While the nightly movements of individual Leadbeater's Possums occur over relatively short distances (e.g. less than 200 m), larger distances are likely to be covered when young animals disperse from their natal territories (Figure 19). Enforced dispersal of sub-adults provides a mechanism to reduce the likelihood of related individuals breeding (Smith 1984b). Inbreeding leads to the loss of genetic diversity and reduced fitness (i.e. the ability to survive and reproduce) and can accelerate the rate of extinction of small, isolated populations (Lande 1988). During dispersal, individual Leadbeater's Possums may be more likely to undertake movements they would normally avoid to seek out new colonies, such as coming to the ground to cross roads (R. van de Ree, pers. comm). High rates of mortality have been recorded for dispersing individuals, particularly juvenile females, as they move through unfamiliar habitat (Smith 1984b, Harley 2005).

The dispersal characteristics of Leadbeater's Possum in montane ash forest is a key knowledge gap that would greatly improve understanding of gene flow and population fragmentation at a landscape-scale, and determine the ability of the species to recolonise habitat disturbed by timber production or bushfire (DEPI 2014c).

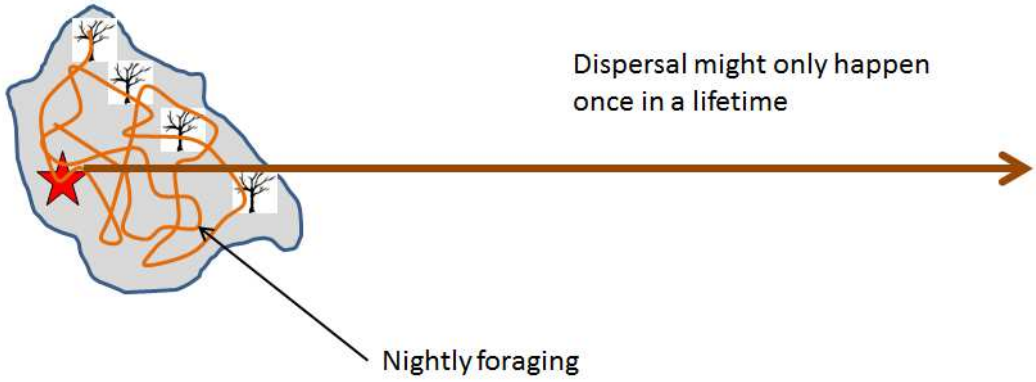


Figure 19. Movement patterns of Leadbeater's Possum, showing nightly foraging and dispersal.

3.1.4 Population dynamics

Due to the history of disturbances (bushfire and timber harvesting) in the Central Highlands and their impact on critical habitat elements for Leadbeater's Possum, particularly the distribution and abundance of hollow-bearing trees, the population is thought to be comprised of a number of spatially separated subpopulations (Commonwealth of Australia 2016). Although spatially discrete, subpopulations may be in close proximity but the movement of animals between them, and hence levels of genetic exchange, may be highly constrained by barriers to dispersal, such as large areas of unsuitable habitat (Hansen *et al.* 2009, Commonwealth of Australia 2016). Genetic analyses have revealed there is currently a high level of genetic diversity amongst animals from across the range, indicating effective dispersal and gene flow. However, there was evidence that recent habitat fragmentation has caused some barriers to gene flow with animals sampled near Powelltown genetically distinct from those in the north of the range (Hansen *et al.* 2009).

The size of subpopulations and the level of connectivity between them are likely to be key factors in ensuring their persistence (Lindenmayer and Lacy 1995, Lindenmayer and Possingham 1996, Hansen *et al.* 2009, Lindenmayer 2000). Small and isolated subpopulations are particularly at risk of extinction due to reduced fitness resulting from inbreeding, and environmental variability causing population fluctuations. A loss of suitable habitat, such as the collapse of hollow-bearing trees, may further reduce the carrying capacity of small habitat patches (i.e. the number of colonies the habitat is able to support), accelerating the loss of genetic diversity (Lindenmayer *et al.* 1993). Population viability analysis predicts that subpopulations need to be larger than a threshold of 200 individuals to have at least a 90% chance of persistence over a 100 year period. Isolated subpopulations of this size are likely to require areas of 600 ha to ensure persistence. Habitat connectivity between smaller subpopulations (e.g. 50 animals) is likely to be an important factor in facilitating dispersal of animals between these populations, increasing the likelihood of persistence across the range (Lindenmayer *et al.* 1993, Hansen *et al.* 2009).

3.2 Impact of potential changes to the current THEZs

The 200 m radius THEZs are currently SPZs, in which timber harvesting (clearfell harvesting, regeneration burning and thinning) is not permitted. Because the size, shape and boundaries of each territory is unknown, a 12.6 ha SPZ provides some assurance that the entire territory of the colony around which the THEZ is established will be protected. It also buffers the resident colony from the impact of activities in the surrounding area (i.e. timber harvesting operations up to the edge of the THEZ), and the resulting edge effects. Being larger than the size of an individual territory, a 12.6 ha THEZ increases the likelihood of protecting adjoining territories within each THEZ allowing for dispersal and gene flow between colonies. However, even when two or three colonies are present (i.e. generally fewer than 10 animals) whether a 200 m radius THEZ is of sufficient size to ensure the long-term persistence of resident colonies is unknown. Computer simulation modelling indicates that subpopulations of 20 or fewer animals are subject to high rates of extinction and are unlikely to persist for longer than 50 years (Lindenmayer and Lacy 1995). Therefore, the persistence of Leadbeater's Possum colonies in 12.6 ha THEZs will most likely depend on the presence of other colonies nearby and the level of habitat connectivity between them to facilitate demographic and genetic exchange more broadly.

3.2.1 Changing the size and shape of THEZ

Reducing the size of the THEZ would reduce the protection of resident colonies. The risk to the colony will increase as the area of the THEZ decreases, potentially resulting in the removal of foraging and/or nesting habitat in part of an occupied territory so that it no longer supports the resident colony. This impact is likely to be greatest for colonies with irregularly shaped territories (e.g. in which the nesting and foraging habitat is dispersed) and where the colony detection point around which the THEZ is centred is near the territory edge (Figure 20). In contrast, increasing the size of the THEZ will not only increase protection of the resident colony but will also increase the likelihood of protecting multiple colonies, improving persistence of the subpopulation through increased capacity for dispersal and gene flow (Lindenmayer and Lacy 1995, Lindenmayer and Possingham 1996, Hansen *et al.* 2009, Lindenmayer 2000).

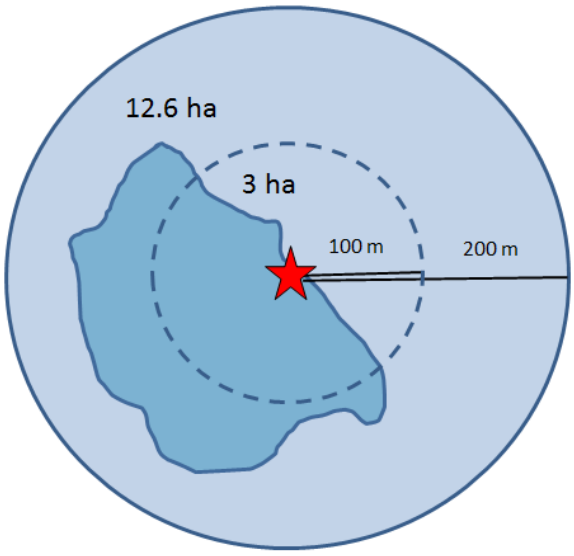


Figure 20. A 12.6 ha timber harvesting exclusion (200 m radius around the detection point) encompassing a non-circular territory in which the animal was detected on the edge of its territory. Part of the territory would not be protected in a 3 ha circular THEZ (100 m radius).

Key knowledge gaps in assessing the likely impact of changing the size and shape of Leadbeater's Possum protection zones include current territory sizes and nightly movement patterns, particularly in areas where nesting and foraging habitat is dispersed. Territory size estimates of 1–3 hectares were based on Leadbeater's Possum colonies that were evenly spaced within areas of generally high quality habitat in the late 1970s (Smith 1984b). Extensive and severe bushfires in 2009, and the high rate of death and collapse of large, old hollow-bearing occurring throughout the Central Highlands has resulted in suitable habitat for Leadbeater's Possum becoming increasingly patchy (Lindenmayer and Possingham 1995a, Lindenmayer and Wood 2010, Lindenmayer *et al.* 2012). In areas where suitable habitat is dispersed, the size and shape of Leadbeater's Possum territories may be much larger than 3 hectares, vary considerably in shape, and consist of a mixture of habitats. As a result, determining an optimum size and shape of protection zones based on perceived high quality habitat will be difficult to achieve and may vary substantially in different areas.

3.2.2 Impact of forest management activities within THEZs

Changing the zoning restrictions to permit some forest management activities within THEZs could impact Leadbeater's Possum in a range of ways, with the impact varying depending on the habitat features affected, the scale of the activity and the time scale over which the impact is likely to operate. Detailed below are the potential impacts on possum colonies and their habitat associated with different forest management activities.

Habitat loss and fragmentation

Forest management activities including timber harvesting, regeneration burning and the construction and maintenance of roads result in the loss and fragmentation of habitat with flow-on effects to resident colonies of Leadbeater's Possum. Due to the time taken for trees to form hollows suitable for Leadbeater's Possum (150 + years), loss of this critical habitat element is a key factor influencing the suitability of habitat patches for the species (Lindenmayer *et al.* 1990, 1997, 2012). Where large, old trees are retained in areas undergoing harvesting, they often have a reduced lifespan and elevated rates of collapse due to the impact of increased wind speeds in the harvested area and the scorching impact of the regeneration burns (Lindenmayer *et al.* 1990, Gibbons and Lindenmayer 1996, Lindenmayer 2009). Dead hollow-bearing trees retained in harvested areas are often incinerated during regeneration burns. These dead trees are also particularly vulnerable if the regeneration burn escapes into the adjoining habitat; colonies occupying these trees would be killed. Escaped burns can also reduce foraging habitat and connectivity such that the habitat is no longer suitable, at least in the short term.

Although traditional clearfell timber harvesting removes all foraging habitat and connectivity in the area harvested, the dense interlocking canopies in the eucalypts and the wattle that regenerates, generally form suitable habitat for movement and foraging within 15 years (Smith and Lindenmayer 1992). However, whether colonies are able to use such stands depends on the presence of hollow-bearing trees, either within the stand, or nearby (Smith and Lindenmayer 1988, Lindenmayer *et al.* 1991b).

Removal of habitat from part of a Leadbeater's Possum territory may result in that area no longer supporting the resident colony. Due to the territorial nature of Leadbeater's Possum, the movement of animals into adjacent habitat may be constrained by neighbouring colonies (Figure 21). The amount of habitat removed may limit the available resources within the remaining area such that the resident colony can no longer survive.

Figure 21. An example of the impact of habitat loss on densely-packed colonies of Leadbeater's Possums. If part of the habitat is lost (as represented by the pale area at the top of the figure), with a substantial proportion of a territory removed, such as for the colony in the centre, the presence of neighbouring colonies will constrain movement by these individuals into adjacent habitat to compensate for this habitat loss, thus impacting their survival.

The suitability of regenerating forests for Leadbeater's Possum is reduced by thinning operations. Thinning increases the growth rate of the retained trees, and while this may lead to the earlier formation of hollows, retained trees will be harvested most likely well before hollows suitable for use by Leadbeater's Possum have developed. Thinning opens forest stands and disturbs understorey vegetation through the passage of machinery, resulting in the loss of mid-storey connectivity that is required by Leadbeater's Possum in order to move through its habitat (DEPI 2014c). The abundance of wattle, an important food source for Leadbeater's Possum, may also be greatly reduced (LPAG 2014a). Regenerating stands are mostly thinned at 18-30 years (DSE 2007); due to their dense structure and often high basal area of wattle, occupancy rates by Leadbeater's Possum can be high in these areas, provided hollows are available (Nelson *et al.* in press).

The loss of critical habitat elements, particularly hollow-bearing trees, can result in the creation of areas of unsuitable habitat. This habitat fragmentation impacts Leadbeater's Possum by reducing the overall amount of suitable habitat, and subdividing previously continuous habitat into patches. As the remaining habitat patches are smaller they will support fewer animals, increasing the risk of genetic effects that influence long-term survival. However, habitat connectivity between smaller habitat patches can facilitate the dispersal of animals between patches, increasing the likelihood of persistence (Lindenmayer and Lacy 1995, Lindenmayer and Possingham 1996, Hansen *et al.* 2009, Lindenmayer 2000).

Impact of roading

Leadbeater's Possum is an arboreal species and individuals are rarely seen on the ground. As a result, existing roads with no connectivity from one side to the other providing a movement pathway for animals to cross, are thought to act as a barrier to normal nightly movement patterns. In these situations, roads are likely to form the edge of a colony's territory (R. van der Ree, pers. comm.).

Research undertaken by the Australian Research Centre for Urban Ecology (ARCUE) in which Leadbeater's Possums were radio-tracked before the installation of rope bridges over a road with no connectivity to facilitate crossings, revealed that animals remained on the same side of the road as they were captured. Once the bridges were installed (Figure 22) however, cameras mounted on

either end of the bridges recorded animals making regular and frequent crossings in both directions (R. van der Ree, pers. comm.). These results suggest that small tracks or roads with connectivity over the road may not act as a barrier to nightly movements of Leadbeater's Possum, but that larger roads without connectivity do. However, further information on the impact of roads of different sizes on nightly foraging patterns and dispersal of individuals, and the extent to which rope bridges could mitigate this impact, would be beneficial in assessing the impact of roading in Leadbeater's Possum protection zones.

Construction of new roads, or upgrading existing overgrown tracks will remove foraging and potentially nesting habitat for Leadbeater's Possums. Hollow-bearing trees adjacent to the road may be designated as 'hazardous trees' and removed. New roads constructed through occupied territories, road widening and the removal of dense vegetation on the side of existing roads may result in colonies becoming unviable if the territory occurs on both sides and there is no connectivity over the road to facilitate animals crossing. During dispersal, animals that come down to the ground to cross roads, are likely to be more vulnerable to predation. Animals foraging on the edge of roads may also be more vulnerable to predation.

Figure 22. Rope bridges installed to facilitate crossings by Leadbeater's Possum, Dowey Spur Track, Yarra State Forest, 2014. This road was forming a barrier prior to the installation of the rope bridges.

Edge effects

Colonies occupying patches of forest adjacent to stands that are subsequently harvested are likely to suffer edge effects. The increased wind and exposure impacts trees immediately adjacent to the harvested area accelerating their loss, particularly hollow-bearing trees (Lindenmayer 2009). There is also evidence that Leadbeater's Possum is sensitive to disturbance in the surrounding landscape, being absent from many retained linear strips of forest between harvested areas, despite the presence of suitable habitat (Lindenmayer *et al.* 1993).

4 Financial impact of Leadbeater's Possum colony protection on VicForests

Prepared by VicForests

4.1 Background

4.1.1 Industry Impact Scope

The Leadbeater's Possum Implementation Committee defined that the benefits and impacts of the 200 m THEZ to be considered within this review are to include actual benefits or impacts that have occurred due to the THEZs created up to 30 January 2017. All THEZs created beyond this date as a result of new colony detections are not included within this analysis, meaning the impact of THEZs created in the future has therefore not been considered.

However, the output of this analysis provides information that can be extrapolated to consider the impacts of colony buffers that may be created in the future if this prescription is retained, including the average increase in operational costs and the impact on the area of forest previously available for harvesting.

4.1.2 Colony Protection Zone Categorisation

For the purpose of this report, analysis has been done on 436 verified Leadbeater's Possum detections that impact State forest zoned as General Management Zone or Special Management Zone (Table 11). This includes 340 verified detections made between July 2014 and 30 January 2017, and 96 previously verified detections.

As part of the Leadbeater's Possum Advisory Group process, an analysis was done to predict the impact of THEZs. This analysis separated the impact of the THEZ into two categories:
- zones protecting colonies that were verified at the time, and
- the impact of 200 additional THEZs created around new Leadbeater's Possum detections.

To enable comparison of the initial impact assessment, the analysis being undertaken within this report also separates the impact of the THEZ into the categories above and also includes an additional category to represent those colonies detected beyond the 200 new THEZs. While colonies continue to be detected, for the purpose of this analysis, as described above, only those identified up to 30 January 2017 are to be considered within this report.

The categories of THEZ analyses are described within this report as:

1. the existing records from 1998 to February 2014 (existing)
2. the new 200 records verified between February 2014 – June 2016 (towards 200)
3. additional records up to 30 January 2017 (beyond 200)

Table 11. Number of Leadbeater's possum sites by time period and land tenure

Land Tenure	Existing	Towards 200	Beyond 200*	TOTAL
State Forest – GMZ / SMZ	96	200	140	436

* Colonies identified up to 30 January 2017

4.2 Industry Impact

4.2.1 Industry Impact Characterisation

As described within the Leadbeater's Possum Advisory Group Technical Report (pg. 39) (LPAG 2013b) there are two main indicators of industry impact:

- the reduction in the amount of forest available to harvest, and
- the increased cost of supplying the available timber due to the operational impact of the colony protection prescription.

The initial estimate of impact considered during the advisory group process was based upon an estimate of the THEZs that would be created. It was recognised at the time that there was a level of uncertainty regarding the impact on the timber industry due to it being unclear how many new colonies would be identified. However, it was assumed that given the rarity of the possum it was unlikely that there would be increased impacts beyond those predicted.

For this review, the indicators and metrics related to the buffers have been categorised as direct and indirect impacts. Assessments within the buffer areas describe direct impacts from delineating the 200 m buffers across the forest landscape within General Management Zone land tenure. Assessments outside the buffer area are identified as indirect impacts.

An overview of the metrics considered for this review is outlined below.

Direct Impacts:

- Loss of timber resource captured by the 200 m buffer
- Lost infrastructure (i.e. landings, roads etc.)
- Sawlog sales foregone

Indirect Impacts:

- Fragments of forest isolated by aggregate buffers
- Roading costs to avoid LBP buffers

4.2.2 Reduction in forest available

Timber harvesting is permitted within General Management Zones and Special Management Zones (with specific limitation) in Victoria's State forest.

The reduction in forest available outlined below refers to forest resource which was available to the timber industry but is no longer available due to the implementation of THEZs around verified Leadbeater's Possum detections. These reductions relate to both the area excluded by the THEZs, and areas outside THEZs that become inaccessible due to the creation of the zones.

4.2.2.1 Available and Suitable Forest within Exclusion Zones

The Timber Harvesting Exclusion Zones considered in this report cover 6,030 hectares of forest across a range of land tenures. Of this 4,046 ha is within General Management Zones or Special Management Zones and therefore potentially available for timber harvesting (Table 12).

Table 12. Land tenures within Timber Harvesting Exclusion Zones

Land Tenure	Area (ha)
Timber Harvesting Permitted: General Management Zone or Special Management Zone	4,046 (67%)
Excluded from Timber Harvesting: Parks and Reserves, Special Protection Zones (including modelled Code of Forest Practice exclusions)	1,939 (32%)
Other	45 (1%)
Total	**6,030**

Not all of the forest contained within the 4,046 ha General Management Zones or Special Management Zones is suitable for timber harvesting due to forest type and other constraints. VicForests' forest models predict that only 3,134 ha of this area is both available and suitable, and therefore likely to be harvested.

This compares with an estimated 2,131 ha predicted by the Leadbeater's Possum Advisory Group (LPAG 2013b, pp 82). The difference is attributed to a significantly higher number of verified colonies detected and also considers that a smaller area of available forest is contained within each THEZ than originally thought. The Advisory Group estimated approximately 60% per zone would be suitable and available forest, which is marginally higher than the actual 51% of the THEZ which comprises suitable and available forest.

4.2.2.2 Forest Types within Exclusion Zones

The previously available and suitable forest within the Leadbeater's Possum Timber Harvesting Exclusion zones consists of 2,848 hectares (91%) ash type forest and 286 hectares (9%) of mixed species forest (Table 13). This is significant as ash forests are the most critical for the ongoing viability of the timber industry. This is broadly consistent across the exclusion zone categories.

Table 13. Types of available and suitable forest within Timber Harvesting Exclusion Zones

THEZ categories	Ash (ha)	Mixed (ha)	Total (ha)
Existing	566 (89%)	73 (11%)	639
Towards 200	1,362 (94%)	85 (6%)	1,447
Beyond 200	920 (88%)	128 (12%)	1,048
Total	**2,848 (91%)**	**286 (9%)**	**3,134**

4.2.2.3 Forest Age within Timber Harvesting Exclusion Zones

Leadbeater's Possum THEZs incorporate State forests ranging in age from 0 – 117 years old (Figure 23). The current prescription for buffer delineation intersects with hectares recently harvested but not yet regenerated.

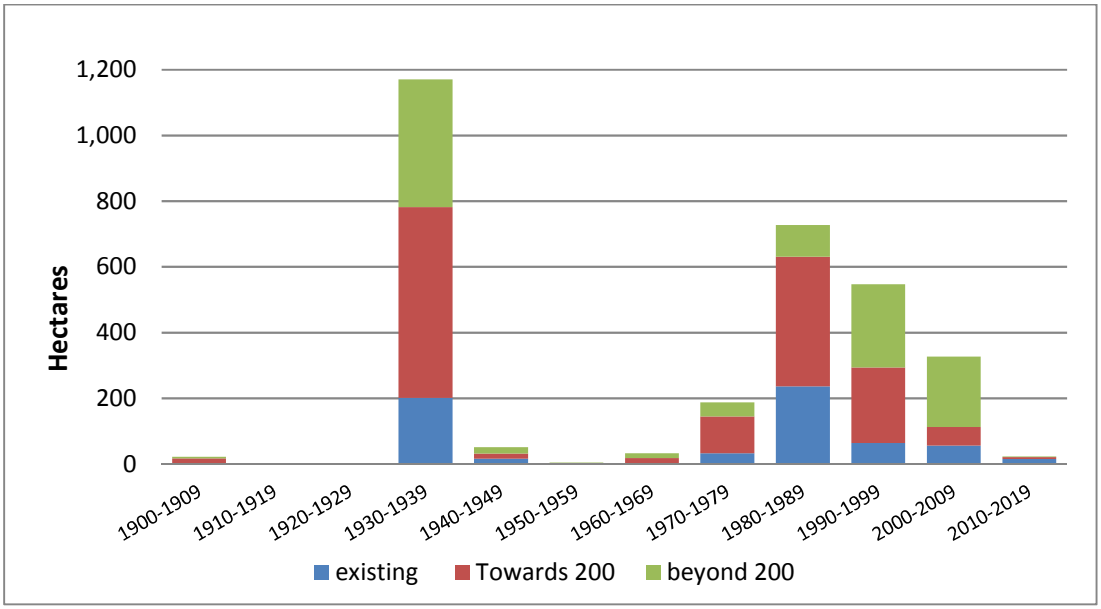


Figure 23. The amount of hectares by ten-year decadal growth category captured by 200 m Timber Harvesting Exclusion Zones (THEZs).

On average, the Leadbeater's Possum buffers capture 2.7 ha of available and suitable Ash and mixed species forest in age class 1930 – 1939, which is the predominant age class currently being harvested.

4.2.2.4 Inaccessible Forest Fragments

The assessment has considered areas of forest which while outside the colony protection zone, have become inaccessible because of the orientation of the zone relative to other forest reserves (Figure 24). Where these areas are small and distant from other available resource these have been characterised as inaccessible fragments because they are highly unlikely to be harvested under current forest management prescriptions.

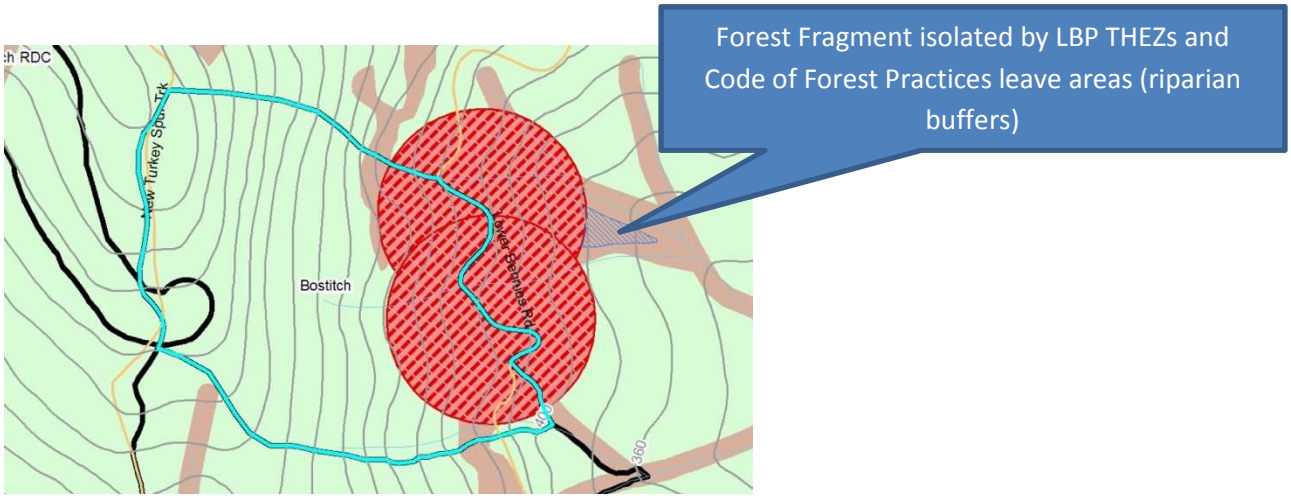


Figure 24. Map image displaying forest fragment.

Leadbeater's Possum buffers impacted approximately 203 hectares of forest by isolating these stands from other merchantable timber stands. There are 119 ha (59%) of 1930 – 1939 regrowth isolated by Leadbeater's Possum THEZs (Figure 25).

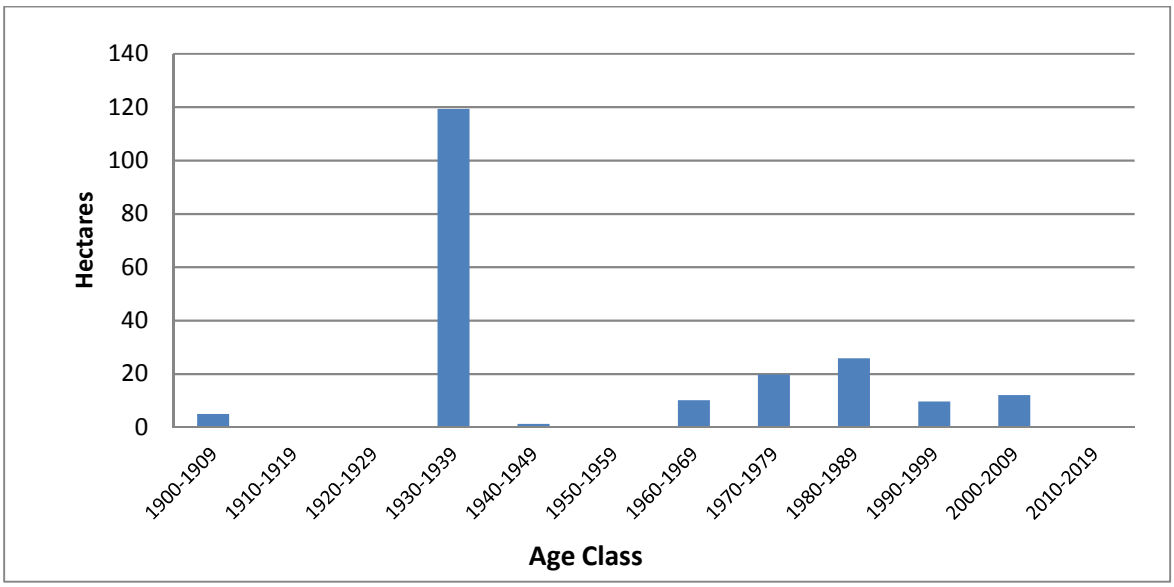


Figure 25. The amount of hectares by ten year decadal growth category fragmented from harvestable coupes and lost from available resource planning due to delineation of 200 m Timber Harvesting Exclusion Zones (THEZs).

4.2.2.5 Inaccessible Areas

There are other areas of forest that are no longer accessible as a result of the creation of THEZs.

Where access options are limited and/or the concentration of colony protection zones is high, the creation of colony protection zones may cause an area of forest to be physically inaccessible under the current prescription.

These areas were also previously available for harvesting but differ from the inaccessible fragments because they are larger in size. Inaccessible Areas can no longer be accessed due to a range of additional factors including terrain, other reserves and other regulatory constraints. Analysis has not been conducted to directly quantify this impact.

4.2.3 Sawlog sales foregone

VicForests has assessed the value of the sawlog which is modelled as available but is contained within THEZs created to protect verified Leadbeater's Possum colonies or is within the 203 ha area of small, isolated fragments.

This analysis has been done to assist with providing an approximate value showing the profit VicForests would have made from timber no longer available as a result of the THEZs. This analysis does not include areas made inaccessible by the THEZs.

A number of steps were taken as part of this analysis:

1. The area of forest excluded due to the creation of colony exclusion zones was determined
2. The merchantable age of each stand was evaluated and a timber volume estimated
3. The potential harvest age of each stand was considered to determine the potential volume of timber that may be extracted from that area
4. A value of Sales Value foregone was determined as net present value.

A detailed review of this methodology has been undertaken by the Leadbeater's Possum Implementation Committee (2015).

The Total Value of timber forgone to 2030 through the implementation of Leadbeater's Possum THEZ's has been determined to be **$14.77 million**[3] expressed in Net Present Value terms (Table 14).

Table 14. Net present value of Sawlog sales forgone to 2030

Colonies	Total Stumpage Net Present Value ($'000)
Existing	2,335
Towards 200	$6,701
Beyond 200	$4,488
Fragmentation	$1,246
Total	**$14,770**

4.2.4 Additional Roading Costs

VicForests regularly constructs new road to enable access to available forest and to allow timber from this forest to be transported to local mills.

Additional roading costs are incurred when the optimum alignment of roads that are yet to be constructed is blocked by the creation of a Leadbeater's Possum THEZ. These additional costs are incurred where the alternative alignment is longer (therefore a greater amount of road is constructed) and/or the road becomes more difficult and costly to construct due to the creation of a THEZ.

In some instances road alignment options are very limited and, as described above, the creation of a THEZ has resulted in areas of previously available forest becoming inaccessible at any cost.

It is currently assumed that no new road construction or major improvements to existing roads will be approved within any THEZ created to protect a verified LBP colony. Therefore, access to timber resource obstructed by THEZs needs to be via the construction of roads that are outside these exclusion zones. The potential location of any new road alignment must take into account physical, regulatory, environmental and financial considerations as judged by experienced field practitioners.

4.2.4.1 Cost assumptions

The construction of roads within the harvest area and loading areas is an inherent cost to the timber industry. The roading costs which have been considered within this analysis are those associated with road construction required to access the harvestable area as a result of the creation of THEZs. While it is recognised that the introduction of additional obstacles such as new reserves created within harvest areas may increase harvest complexity and therefore costs, for the sake of this analysis it has been assumed that the creation of THEZs has not impacted these in coupe costs.

These costs take into account the length of additional road required, the potential increase per kilometre, costs of constructing that road and additional road elements (such as stream crossings required). These estimates have been determined by undertaking a desk top analysis based on the experience of staff responsible for managing road construction.

[3] This value applies to harvesting over the period to 2030 and applies a 7.98% discount rate over 15 years in accordance with agreed standards for estimating THEZ economic impact.

4.2.4.2 Road Planning Assumption

It is assumed that the initial planned road line is the optimum location. Changes to planned road alignments therefore lead to sub-optimum locations resulting in additional costs due to larger side cuts, steeper grades, potential need for switchbacks, and additional road armouring (gravel).

The need for realignment can be characterised in the following categories:

1. **Creation of Intersections with Existing Roads**

   In an area impacted by a THEZ, it is possible at times to intersect a newly constructed road with an existing road that is not affected by the THEZ. However, while the length of road does not in these instances, the creation of an intersection at a less suitable location leads to increased costs. This will generally result in greater earth works to manage the safe intersection of two roads.

2. **Roadline Realignment**

   Where roads are obstructed by THEZs they can be realigned. However, road alignments are often heavily influenced by suitable stream crossing points, therefore forced realignment will often lead to the need for sub-optimal crossing points which can lead to significant increases in road lengths and costs.

   These costs potentially include steeper gradients requiring increased earth works and more armouring.

3. **Complete Redesign**

   Where road alignment is obstructed yet there is no capacity to simply realign this road to avoid the THEZ, a significant redesign of the roadline is required to determine if it is feasible. This will generally be caused by colonies covering the only suitable intersection point with an existing road and other options outside the colony reserve being unsuitable (generally due to slope).

4.2.4.3 Impacts on roading

Sixty-nine coupes currently on VicForests' Timber Release Plan were found to be impacted by Leadbeater's Possum 200 m THEZs. Of these:

- Access to 12 coupes (17%) was impacted, and no viable alternative option was identified.
- Access to 43 coupes (62%) was impacted with viable alternatives found at additional cost to avoid the THEZ;
- Access to 14 (20%) coupes was not impacted by the Leadbeater's Possum buffers.

In addition to these coupes, actual costs for three coupes were summed to provide additional detail to the impacts of Leadbeater's Possum buffers to road plans. Costs associated with road redesign are presented in Table 15.

Table 15. Estimated road costs and administrative overhead charges by three planning categories for coupes impacted by Leadbeater's possum THEZs.

	Complete Redesign	Road Realignment	More Difficult Take off	Total
Actual Roading Cost Roads already constructed	$120,000	$52,000	0	$172,000
Additional Road length (m)	13,210	1,400	0	14,610
Additional Stream Crossings/take off point	5	3	2	-
Total Roading Construction Cost	**$4,233,000**	**$352,000**	**$60,000**	$4,645,000
Overhead	**20%**	**20%**	**20%**	20%
Total Cost	**$5,079,600**	**$422,400**	**$72,000**	**$5,574,000**

4.2.5 Additional management costs

The ongoing creation of Leadbeater's Possum THEZs places an additional management burden on the timber industry. Where new zones are created over areas which have already been fully or partially planned for harvest this planning effort is either partially or fully lost. This includes effort lost in field assessment, road construction planning, field marking, site preparation and infrastructure construction.

Of greater impact is the disruption to harvest schedules, which in turn leads to increased risk of VicForests failing to meet customer commitments. This risk arises not solely because of the resource lost within the protection zone, rather it reflects the challenge of locating, planning and preparing alternative areas for harvest when the currently scheduled areas become unavailable. This is particularly the case where colony protection buffers impact on roadlines to access scheduled coupes because of the complexity and time taken to plan roads.

This review has not determined a financial quantification of the impact of this scheduling risk.

5 Impact of Timber Harvesting Exclusion Zones on timber supply

Prepared by DELWP

In May 2017, the Victorian Environmental Assessment Council (VEAC) published an assessment of fibre and wood supply from eastern Victoria. The terms of reference for the assessment were to:

- identify the current, and currently projected, fibre and wood supply to industry from eastern Victoria; and
- to identify the current and likely future constraints to this supply.

In the assessment report, VEAC presents findings from modelling carried out by VicForests to estimate the impacts of a range of factors on sustainable wood supply levels. This modelling and analysis has been subject to independent evaluation as part of the VEAC assessment process.

The analysis carried out by VicForests for VEAC differs to the analysis VicForests provided for Chapter 4 of this report in a number of ways:

i. the analysis in the VEAC report uses VicForests' own modelling approach developed to produce the resource outlook, rather than the one developed through the LPAG process, which is used in chapter 4 of this report
ii. the baseline for the number of colonies differs between the two approaches (detections to November 2015 rather than January 2017), and
iii. the VEAC analysis includes projections of future impacts including an assumption that Leadbeater's Possum colonies will continue to be detected and protected through THEZs for a further seven years from November 2015.

VEAC found that the age structure of the ash forests in Victoria's Central Highlands forest region is very unbalanced. Forest stands originating from the 1939 bushfires dominate the area of regrowth forest in eastern Victoria. This 1939 regrowth is the primary source of high-value sawlogs in Victoria due to the size and wood quality of the Mountain Ash and Alpine Ash. The impacts of subsequent fires, in particular the 2009 Black Saturday fires, have further skewed the age class distribution of ash species. A primary challenge facing VicForests and the native forest industry is the exhaustion of the 1939 ash regrowth after 2030, but before sufficient new forest resources from subsequent regeneration events are suitable to harvest.

VicForests regularly publishes a Resource Outlook containing estimates of sustainable harvest levels (Table 16). In terms of high-value sawlogs from Mountain Ash and Alpine Ash species, VicForests' estimates of sustainable harvest levels have reduced by more than 50% over the past decade.

Table 16. VicForests' forecast of future annual sustainable harvest level: D+ ash sawlog

Year of forecast	Volume (m^3 per year)
2009	293,000
2013	220,000
2016	175,000
2017	132,000

These reductions have occurred due to the impacts of unexpected events which are not addressed in VicForests' strategic wood supply modelling process.

In the following analysis of the impact of the THEZs on timber supply, DELWP has relied on VicForests' resource figures. VicForests holds the information and systems to calculate impacts on sustainable timber supply.

The primary driver behind the reduction in sustainable harvest level of 73,000 m^3 per year between 2009 and 2013 was bushfire, and in particular the 2009 Black Saturday fires.

The reduction of 88,000 m^3 per year since 2013 is due to a range of factors related to the protection of environmental values and changes to the regulations governing timber harvesting operations. VicForests' estimates include:

- 22,000 m^3 reduction per year due to the impact (direct and indirect) of measures in place to protect the Leadbeater's Possum and other biodiversity values such as rainforest as of November 2015;
- 23,000 m^3 reduction per year due to the removal of areas which VicForests has assessed as unlikely to be harvested for a range of commercial and ecological forest management reasons; and
- 43,000 m^3 reduction per year due to the expected future impact of measures in place to protect the Leadbeater's Possum from November 2015 into the future.

Although not presented in the VEAC assessment report, these figures can be further disaggregated to show the specific impacts of THEZs put in place around verified detections of Leadbeater's Possum.

The reduction of 22,000 m^3 per year due to measures in place as of November 2015 includes:

- 7,000 m^3 reduction per year due to loss of access to the area within the THEZ (direct);
- 5,000 m^3 reduction per year due to updating of the forest zoning scheme for the protection of rainforest, other threatened species and to allow for other forest uses;
- 10,000 m^3 reduction per year due to fragmentation and community concerns resulting in loss of access to State forest outside the THEZs – primarily in areas where there is a high density of THEZs.

In terms of the impact of THEZs after November 2015, VicForests' forecasts include an additional 18,000 m^3 reduction per year from the direct impact of projected THEZs and resource fragmentation associated with these. As such, the direct impact of THEZs (approximately 25,000 m^3 per year) accounts for an estimated 11% reduction in forecasts of sustainable harvest levels compared to the 2013 Resource Outlook.

VicForests advises that the largest impact on future volumes is resource isolation, including in forest areas adjacent to the THEZs becoming inaccessible. This adds potential access issues in the future, due to areas adjacent to THEZs being more difficult and costly to access.

Uncertainties

The greatest uncertainties associated with predicting the future impact of THEZs on timber supply are the total population size of the Leadbeater's Possum, and the level of future survey effort. Both these factors will affect the number and rate at which new colonies of Leadbeater's Possums are

detected in the future. The extensive survey effort that has occurred over the past 3 years through the implementation of the LPAG recommendations has now finished and it is unknown what level of survey effort will be undertaken in the future.

The VEAC assessment also considered the major uncertainties associated with future sustainable harvest levels.

For comparison, analysis conducted for VEAC estimates that potential for bushfires over the next 20 years has the potential to reduce the harvestable area of 1939 ash regrowth by about a further 20%.

Looking further into the future, modelling of climate change impacts carried out for the VEAC assessment predicts that by the end of the century there may be reductions in standing volume and stand density of 15%.

6 Examination of alternative options for protection of detected Leadbeater's Possum colonies

Prepared by DELWP

The *Code of Practice for Timber Production 2014* includes specific prescriptions for the protection of Leadbeater's Possum colonies that are detected in the field. The current prescriptions that apply to the Central Highlands Forest Management Area are set out below.

Leadbeater's Possum Colony Prescription

The *Management Standards and Procedures for timber harvesting operations in Victoria's State forests 2014, Table 13 Rare or threatened fauna and invertebrate prescriptions (p77)* (DEPI 2014a) states the following management action for a Leadbeater's Possum colony within the Central Highlands FMA: *"Where evidence of this value is found in the field follow clause 2.1.1.3 of this document using table 4 in Appendix 5 of the Planning standard for information"* (DELWP 2014d).

Clause 2.1.1.3 (p23) of the *Management Standards and Procedures* states: "*Where evidence of a value that requires protection via the establishment or amendment of an SPZ or SMZ is found in the field application must be made to the Secretary or delegate prior to commencement of the timber harvesting operation to create or amend an SPZ or SMZ in accordance with Appendix 5 the Planning Standards. SMZ applications must be accompanied by an SMZ plan and must be complied with during timber harvesting operations."*

Table 4 Detection based FMZ rules for fauna in the *Planning Standards for timber harvesting operations in Victoria's State forests 2014, Appendix 5 to the Management Standards and Procedures for timber harvesting operations in Victoria's State forests 2014* (p39) states the zoning management action for a Leadbeater's Possum colony: *"Establish a SPZ of 200m radius centred on each verified Leadbeater's Possum colony"*. The table includes the following under the "*Review*" heading: "*The effectiveness of this action in supporting the recovery of the Leadbeater's Possum will be reviewed after two years of surveying (commencing July 2014) or once 200 new colonies are located whose exclusion zones impact the GMZ or SMZ, whichever comes first"*.

The intention of the current rule is:

> *To allow the species to recover by providing protection to all known and newly discovered colonies of Leadbeater's Possums. In recognition of the recent fire events and ongoing habitat decline, which have led to a reduced population of Leadbeater's Possum, the remaining wild population is critical to the recovery of the species. (LPAG 2014a)*

An option remains to continue the prescription in its current form. Earlier chapters of this report indicate the significant benefits of the THEZ for the Leadbeater's Possum. For example, reducing extinction risk for the population within the Leadbeater's Possum reserve system by 34%. At the same time, Chapter 4 indicates the costs to industry.

This chapter explores alternative options or modifications that could be made to the THEZ, with a discussion of the key issues and relative impacts. Options include consideration of:

- size of exclusion zones
- shape of exclusion zones

- activities permitted within exclusion zones
- location of exclusion zones in relation to existing protected areas
- discontinuation of exclusion zones
- strategic options

The impact on Leadbeater's Possum of potential alternative options is informed by the ecological aspects of this report, outlined in Section 3, and the impact on the timber industry, as outlined in Sections 4 and 5.

6.1 Features of Timber Harvesting Exclusion Zones: discussion of alternative options

6.1.1 Size

The size of the timber harvesting exclusion zone (THEZ) under current rules (200 m radius circular area of 12.6 ha) is based on an understanding of territory size (of approximately 3 ha) and a precautionary approach to protecting the colony given that the precise location, size and shape of the territory is unknown. The current size of the THEZ allows for larger territories, which is likely in areas where nesting and foraging habitat are separated, and provides additional benefits through the high likelihood of protecting more than one colony. A 200 m radius THEZ is also likely to provide a buffer or area of unharvested forest around the colony territory to protect it from edge effects such as windthrow.

A range of different sized THEZs were considered by LPAG (2014b). A 100 m radius THEZ was considered to have 'low' benefit to Leadbeater's Possum (equal to an assumed territory size of 3 ha but without knowing the location of the territory boundary); a 4 ha area (equal to assumed territory size selecting the most appropriate area around the record) and a 200 m radius THEZ were considered to have 'low-medium' benefit; a 500 m radius THEZ was considered to have a 'medium' benefit and a 1 km buffer a 'high' benefit, due to the increased size of the buffer around the colony and protection of additional colonies representing neighbourhoods of colonies. A 1 km radius THEZ surrounding a colony has also been recommended by Lindenmayer *et al*. (2013b).

The 200 m radius size was recommended by the LPAG after considering the balance between protection for the possum and impacts on the timber industry.

1. **Larger or smaller THEZ**

Impacts for the Leadbeater's Possum

Reducing the size of the THEZ increases the likelihood that foraging and/or nesting habitat is lost in part of the colony's territory and therefore increases the risk that the colony will not persist. The amount of risk increases significantly as THEZ size reduces toward the likely territory area of 3 ha. This risk could be mitigated to some extent by modifying the shape of the THEZ to match high quality habitat (see below), although this does not address risks such as part of the protected area being occupied by another colony and hence unavailable to the target colony. A smaller THEZ also increases exposure of the colony to edge effects when adjacent areas are harvested, however, the distance into the colony's territory to which these effects may be felt are not well understood.

A smaller THEZ is likely to increase habitat fragmentation, unless there are viable options to connect the THEZ to other protected areas of forest while still adequately protecting the colony (see Section 3.2.1). This negatively impacts long term persistence, as clusters of colonies with adequate connectivity are important to allow for dispersal and genetic transfer between colonies. Colonies in small isolated patches are highly unlikely to persist. A smaller THEZ is less likely to protect nearby colonies in addition to the target colony. Additional colonies could be protected through surveying adjacent areas and protecting these colonies where found, however, this would not fully address fragmentation risks.

A larger THEZ increases the likelihood of protecting more than one colony, improving the chance of long term persistence by maintaining population processes, and of providing an adequate buffer around colonies. A larger THEZ may also increase the likelihood of protecting areas of forest not currently occupied by LBP. However, this provides capacity for population growth and allows for changes in territory boundaries in response to changes in forest structure and other critical habitat elements for Leadbeater's Possums.

Impacts for the timber industry

Establishing a THEZ reduces the area of forest available for harvesting – therefore THEZ size relates directly to availability of timber. However, given that there is often more than one record within current THEZs (currently considered duplicates), if smaller THEZs were used, this could lead to an increased number of THEZs if these were determined to be detections of separate colonies and therefore more fragmentation of the timber resource (and vice versa). As such, the relationship is unlikely to be strictly proportionate. Further analysis would be required to quantify this effect.

A larger THEZ increases the likelihood that roads and existing timber harvesting infrastructure will be covered by the THEZ - leading to increased costs if additional infrastructure or roading needs to be constructed or potentially making some previously harvestable areas uneconomic to harvest. A smaller THEZ may, in some cases, be easier to road around potentially reducing impacts on industry.

A larger THEZ requires greater demarcation in the field, which is more difficult and time consuming.

Administrative implementation considerations

There are no significant practical issues associated with implementing a smaller or larger THEZ in the planning scheme.

6.1.2 Shape of the Timber Harvesting Exclusion Zone

The current prescription is for a circular THEZ, based on ease of implementation in the planning scheme and provision of certainty for industry as soon as a detection is recorded about the area which needs to be protected from harvesting. It is also relatively easy to demarcate in the field from a known central coordinate point using Global Positioning System (GPS).

However, a circular shape does not account for specific features in the landscape. As such it has the potential to protect some areas of forest that may be unsuitable as habitat and therefore of limited immediate benefit to the Leadbeater's Possum. It may fragment harvestable areas and cover roads, recently harvested areas and unrehabilitated coupe infrastructure. This causes operational difficulties, can remove practical or economic access to some forest areas and increases costs for the timber industry. Three potential criteria in relation to modifying the shape of the exclusion zone are described below.

1. Irregular shape – modify the shape of the THEZ to avoid roads

Impacts for the Leadbeater's Possum

Existing, recently maintained roads are likely to form a barrier to LBP movements where there is no vegetation connectivity in the mid-storey. In these cases the road may form a territory boundary and modifying the shape of the THEZ so it runs along one side of the road would pose a relatively low risk to the colony. For any given size of THEZ, there is potential for enhanced benefit from an irregular THEZ compared to a circular THEZ if the protected area better captures and buffers the actual territory area.

Modifying the THEZ to avoid an area where a new road will be constructed in the future may lead to the removal of foraging and nesting habitat during road construction, or divide or disconnect the territory. This may result in loss of the colony, particularly where no alternative adjacent suitable or unoccupied habitat is available. The risks to the colony would be similar in the case of upgrading an existing road (including overgrown roads) where there is mid-storey connectivity across the road and this would be removed by works to make the road useable again.

This risk may be mitigated to some extent through prescriptions requiring retention of a degree of canopy and mid-storey connectivity during road construction. This could be achieved though road alignment, road width and minimised roadside clearing. There is also some evidence that the installation of rope bridges to provide movement pathways for Leadbeater's Possum over roads could be an effective mitigation measure. Sufficient numbers of these would be required to ensure at least one for each potential colony along the length of the road (e.g. at 100 m intervals).

In cases where this avoids the creation of a new or longer road to maintain access around the THEZ, this is likely to reduce other environmental impacts such as soil disturbance.

Impacts for the timber industry

According to VicForests analysis, road access to 69 coupes on the current Timber Release Plan in the Central Highlands has been affected by THEZs (see Section 4) and the largest impact on future sustainable harvest levels is from loss of access to areas due to inability to build new access roads through THEZs.

This option would remove or reduce the additional costs associated with restrictions on carrying out road works inside the THEZ, except in cases where it was not yet known that a new road would be constructed at the time the THEZ was established. Given that the road access issues for industry relate primarily to the construction of new roads through THEZs, this exception may represent a significant limitation in the amount of benefit this option can provide to industry.

If the size of the THEZ is kept the same, there is a potential the THEZ may cover more harvestable area, as existing roads are unlikely to contain merchantable timber.

In addition, this option may create operational delays as there would be uncertainty on area to be protected until a planning determination was made.

Practical implementation considerations

To implement this option in the planning scheme, a determination will need to be made as to which side of the road the colony is located. In cases where the detection is made from or near to a road, additional surveying by government and/or a change to the survey standard for the detection (seeking details such as direction and estimated distance of the LBP from provided coordinates) will be required.

The locations of existing, currently maintained roads are mapped but this often contains inaccuracies. Use of aerial photography would help in determining the location of existing roads, where these have not become overgrown. Field inspection will be required to determine the location of overgrown and new roads with sufficient accuracy. Without this, there is a risk that either a subsequent zoning amendment would be required to realign the THEZ with the road or approval would be needed to carry out works on the portion of road covered by the THEZ (if it remains Special Protection Zone (SPZ) – see below).

In the case of future road construction, it may not be known at the time of implementation of the THEZ if a road will be required or where it would be located.

Implicit in this option is the requirement for additional planning and deliberation about the boundary of the THEZ. A prescription to guide the design will not provide a clear cut answer in each case and the inherent ambiguity could lead to planning delays while the design is deliberated.

2. Irregular shape – modify the shape of the THEZ to protect the 'best' habitat

Impacts for the Leadbeater's Possum

Protecting perceived high quality habitat within the vicinity of records increases the likelihood that the 'best' habitat will be included within the THEZ to support the detected colony.

However, occupied territories may consist of a mixture of habitats leading to some areas that actually support Leadbeater's Possum being assessed as low quality and not being protected. This will be exacerbated in areas where foraging and nesting habitat are separated.

In addition, there is a risk that the definition and assessment of high quality habitat could be inaccurate leading to the protection of unsuitable or unoccupied habitat outside of the colony territory. Further analysis is needed to consider uncertainties in the extent of variability and difficulty in accurately predicting occupied habitat, and hence the scale of this risk.

Impacts for the timber industry

If the shape of the THEZ is modified to protect the best habitat but the size is kept the same, there is a risk the THEZ covers more harvestable area and therefore has a greater impact on timber volume as there is significant overlap between Leadbeater's Possum habitat and high production timber stands.

It is likely that in many cases the THEZ will be shaped to avoid existing currently maintained roads. However, overgrown roads with mid-storey connectivity and new roads would not necessarily be avoided and therefore the costs associated with roading around THEZs and incidence of inaccessible areas are unlikely to be significantly addressed by this option.

In addition, this option may create operational delays as there will be uncertainty about the area to be protected until a planning determination is made. If THEZ boundaries are not mapped to landscape features such as ridges, streams and roads, they will be identified in the field using GPS.

Administrative implementation considerations

Implementing this option in the planning scheme will require development of criteria to identify good quality habitat, such as presence of hollow-bearing trees, predominance of smooth-barked eucalypts, a dense interlocking canopy or mid-storey and high densities of wattle. However, planning decisions would remain subjective to some degree.

Criteria would need to be based on existing knowledge about Leadbeater's Possum habitat and behaviours and the extent to which this varies in different habitats, age classes, structural features and landscape contexts. As with the previous option, implicit in this option is the requirement for additional planning and deliberation about the boundary of the THEZ. A prescription to guide the design will not provide a clear cut answer in each case and the inherent ambiguity could lead to planning delays while the design is deliberated.

Recently collected LiDAR data on forest structure in the Central Highlands could enable desktop analysis of the level of mid-storey connectivity, which may reduce the requirement for field assessments. However, there are limitations to this data in that it cannot provide definitive information on the presence of hollow-bearing trees, particularly sub-canopy stags that are preferred for nesting. Implementation is likely to cost more than for the current prescription – requiring both greater time and expertise to determine the 'correct' shape.

To maximise the likelihood of protecting high quality and occupied habitat, additional time and cost would be required to conduct field inspections, including development of field manuals and training by experienced ecologists.

3. Irregular shape – avoid recently harvested areas that have not yet undergone regeneration works

Impacts for the Leadbeater's Possum

This option would have limited immediate impact on the Leadbeater's Possum, given recently harvested areas do not provide Leadbeater's Possum habitat.

However, if stags are present within the harvested area there is a significant risk that these would be lost either through hazardous tree removal or high intensity regeneration burning, meaning a loss of potential nesting sites. This risk could be managed by conducting low intensity regeneration burns or mechanical disturbance. In the medium term, regeneration makes it more likely that the area will provide potential foraging habitat. In the long term, the area is subject to harvesting and potential removal of habitat.

Impacts for the timber industry

To date, this issue has impacted a small number of coupes, across relatively small areas typically <1 ha. This option would provide regulatory clarity for VicForests in carrying out regeneration of the affected areas.

Without rehabilitation and regeneration activities being undertaken, it is unlikely that these areas will regenerate with eucalypts and be productive for timber. Adjusting the THEZ boundary to allow

regeneration activities significantly reduces the likelihood that more costly mechanical disturbance will be needed to regenerate adjoining areas.

Administrative implementation considerations

There are no significant practical issues in implementing a THEZ in the planning system that avoids an area that has been harvested. The THEZ boundary can be aligned using coupe boundary information provided by VicForests.

Modifying the shape of the THEZ is one mechanism to provide regulatory clarity for VicForests in carrying out regeneration of the area. This could also be achieved through changing the planning designation of the THEZ (see Section 6.1.3 below) or through changes to rules in the Code.

6.1.3 Activities allowed in the exclusion zone – Allowable activities

Currently, most timber harvesting operations are not allowed inside the THEZ. The exceptions are haulage on existing roads and a limited range of other activities, if approved. This provides a high level of protection for the colony given the species' relative susceptibility to disturbances in forest structure and the loss of particular habitat elements. The Leadbeater's Possum is forest dependent and requires habitat elements (hollow-bearing trees) that may take centuries to develop. They are also territorial, with need for connectivity across the territory (and between territories for dispersing individuals).

The forest management zoning scheme assigns areas of forest to one of three categories (General Management Zone (GMZ), Special Management Zone (SMZ) and Special Protection Zone (SPZ)). THEZs established to protect Leadbeater's Possum colonies are currently designated as SPZ. The Code prohibits any timber harvesting operations taking place inside SPZ areas, except where approval is granted by the Minister or her delegate.

There is specific provision in the Code to allow for approval of road construction and maintenance activities inside the THEZ, where this is assessed as having a lesser environmental impact than the alternative (e.g. roading around the THEZ).

Two potential types of changes are described in relation to allowing activities within some or all of the THEZ.

1. **Allow roading activities, use of existing coupe infrastructure and/or regeneration activities**

Impacts for the Leadbeater's Possum

For impacts of roading and regeneration areas see discussion in the 'shape' section above. The exception is that allowing regeneration within the THEZ, rather than modifying the THEZ to avoid areas to be regenerated, means that the regenerated area would not be harvested in the future and so could potentially provide habitat over the long term as well as in the medium term.

There is expected to be minimal immediate impact to the Leadbeater's Possum in the continued use of existing coupe infrastructure for current harvesting operations. Upon completion of use, the area would be regenerated and potentially provide future habitat.

Where this option avoids the construction of additional coupe infrastructure outside the THEZ to enable harvesting in surrounding areas this will reduce other environmental impacts such as soil disturbance.

Impacts for the timber industry

For impacts of roading and regeneration areas see discussion in the 'shape' section above. The exception being that the road location would not need to be known at the time the THEZ was established, so this option is likely to offer greater benefit to industry than modifying the shape of the THEZ as it is better suited to enabling the construction of new roads.

Establishment of THEZs over existing coupe infrastructure such as log landings and snig tracks has impacted a small number of coupes to date, so the overall benefit of this option to the timber industry is likely to be small. However, it may be important to the economic viability of individual coupes and in some cases, adjacent coupes.

Administrative implementation considerations

This option could be delivered in a number of ways.

If the THEZ, or parts of the THEZ, were instead categorised as SMZ this would provide greater regulatory flexibility to specify which timber harvesting activities were acceptable and unacceptable and in which circumstances. Alternatively, changes could be made to the Code to specify allowed activities within Leadbeater's Possum THEZs and apply any conditions.

To deliver this option, the allowable activities, conditions to be applied and activities not allowed could be applied to all THEZs upfront, providing greater regulatory certainty, or be applied on a case by case basis, for example, through an SMZ plan, creating greater flexibility to respond to local conditions but increasing administrative costs.

To manage the risks to the Leadbeater's Possum it is likely to be necessary to develop a set of criteria for determining whether road construction would be appropriate, how the location of any new road should be determined (for example, avoiding hollow bearing trees) and any mitigation measures that should apply, for example, to retain connectivity.

In the case of roading activities, as noted above, the Code already contains provision for approval to be given for road works to be carried out inside the THEZ. There is no equivalent provision for approval of regeneration activities or use and rehabilitation of coupe infrastructure.

2. Allow timber harvesting in some areas within the exclusion zone

Impacts for the Leadbeater's Possum

Harvesting within the THEZ significantly increases the risk to the Leadbeater's Possum colony for which the THEZ was established. Even less intensive harvesting methods such as thinning would create disconnection in the midstorey and limit Leadbeater's Possum movement across the territory. It would also reduce foraging habitat in the short term. This risk could be managed to some extent if harvesting was limited to areas surveying indicated were unlikely to be Leadbeater's Possum habitat, however it is difficult to definitively determine if an area may be occupied based on habitat criteria alone.

In addition, any harvesting of the oldest age-class of trees (78 year old regrowth from the 1939 bushfire) will reduce the availability of future nesting habitat, impacting long term habitat suitability.

This option increases the risk to Leadbeater's Possum of fragmentation of habitat and colonies.

In areas where there are limited hollows and declining wattle density, modified harvesting could potentially improve future habitat through more rapid hollow development, however this would take decades to eventuate, and would risk the survival of the colony on the site in the short term.

Impacts for the timber industry

Allowing harvesting inside the THEZ has the potential to provide additional timber volume – with the size of the benefit dependent on the precise rules applied (e.g. limitations on harvesting method, proportion of area or type of forest available to harvest). However, as there is significant overlap between habitat and timber suitable for harvest (older age classes) it is likely much of this timber would need to remain unavailable to manage risks to the colony.

Quantitative analysis of forgone timber volumes from THEZs has not been presented by VicForests in Chapter 4, however retaining access to a proportion of this is unlikely to be significant in its contribution to overall annual timber harvest volumes.

Harvesting within the THEZ may also allow some adjacent fragments to be harvested by creating a unit that is economic to harvest, although without further analysis it is not possible to determine whether this benefit would be significant.

Commercial thinning can increase the growth rate and health of remaining trees to bring forward future timber supply. Commercial thinning opens the canopy of the forest, meaning roads constructed in areas that have been thinned dry more quickly and are more suitable for use throughout the year – this would increase operational flexibility.

Administrative implementation considerations

Rules would need to be developed to specify the location, type and extent of harvesting allowed over time and any additional conditions that should be applied such as additional surveying. Development of these rules requires further consideration of the specific habitat requirements of Leadbeater's Possum, risks of activities to colony persistence and scale of potential benefits for industry.

To minimise the risks from harvesting activities, additional resources would be required for detailed surveys to determine if colonies were present within the area planned for harvesting, as it is difficult to be definitive on whether the site is occupied based on habitat assessments.

6.1.4 Changing the shape and location of THEZ in relation to existing protections

The THEZ could be moved and reshaped to either:

- Align the THEZ boundary with existing, adjacent SPZ and other Code protected areas.
- Merge the THEZ with existing SPZ or Code protected areas if adjacent to the detection site (thereby reducing the area of additional protection created).

There may be existing SPZs nearby the detection site that protect other forest values such as a range of threatened species. In addition, areas such as steep slopes and buffers around permanent streams are protected from timber harvesting by Code restrictions. While steep slopes are less likely to contain suitable habitat, gullies may form habitat and are more likely to contain mature trees due to ongoing protection from harvesting.

Impacts for the Leadbeater's Possum

Moving and reshaping the THEZ so that it is aligned to other nearby protected areas will potentially increase the areas of contiguous protected habitat for Leadbeater's Possum, provided that those adjacent areas contain suitable habitat. However, depending on the individual case, moving the THEZ increases the risk that it does not provide adequate protection or does not protect at all the target colony. This risk could be mitigated to some extent through field assessment to better understand the area likely to be occupied by the colony.

Merging or incorporating the THEZ into existing protected areas increases the risk that an inadequate size or area of habitat is protected to support the colony. This risk might be mitigated to some extent if habitat criteria were included in the criteria for determining the size and shape of the THEZ (see Section 6.1.2).

The scale of these risks would depend on specific implementation criteria, are likely to vary significantly depending on site characteristics and would require further analysis to quantify.

Impacts for the timber industry

Both alternatives are likely to partially address loss of timber volume through fragmentation.

Merging the THEZ with areas already unavailable for timber harvesting would also reduce the loss of timber volume from within the THEZ.

The scale of these benefits would depend on specific implementation criteria, are likely to vary significantly depending on site characteristics and would require further analysis to quantify.

Administrative implementation considerations

The practical administrative considerations are similar to those involved in modifying the shape of the THEZ. This option will require development of criteria for moving and reshaping the THEZ and managing risks to the Leadbeater's Possum. Additional field surveying may be required to adequately manage risks to the colony.

6.1.5 Discontinue protection of colonies

Impact for the Leadbeater's Possum

Unless alternative and effective measures are implemented, this option will result in a loss of Leadbeater's Possum colonies, and a loss and fragmentation of habitat, reducing the viability of sub-populations. This option could have a significant impact on the overall population by reducing the population size and causing a loss of genetic diversity reducing fitness. These impacts will be exacerbated if future broad-scale fires impact the population.

Impact for the timber industry

This option will remove any impacts of future THEZs on timber harvesting operations, although impacts from existing THEZs would remain unless these were also removed.

However, to retain market access the suite of remaining measures would need to be demonstrated to be supporting the recovery of the possum, otherwise industry led colony protection measures may be required.

Harvesting in areas where colonies have been located, especially populations located by community groups, may reduce VicForests' social licence.

Administrative implementation considerations

There are no significant practical issues with implementing this option in the planning scheme.

6.1.6 Strategic options

Although outside the scope of this report, broader consideration could be given to the range of protections for the Leadbeater's Possum over the longer term.

This might include consideration of whether additional information gained since the LPAG recommendations in 2014 warrants adjustment to the package of measures implemented to conserve the Leadbeater's Possum.

The planning scheme for State forests across the Central Highlands includes SPZs which protect a range of forest values. The scheme could be reviewed to consider whether these can more efficiently and effectively provide protections for Leadbeater's Possum alongside protections for other threatened species while providing for activities such as recreation and timber harvesting, or improved access to timber supply outside of THEZs and SPZs.

Such an approach could consider the extent and distribution of current and future habitat for a range of threatened species. It could also include consideration of habitat within existing parks and reserves, and threats such as climate change and future bushfire, to design a 'reserve' system (i.e. parks and Special Protection Zones) that delivers the greatest benefit for Victoria's forest-dependent species, including Leadbeater's Possum. Beyond this reserve design, further biodiversity benefits could be achieved through improved threat management such as targeted weed and pest animal control and habitat creation (e.g. artificial hollows for Leadbeater's Possum) to deliver an overall package that maximises the biodiversity benefits and helps deliver against targets in Victoria's Biodiversity Plan, *Protecting Victoria's Environment – Biodiversity 2037*.

Consideration should also be given to the impacts and timing of a shift to a 'landscape' approach to providing adequate protections for Leadbeater's Possum and other threatened species, and how or whether a detection based planning rule would continue to sit alongside this.

6.2 Findings

The review of the 200 m THEZ clearly indicates that the action is making a positive contribution to the conservation of Leadbeater's Possum. The THEZs have protected 436 additional Leadbeater's Possum colonies, with an additional 4,046 hectares of State forest reserved in Special Protection Zones. Without this protection, many of these possum colonies may have been at the risk of inadvertent destruction from timber harvesting.

The THEZs have been relatively effective in reducing the extinction risk of Leadbeater's Possum – with modelling estimating a reduction of approximately 34% for populations within the Leadbeater's Possum reserve system[4]. As such the THEZs are likely to go part of the way towards achieving the LPAG aim of slowing the projected decline in population numbers in the Central Highlands, so that there are sufficient individuals for the species to recover in the future. However, the species remains at risk of extinction, especially when considering the likelihood of future fires and continued efforts to provide protection will be required.

[4] This is based on a future scenario of 200 years without bushfire. This is highly unlikely but the figure is useful to demonstrate the relative effectiveness of protection of colonies from timber harvesting.

The current application of THEZs has resulted in direct impacts to industry through exclusion of timber harvesting in 3,134 ha of GMZ / SMZ that was previously available and suitable for timber harvesting. Of this, only 1,171 ha is 1939 regrowth forest, the primary source of high-value sawlog.

VicForests has estimated that the existing THEZs will reduce sawlog harvesting revenues by $14.77 million Net Present Value to 2030. The increased costs of road construction represent an indirect cost and are estimated at $5.6 million for access to coupes on the current TRP.

Using a different methodology, the impact of current and future THEZs has led to a reduction in VicForests' forecasts of sustainable sawlog harvest levels of 11% since 2013. VicForests' forecasts also include the impacts of fragmentation, community concerns and potential access constraints in the future restricting access to timber supply outside of the THEZs. The current 200 m THEZ prescription provides a compromise between the two objectives of supporting the recovery of Leadbeater's Possum while maintaining a sustainable timber industry.

The relative effectiveness and success of the current 200 m THEZ prescription in providing protection to the Leadbeater's Possum, indicates the size of the THEZ is appropriate as a compromise between competing objectives, noting that continued efforts are required to protect the species.

The effectiveness of the THEZ is not only important for the Leadbeater's Possum, it is also important for the timber industry as effective conservation measures are needed to retain market access and social licence.

Understanding both the direct and indirect impacts the current prescription has on the timber industry provides opportunity to refine the way the current THEZ prescription is applied, particularly in relation to access and road construction. Construction of new roads inside the THEZ may create risks for the Leadbeater's Possum through loss of habitat and disconnection within territories. To manage this risk it is appropriate that clear rules should apply in determining whether and where road construction would be appropriate.

Further work is required to establish the precise criteria to be applied, for example, to ensure road construction does not remove critical habitat features or otherwise result in the colony becoming unviable. Guidance should also be developed to support the application of appropriate mitigation measures, including to ensure retention of habitat connectivity across the road. These should be guided by the ecological requirements of the species, including the important new information about the species' habitat gained through surveying conducted since the 200 m THEZ prescription was put in place in 2014. Decision making can also be supported through the use of new data, such as LiDAR data recently gathered across the Central Highlands.

Changing the shape of the THEZ to maximise habitat protection or avoid the known location of roads, is one approach to reducing indirect impacts on industry whilst maintaining benefits to the Leadbeater's Possum. However, this may be limited in its effectiveness given that industry access issues primarily relate to the construction of new roads and the location of these may not be known at the time a THEZ is implemented.

The *Code of Practice for Timber Production 2014* contains provisions to exempt roading activities within SPZs. These provisions could be applied to reduce indirect impacts to industry by allowing for roading where this does not create undue risk to Leadbeater's Possum colonies.

A broader approach to surveying the full range of the Leadbeater's Possum habitat would provide vital information to inform longer-term approaches to protecting the species through a landscape scale approach to forest management.

7 Conclusion

Prepared by DELWP

The Leadbeater's Possum Advisory Group (LPAG) was established in 2013 to make recommendations to support the recovery of Leadbeater's Possum while maintaining a sustainable timber industry. A suite of measures were introduced based on LPAG's recommendations, including implementation of a 200 m timber harvesting exclusion zone (THEZ) to protect verified detections of Leadbeater's Possum within the Central Highlands. The LPAG also recommended that the effectiveness of this rule be reviewed once 200 Leadbeater's Possum detections had been verified, or after two years of surveying.

Both the Leadbeater's Possum and Victoria's native timber industry are dependent on ash forests of the Central Highlands, which provide both nesting and foraging habitat and high-value sawlogs. Severe bushfires in the Central Highlands have impacted the Leadbeater's Possum and the native timber industry, and have heightened the importance for these forests to be managed in a way that supports the dual outcomes of recovery for the Leadbeater's Possum and a sustainable timber industry.

Key findings of the review are described below, including recommendations to support recovery of the Leadbeater's Possum while maintaining a sustainable timber industry.

7.1 Protection for Leadbeater's Possum

The review found that the 200 m THEZ has been relatively effective in reducing the extinction risk of Leadbeater's Possum (by an estimated 34%) for populations within the Leadbeater's Possum reserve system in the Central Highlands, and therefore slowing the projected decline in population numbers. However, there remains a residual risk of extinction, particularly with the likelihood of future bushfires, and continued efforts to provide protection will be required.

The application of the 200 m THEZ to 31 January 2017 has resulted in immediate protection for 436 additional colonies. An additional 4,046 hectares of State forest has been reserved in Special Protection Zones (SPZs) at locations where a colony is known to occur. The 200 m THEZ prescription has been a useful tool in improving the effectiveness of the reserve system for Leadbeater's Possum protection, achieving a significant reduction in risk of extinction through a relatively modest increase in the formal reserve system for Leadbeater's Possum (approximately 13%).

The THEZs have been applied across the full range of the Leadbeater's Possum within the Central Highlands, reducing the risk that a single bushfire could impact a significant proportion of the population protected by THEZs.

The increased number of detections of Leadbeater's Possum relates to the significant increase in sampling since 2014, and the use of more efficient survey techniques. It also points to the value of citizen science in achieving biodiversity outcomes.

Even with this increase in sampling, significant information gaps remain. Surveys have only sampled a small proportion of the whole range and potential habitat of Leadbeater's Possums, and the 200 m THEZ prescription has only protected a relatively small proportion of the area of suitable habitat. Further field surveys across the entire landscape including within parks and reserves, would provide additional information to inform a more strategic, landscape-scale approach to support the species' recovery into the future.

7.2 Impacts to the timber industry

The 200 m THEZ has also resulted in direct and indirect impacts to the timber industry through reduced timber availability (direct impacts) and increased operational costs, resource fragmentation and loss of access to timber outside of THEZs (indirect impacts).

Direct impacts are from the area and volume of timber located within a THEZ, and therefore unavailable for timber harvesting. VicForests estimated the direct impact of the THEZs to be loss of access to 3,134 hectares of State forest in areas that were previously available and suitable for timber harvesting. Of this, only 1,171 ha is 1939 regrowth forest, the primary source of high-value sawlog in Victoria.

The direct and indirect impacts to VicForests' business operations from the THEZs have been estimated in two alternative ways (financial and timber volume):

In financial terms:

- The direct impact is $14.77 million in sawlog revenue foregone over the period to 2030.
- The indirect impact of the THEZs is estimated at $5.574 million for additional road works to access coupes on the current TRP.

Based on VicForests' estimates included in VEAC's fibre and wood supply assessment report, the direct impact of current and anticipated 200 m THEZs (approximately 25,000 m^3 per year) is relatively moderate, particularly when compared to other impacts on sustainable timber supply such as bushfire, which was the primary driver of reductions in sustainable harvest levels by 73,000 m^3 per year between 2009 and 2013. The direct impact of approximately 25,000 m^3 per year is the equivalent of 11% of VicForests' 2013 forecast of a sustainable sawlog harvest level. The area within the THEZs represents 2.5% of the area of forest available for harvesting within the Central Highlands, or 4.1% of the available ash forest.

However, the combined effect of direct and indirect impacts of the 200 m THEZ on the timber industry is more substantial.

The THEZ contributes to the indirect impacts to industry due to potential fragmentation difficulties accessing timber supply. The most significant contributor to indirect impacts are the increased costs of constructing roads and related loss of access to timber as these costs and operating conditions become prohibitive.

Other indirect impacts, not quantified by VicForests include:

- management costs – these are planning costs to undertake field assessments, plan road construction, field marking, site preparation and infrastructure construction; and
- planning costs to reschedule coupes.

VicForests estimates future THEZs could have a significant impact should detections continue at current rates and no other changes be made to mitigate significant indirect impacts related to road access.

Understanding both the direct and indirect impacts the current prescription has on the timber industry provides opportunity to reduce unintended (indirect) impacts of the prescription through the way it is applied, particularly in relation to access and road construction. Further work is required to ensure road construction within a THEZ is appropriately managed and does not remove critical habitat features or have other significant detrimental effects on Leadbeater's Possum colonies, and to determine appropriate mitigation measures to these risks.

7.3 Recommendations

Based on the above findings, this review makes the following recommendations for the continued recovery of the Leadbeater's Possum while maintaining a sustainable timber industry.

Recommendation 1: Continue the 200 m Timber Harvesting Exclusion Zone prescription around verified Leadbeater's Possum colonies.

The current THEZ prescription has been effective in providing protection to Leadbeater's Possum colonies and remains an appropriate compromise between the two objectives, noting that further efforts are required to protect the species and reduce costs to industry.

Recommendation 2: Review how the THEZ is applied to reduce unnecessary indirect impacts on the timber industry while ensuring adequate protection for Leadbeater's Possum.

The *Code of Practice for Timber Production 2014* provides for VicForests to apply for approval to construct roads through THEZs.

DELWP should update processes for assessing proposals for exemptions to construct roads through SPZs, ensuring that risks to the Leadbeater's Possum continue to be mitigated. This will provide greater clarity for industry on the circumstances in which road construction is appropriate and can be approved. It should include developing guidelines for the application of mitigation measures and be based on the information gathered in this report and further advice from biodiversity experts and operational foresters.

DELWP should also commit to processing individual applications within a specified timeframe, once a completed application is received.

Recommendation 3: Undertake further field studies to improve knowledge of Leadbeater's Possum.

DELWP should undertake a program of field surveys across parks, reserves and timber harvesting areas to further identify Leadbeater's Possum's distribution and abundance across the Central Highlands. VicForests should continue to conduct pre-harvest surveys in proposed coupes in State forests.

Collecting more information about the distribution and abundance of Leadbeater's Possum colonies will help to reduce uncertainty around the population estimate and provide additional knowledge about habitat requirements and distribution to help guide future actions to support recovery of the species.

Recommendation 4: Further develop species models as the basis for improved forest management planning and conservation management.

DELWP should continue to develop improved models that better predict the current and future distribution of Leadbeater's Possum populations and habitat and that enable the assessment of the species' likely persistence across State forests, parks and reserves in consideration of a range of threats and actions to mitigate these including bushfire.

Recommendation 5: Review THEZs and other existing SPZs in the Central Highlands to optimise for timber availability, protection for Leadbeater's Possum, threatened species and other forest values.

Following additional surveying and improvements to models, the department should review the Central Highlands State forest zoning scheme (including the THEZ) to take into account new information and changes in the forest since the Leadbeater's Possum reserve system was established in 2008.

In the review, efficiencies should be sought across protections for all threatened species and other values such as recreation and water supply. Consideration should be given to whether the revised zoning scheme provides effective protections for the Leadbeater's Possum and therefore whether the 200 m THEZ rule should be discontinued. The effectiveness of zoning protections should also be compared to a broader suite of current and potential Leadbeater's Possum protection measures, including on ground actions.

Recommendation 6: Transition to landscape-scale planning for threatened species management.

A strategic landscape-scale planning and management approach is more likely to deliver a greater benefit to the conservation and recovery of Leadbeater's Possum than the ongoing detection-based THEZ prescriptions. A landscape scale approach that moves away from the use of detection-based prescriptions will also provide greater certainty and reduced costs to industry.

In line with *Protecting Victoria's Environment - Biodiversity 2037,* Victoria is moving away from prioritising actions for individual species to an approach that considers all species and all threats and possible actions together to inform priority actions that efficiently deliver the maximum benefit for the most species. This requires a transition to a landscape scale, multiple threatened species planning and management approach that aims to deliver the maximum benefit for the highest number of threatened forest-dependent species.

References

Adams, M.H. and Attiwill, P.M. (1984). The role of *Acacia* spp. in nutrient balance and cycling in regenerating *Eucalyptus regnans* F. Muell forests I. Temporal changes in biomass and nutrient content. *Australian Journal of Botany* **32**, 205–215.

Burgman, M.A., Ferson, S., and Akçakaya, H.R. (1993). Risk Assessment in Conservation Biology. Chapman and Hall, London.

Commonwealth of Australia (2016). *National Recovery Plan for Leadbeater's possum* (Gymnobelideus leadbeateri). Consultation Draft, February 2016.

Commonwealth of Australia and Department of Natural Resources and Environment (1997). Comprehensive Regional Assessment – Biodiversity. Central Highlands. The Commonwealth of Australia and Department of Natural Resources and Environment, Canberra.

Department of Environment and Primary Industries (DFEPI) (2014a). 'Management standards and procedures for timber harvesting operations in Victoria's State Forests 2014.' Department of Environment and Primary Industries, Melbourne. https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0023/29309/Management-Standards-and-Procedures-for-timber-harvesting-operations-in-Vics-State-forests-2014.pdf

Department of Environment and Primary Industries (DEPI) (2014b). 'Code of practice for timber production 2014.' Department of Environment and Primary Industries, Melbourne. https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0016/29311/Code-of-Practice-for-Timber-Production-2014.pdf

Department of Environment and Primary Industries (DEPI) (2014c). 'Action Statement No. 62: Leadbeater's Possum *Gymnobelideus leadbeateri*.' Department of Environment and Primary Industries, Melbourne.

Department of Environment and Primary Industries (2014d). 'Planning Standards for timber harvesting operations in Victoria's State forests 2014: Appendix 5 to the Management Procedures for timber harvesting in Victoria's State forests 2014'. The State of Victoria Department of Environment and Primary Industries. https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0021/29307/Planning-Standards-for-timber-harvesting-operations-in-Vics-State-forests-2014.pdf

Department of Environment Land Water and Planning (DELWP) (2015). *Threatened Species Survey Standard: Leadbeater's Possum*. Department of Environment, Land, Water and Planning, Melbourne. http://www.delwp.vic.gov.au/__data/assets/pdf_file/0006/299643/LBP-Survey-Standard-2015-artwork.pdf

Department of Environment, Land, Water and Planning (DELWP) (2016). 'Supporting the recovery of the Leadbeater's Possum: Progress report December 2016.' Department of Environment, Land, Water and Planning, Melbourne.

Gibbon, P. and Lindenmayer, D.B. (1997). Developing tree retention strategies for hollow-dependent arboreal marsupials in the wood production eucalypt forests of eastern Australia. *Australian Forestry* **60**, 29-45.

Hansen, B.D., Harley, D.K.P., Lindenmayer, D.B. and Taylor, A.C. (2009). Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. *Molecular Ecology* **18**, 3346-3362.

Harley, D. (2002). The discovery of Leadbeater's possum *Gymnobelideus leadbeateri* along the Woori Yallock Creek, Yellingbo. *Victorian Naturalist* **119**, 233-235.

Harley, D.K.P. (2004). A review of recent records of Leadbeater's Possum (*Gymnobelideus leadbeateri*). Pp. 330–338 in Goldingay, R. and Jackson, S. (Eds.) *The Biology of Australian Possums and Gliding Possums.* Surrey Beatty and Sons, Sydney.

Harley, D.K.P. (2005). 'The life history and conservation of Leadbeater's Possum (*Gymnobelideus leadbeateri*) in lowland swamp forest. Ph.D. thesis.' Monash University, Clayton.

Harley, D. (2016). An overview of actions to conserve Leadbeater's Possum (*Gymnobelideus leadbeateri*). *Victorian Naturalist* **133**, 85-97.

Harley, D.K.P., Holland, G.J., Hradsky, B.A.K. and Antrobus, J.S. (2014). The use of camera traps to detect arboreal mammals: lessons from targeted surveys for the cryptic Leadbeater's Possum *Gymnobelideus leadbeateri*. Pp. 233-244 In Meek, P and Fleming, P. *Camera trapping: wildlife management and research*. (Eds) CSIRO Publishing, Collingwood.

Harley, D.K.P. and Lill, A. (2007). Reproduction in a population of the endangered Leadbeater's possum inhabiting lowland swamp forest. *Journal of Zoology* **272**, 451-457.

Harley D.K.P., Worley, M.A. and Harley, T.K. (2005). The distribution and abundance of Leadbeater's possum *Gymnobelideus leadbeateri* in lowland swamp forest at Yellingbo Nature Conservation Reserve. *Australian Mammalogy* **27**, 7-15.

Koehn, J.D., and Todd, C.R. (2012). Balancing conservation and recreational fishery objectives for a threatened fish species, the Murray cod, *Maccullochella peelii*. *Fisheries Management and Ecology* **19,** 410–425.

Lacy, R.C. (2000). Considering threats to the viability of small populations using individual-based models. *Ecological Bulletins* **48**, 39-51.

Lande, R. (1988). Genetics and demography in biological conservation. *Science* **241**, 1455-1460.

Leadbeater's Possum Advisory Group (LPAG) (2014a). Leadbeater's Possum Recommendations: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security.

Leadbeater's Possum Advisory Group (LPAG) (2014b). Leadbeater's Possum Technical Report: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security.

Lindenmayer, D. (2000). Factors at multiple scales affecting distribution patterns and their implications for animal conservation–Leadbeater's Possum as a case study. *Biodiversity and Conservation* **9**, 15-35.

Lindenmayer, D.B. (2009). *Forest pattern and ecological process: a synthesis of 25 years of research*. CSIRO Publishing, Collingwood.

Lindenmayer, D.B., Cunningham, R.B., MacGregor, C., Incoll, R.D. and Michael, D. (2003). A survey design for monitoring the abundance of arboreal marsupials in the Central Highlands of Victoria. *Biological Conservation* **110**, 161-167.

Lindenmayer, D.B., Blanchard, W., McBurney, L., Blair, D., Banks, S.C., Driscoll, D., Smith, A.L. and Gill, A.M. (2013a) Fire severity and landscape context effects on arboreal marsupials. *Biological Conservation* **167**, 137-148.

Lindenmayer, D.B., Blanchard, W., McBurney, L., Blair, D., Banks, S., Likens, G.E., Franklin, J.F., Laurance, W.F., Stein, J.A. and Gibbons, P. (2012). Interacting factors driving a major loss of large trees with cavities in a forest ecosystem. PLoS One, 7(10), e41864.

Lindenmayer, D.B., Blair, D., McBurney, L. and Banks, S. (2013b). *New restoration forest management prescriptions to conserve Leadbeater's possum and rebuild the cover of ecologically mature forest in the Central Highlands of Victoria*. Fenner School of Environment and Society, The Australian National University, Canberra.

Lindenmayer, D.B., Blair, D., McBurney, L., and Banks, S.C. (2015). *Mountain Ash: fire, logging and the future of Victoria's giant forests*. CSIRO Publishing, Clayton.

Lindenmayer, D.B., Clark, T.W., Lacy, R.C. and Thomas, V.C. (1993). Population viability analysis as a tool in wildlife conservation policy: with reference to Australia. *Environmental Management* **17**, 745-758.

Lindenmayer, D.B., Cunningham, R.B., Tanton, M.T. and Smith, A.P. (1990). The conservation of arboreal marsupials in the montane ash forests of the central highlands of Victoria, south-east Australia: II. The loss of trees with hollows and its implications for the conservation of Leadbeater's Possum, *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae). *Biological Conservation* **54**, 133–145.

Lindenmayer, D.B., Cunningham, R.B., Tanton, M.T., Smith, A.P. and Nix, H.A. (1991a). Characteristics of hollow-bearing trees occupied by arboreal marsupials in the montane ash forests of the central highlands of Victoria, south-east Australia. *Forest Ecology and Management* **40**, 289–308.

Lindenmayer, D.B., Cunningham, R.B., Tanton, M.T., Nix, H.A. and Smith, A.P. (1991b). The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia: III. The habitat requirements of Leadbeater's Possum *Gymnobelideus leadbeateri* and models of the diversity and abundance of arboreal marsupials. *Biological Conservation* **56**, 295–315.

Lindenmayer, D.B., Cunningham, R.B. and Donnelly, C.F. (1997). Decay and collapse of trees with hollows in eastern Australian forests: impacts on arborial marsupials. *Ecological Applications* **7**, 625–641.

Lindenmayer, D.B., and Lacy, R.C. (1995). Metapopulation viability of arboreal marsupials in fragmented old-growth forests: comparison among species. *Ecological Applications* **5**, 183-199.

Lindenmayer, D.B. and Meggs, R.A. (1996). Use of den trees by Leadbeater's Possum (*Gymnobelideus leadbeateri*). *Australian Journal of Zoology* **44**, 625-638.

Lindenmayer, D.B. and Possingham, H.P. (1995a). Modelling the viability of metapopulations of the endangered Leadbeater's possum in southeastern Australia. *Biodiversity and Conservation* **4**, 984-1018.

Lindenmayer, D.B. and Possingham, H.P. (1995b). Modelling the impacts of wildfire on the viability of metapopulations of the endangered Australian species of arboreal marsupial, Leadbeater's Possum. *Forest Ecology and Management* **74**: 197-222.

Lindenmayer, D.B. and Possingham, H.P. (1996). Modelling the inter-relationships between habitat patchiness, dispersal capability and metapopulation persistence of the endangered species, Leadbeater's Possum, in south-eastern Australia. *Landscape Ecology* **11**, 79-105.

Lindenmayer, D.B., Smith, A.P., Craig, S.A. and Lumsden, L.F. (1989). A survey of the distribution of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy in the Central Highlands of Victoria. *Victorian Naturalist* **106**, 174-178.

Lindenmayer, D.B. and Wood, J.T. (2010). Long-term patterns in the decay, collapse, and abundance of trees with hollows in the mountain ash (*Eucalyptus regnans*) forests of Victoria, southeastern Australia. *Canadian Journal of Forest Research* **40**, 48-54.

Lumsden, L.F., Nelson, J.L., Todd, C.R., Scroggie, M.P., McNabb, E.G., Raadik, T.A., Smith, S.J., Acevedo, S., Cheers, G., Jemison, M.L. and Nicol, M.D. (2013). *A New Strategic Approach to Biodiversity Management - Research Component*. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Department of Environment and Primary Industries, Heidelberg, Victoria. <http://www.depi.vic.gov.au/__data/assets/pdf_file/0008/192932/DEPI_ARI_web.pdf>.

McCarthy, M.A. and Lindenmayer, D.B. (1998). Multi-aged mountain ash forest, wildlife conservation and timber harvesting. *Forest Ecology and Management* **104**, 43–56.

McCarthy, M.A., and Thompson, C. (2001). Expected minimum population size as a measure of threat. *Animal Conservation* **4**, 351–355.

Menkhorst, P.W. and Lumsden, L.F. (1995). Leadbeater's Possum *Gymnobelideus leadbeateri*. Pp. 104-107 in Menkhorst, P.W. (Ed). *Mammals of Victoria: distribution, ecology and conservation.* Oxford University Press, Melbourne.

Nelson, J.L., Durkin, L.K., Cripps, J.K., Scroggie, M.P., Bryant, D.B., Macak, P.V. and Lumsden, L.F. (in press). *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.

Nelson, J.L., Lumsden, L.F., Durkin, L.K., Bryant, D.B., Macak, P.V., Cripps, J.K., Smith, S.J., Scroggie, M.P. and Cashmore, M.P. (2015). Targeted surveys for Leadbeater's Possum in 2014-15. Report for the Leadbeater's Possum Implementation Committee. Arthur Rylah Institute for Environmental Research. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Smith, A.P. (1984a). Diet of Leadbeater's Possum, *Gymnobelideus leadbeateri* (Marsupialia). *Australian Wildlife Research* **11**, 265–273.

Smith, A. (1984b). Demographic consequences of reproduction, dispersal and social interaction in a population of Leadbeater's Possum (*Gymnobelideus leadbeateri*). Pp. 359-373 in Smith, A. P. Hume, I.D. (Eds). *Possum and gliders*. Australian Mammal Society, Sydney.

Smith, A.P. and Harley, D.P.K. (2008). Leadbeater's Possum *Gymnobelideus leadbeateri* Pp. in 226-228 Van Dyck, S. and Strahan, R. (Eds). *The mammals of Australia*. Third edition. Reed New Holland, Australia.

Smith, A.P. and Lindenmayer, D.B. (1988). Tree hollow requirements of Leadbeater's Possum and other possums and gliders in timber production ash forests of the Victorian Central Highlands. *Australian Wildlife Research* **15**, 347–362.

Smith, A.P. and Lindenmayer, D.B. (1992). Forest succession and habitat management for Leadbeater's possum in the state of Victoria, Australia. *Forest Ecology and Management* **49**, 311–332.

Smith, S. and Morey, J. (2001). Options for a permanent reserve system for the conservation of Leadbeater's Possum. Draft Report, Flora and Fauna Program, Department of Natural Resources and Environment, Melbourne.

Smith, A.P., Nagy, K.A., Fleming, M.R. and Green, B. (1982). Energy requirements and water turnover in free-living Leadbeater's Possums, *Gymnobelideus leadbeateri* (Marsupialia: Petauridae). *Australian Journal of Zoology* **30**, 737-750.

Threatened Species Scientific Committee (2015) 'Conservation advice: *Gymnobelideus leadbeateri.* http://www.environment.gov.au/biodiversity/threatened/species/pubs/273-conservation-advice.pdf.'

Todd, C.R., Jenkins, S., and Bearlin, A.R. (2002). Lessons about extinction and translocation: Models for eastern barred bandicoots (*Perameles gunnii*) at Woodlands Historic Park, Victoria, Australia. *Biological Conservation* **106**, 211-223.

Todd, C.R., Lindenmayer, D.B., Stamation, K., Acevedo–Cattaneo, S., Smith, S. and Lumsden, L.F. (2016). Assessing reserve effectiveness: application to a threatened species in a dynamic fire prone forest landscape. *Ecological Modelling* **338**, 90-100.

Todd, C.R., Ryan, T., Nicol, S.J., and Bearlin, A.R. (2005). The impact of cold water releases on the critical period of post-spawning survival and its implications for Murray cod (*Maccullochella*

peelii peelii): a case study of the Mitta Mitta River, in south-eastern Australia. *River Research and Applications* **21**, 1035–1052.

Wilkinson, H.E. (1961). The rediscovery of Leadbeater's Possum. *Victorian Naturalist* **78**, 97-102.

Glossary

Terms used in this report are defined below (mostly taken from LPAG 2014b).

Bushfire – under the Code of Practice for Bushfire Management on Public Land, a bushfire is defined as a general term used to describe a fire in any vegetation (DSE 2012c). For the purposes of this report, the term bushfire is used exclusively for wildfires (i.e. those triggered through natural processes, lightning, accidental or deliberate human ignition) and does not encapsulate planned burning activities.

Central Highlands – the forested area to the north-east of Melbourne broadly encapsulated by the Central Highlands Regional Forest Agreement Area.

Clearfell / clear-felling – silvicultural method of harvesting a coupe whereby all merchantable trees, apart from those to be retained for wildlife habitat, are removed (DSE 2007).

Code - the Code of Practice for Timber Harvesting Operations 2014 (DEPI 2014a).

Coupe – as defined in the *Sustainable Forests (Timber) Act 2004* means a specific area of State forest identified for the purposes of a timber harvesting operation in a timber release plan or, on private land a single area of forest or plantation of variable size, shape and orientation from which timber is harvested in one operation (DEPI 2014b).

General Management Zone (GMZ) – area within State forest that is managed for a range of uses and values, with the sustainable production of timber and other forest products being a major use. Within the GMZ there are areas that are excluded from harvesting operations due to the requirements of the Code of Practice for Timber Production. These areas include stream buffers and slopes generally greater than 30° (DSE 2012b).

Hollow-bearing tree – any tree, dead or live, that contains a hollow of any shape or size.

Leadbeater's Possum Management Units (LMU) – 21 LMU's have been delineated for Leadbeater's Possum management covering the known distribution of Leadbeater's Possum in the Central Highlands, based on the extent and spatial distribution of ash forest. Each LMU generally contains between 6,000 – 10,000 hectares of ash forest and is composed of one or more adjacent forest management blocks containing contiguous patches of ash forest.

Leadbeater's Possum Reserve – an area in the Central Highlands of 30,520 hectares set aside in 2008 specifically for Leadbeater's Possum conservation, of which 58% is within national parks and 42% reserved in SPZs in State forest.

Mixed species – for the purpose of this report, mixed species are considered to be non-ash tree species.

National Park – areas of preservation and protection of the natural and cultural heritage values of parks and prescribe various matters as required by Section 17 of the National Parks Act 1975.

Population viability analysis (PVA)– a modelling technique for the estimation of extinction probability based on threats to survival.

Potential habitat for Leadbeater's Possum – montane ash forest and snow gum woodland within the range of the species in the Central Highlands. This GIS layer was developed using a combination of Statewide Forest Resource Inventory (SFRI) data (primarily available just for State forests) and an alternative dataset based on a non-tenure specific description of structural vegetation in Victoria (SVEG100) for parks and reserves. The species selected as potential habitat from these layers

included: Alpine Ash *E. delegatensis*; Mountain Ash *E. regnans*; Shining Gum *E. nitens*; Snow Gum *E. pauciflora*; and Myrtle Beech *Nothofagus cunninghamii*) (LPAG 2014a).

Regeneration – the renewal or re-establishment of native forest flora by natural or artificial means following disturbance such as timber harvesting or fire (DSE 2007).

Retained trees – trees retained on a coupe during a harvesting operation because they are unmerchantable, are to serve as seed trees or wildlife habitat trees, or have been selected to grow on after thinning (DSE 2007).

Rotation – the planned number of years between the regeneration of a forest stand and its final harvesting, taking into account the full range of values and uses the owner wishes to derive from the forest (DSE 2007).

Sawlog - a log considered suitable in size and quality for producing sawn timber.

Special Management Zone (SMZ) - areas of State forest that cover a range of natural or cultural values and are managed to conserve specific features. The protection or enhancement of these values requires modification to timber harvesting or other land use practices rather than their exclusion. Timber and other forest produce may be harvested from this zone under certain conditions.

Special Protection Zone (SPZ) - areas of State forest managed for conservation. Larger components of the zone are based on representative examples of vegetation communities and old growth, as well as localities of key threatened and sensitive flora and fauna species. This zone is managed to minimise disturbances or processes that threaten its respective values, and timber harvesting is excluded.

State forest - as defined in section 3 of the *Forests Act 1958*. State forest comprises publicly owned land which is managed for the conservation of flora and fauna; for the protection of water catchments and water quality; for the provision of timber and other forest products on a sustainable basis; for the protection of landscape, archaeological and historical values; and to provide recreational and educational values (DSE 2007).

Territory – used to describe the home range of a colony which is defended from adjacent colonies.

Thinning – the removal of part of a forest stand or crop, with the aim of increasing the growth rate and/or health of retained trees and, in commercial thinning, obtaining timber from trees that would otherwise eventually die before final harvest (DSE 2007).

Timber harvesting exclusion zone (THEZ) – a 200 m radius area of SPZ established specifically to protect Leadbeater's Possum colonies using LPAG (2013b) definitions, where all forms of timber harvesting operations are excluded.

Timber harvesting operation – means any of the following kinds of activities carried out by any person or body for the purposes of sale or processing and sale —

(a) felling or cutting of trees or parts of trees;
(b) taking or removing timber;
(c) delivering timber to a buyer or transporting timber to a place for collection by a buyer or sale to a buyer;
(d) any works, including road works and regeneration, ancillary to any of the activities referred to in paragraphs (a) to (c)—

but does not include the collection of firewood for domestic use (DEPI 2014b).

Timber Harvesting Plan – a plan prepared under the Code of Practice for private native forests and plantations, usually consisting of a map identifying the area(s) to be harvested and a statement of conditions applying to the operation, and lodged with the Responsible Authority. The plan may apply to a single coupe or to an area in which a number of coupes are to be harvested (DEPI 2014b).

Timber Release Plan – a plan prepared by VicForests in accordance with the Part 5 of the *Sustainable Forests (Timber) Act 2004*. Plans are required in respect of an area to which an allocation order applies for the purposes of harvesting timber resources and undertaking associated management activities in relation to those timber resources. The Timber Release Plan must be consistent with the Code of Practice and made publicly available (DSE 2007).

Appendix 1: Methodology for documenting the effectiveness of 200 m radius timber harvesting exclusion zones in supporting the recovery of Leadbeater's Possum

Many methodology steps outlined below are based on spatial analyses conducted in ArcGIS 10.3.1. All spatial data is viewed and analysed under the following projections and coordinate system: Universal Transverse Mercator (UTM) Projection; Geocentric Datum of Australia (GDA); Map Grid of Australia 1994 (MGA94) Zone 55.

Metric	Rationale	Assumptions	Source of Information	Methodology
Documenting the extent of additional protection for Leadbeater's Possum colonies				
Number of colonies protected in State forest (GMZ or SMZ), and number of colonies in State forest (SPZ) and parks	Protection of colonies in State forest with a 200 m radius timber harvesting exclusion zone (THEZ) will support the recovery of Leadbeater's Possum (LBP) by reducing the likelihood of colonies and their habitat being destroyed during harvesting operations. Having clear documentation of the number of colonies will enable consistency and transparency in reporting these figures. Although records in parks and reserves do not contribute to the tally of new colonies in state forest which are the focus of this review, these numbers will be documented for comparison and transparency.	1. One THEZ = one colony. New records that fall within an existing THEZ are considered duplicates (as per LPAG technical report) and are not included in the tally. Therefore although more than one colony may occur within a THEZ, for counting purposes, 1 THEZ = 1 colony 2. Any records from within parks and reserves but where the THEZ impacts GMZ or SMZ are included in the State forest tally. 3. LBP records resulting in THEZs were broken into three time frames: 'Existing' records = records from 1 January 1998 – 28 February 2014, 'Towards 200' records = records from March 2014 to 6 June 2016 when 200 new THEZs had been established, and 'Beyond 200' records = records received by DELWP resulting in new THEZs after reaching the 200 target, up until 30 January 2017.	• LBPAG_SITES_CHRFA • LBPAG_BUFF_CHRFA • FORESTS. FMZ100_20131011 • "Individual_colonies_ ExRes" layer	For the 'Towards 200' and 'Beyond 200' time periods, the number of THEZs equates to number of colonies in GMZ/SMZ (200 and 140, respectively). The remaining 155 colonies are predominantly from the 'Existing' time period and were obtained by applying a definition query to LBPAG_SITES_CHRFA: LBP_USAGE = '200m radius timber harvest exclusion zone applied (LBPAG 2014, Rec. 1.1)' or '200m radius buffer applied within existing reserve (LBPAG 2014, Rec. 8.1)'. SITES were further filtered to obtain 'colony' centroids by selecting records at least 200m from others, and/or selecting the earliest-observed record from groups of records, such that one is counted as a 'colony' and any others within 200 m are considered duplicate records from the same colony and are not counted towards the tally of colonies.

Metric	Rationale	Assumptions	Source of Information	Methodology
Source of new colony records – number and % of colonies by groups involved and not involved in implementation.	LBP records have resulted from ARI targeted surveys, universities, other government organisations, community groups and other individuals. An assessment of how many records were provided by these groups will give an indication of the level of contribution these reports have made to the total number of new exclusion zones.	1. This metric is a count of records by different groups leading to the establishment of new THEZs since the LPAG policy was established. Existing records from 1998-2014 are not included in this count, nor are duplicate records (i.e. multiple records from within the same THEZ).	• LBPAG_SITES_CHRFA (exported to Excel, with relevant Vlookup formulas to "LBP Register_2014.xlsx") • "LBP Register_2014.xlsx" (DELWP internal file, curated by Forest Policy & Planning)	Pivot table in Excel. Report Filter parameters: RECORDTYPE = New (verified) record post-February 2014 Row labels: SRC_GROUP Values: Count of RECORDTYPE. Report this breakdown as per the 2016 LBP progress report.
Effectiveness of obtaining reliable records of LBPs from community groups. - % of reports from community groups that result in verified records - % of reports from community groups that were verified using desktop analysis vs needing field verification surveys	An assessment of how many verified records were provided by the community, both ones that could be verified via desktop examination and those that required field verification will give an indication of how accurate these externally reported records are.		• "LBP Register_2014.xlsx" (DELWP internal file, curated by Forest Policy & Planning) • LBPAG_SITES_CHRFA (exported to Excel, with relevant Vlookup formulas to "LBP Register_2014.xlsx")	Filter columns in Excel. Column label: Verified (y/n) Pivot table in Excel. Report Filter parameters: RECORDTYPE = New (verified) record post-February 2014 Row labels: Requires field verification Values: Count of RECORDTYPE. Since 1 March 2014 (up to cut-off date 30 Jan 2017), non-LPAG implementation reports of new colonies (ie. excluding duplicates) = 117.

Metric	Rationale	Assumptions	Source of Information	Methodology
Number (and %) of colonies located in areas with a predicted probability of >65% from the ARI Occupancy Model	A model predicting the likelihood of occupancy by LBP throughout the species known range was developed in 2012 (reported in Lumsden *et al.* 2013). The Leadbeater's Possum Advisory Group (LPAG) recommended a 2 year timber harvesting moratorium on areas predicted to have a high probability of occupancy (>65%) to allow surveys to be undertaken, and any colonies found protected (LPAG 2014b). A measure of the effectiveness of this action in protecting colonies and their habitat is the number and % of colonies surveyed during the two years when the moratorium was in place.	1. One THEZ = one colony. 2. The % of colonies is based on those detected within the area covered by the timber harvesting moratorium while it was in place (April 2014 – April 2016). The majority of records included are therefore from ARI targeted surveys.	• LPAG_BUFF_CHRFA • ARI occupancy model	1. Filter OCC_MODEL_proj with definition query ""GRIDCODE" = 4"". 2. Filter LBPAG_BUFF_CHRFA with definition query ""LBP_DESC" = "Towards 200 LBP colonies" 3.Select query in ArcGIS to tally no. of THEZs that intersect with OCC_MODEL_proj. 4. % of colonies figure is based on the 'Towards 200 category'
% of high probability habitat surveyed (>65%)	Areas predicted to have a high probability of occupancy by LBP (>65%) were a focus of surveys undertaken by ARI (ARI targeted surveys) while the timber harvesting moratorium was in place. The percentage of the high probability habitat surveyed will provide an indication of survey effort in these moratorium areas.	1. Only includes ARI targeted survey sites. 2. Does not include parts of the >65% probability of occupancy areas that were already buffered, were small fragments (< 5 ha), were inaccessible (> 400m from roads or tracks), unsuitable habitat (i.e. non-ash eucalypts) or had been harvested in the last 10 years.	• ARI occupancy model	At the outset of targeted surveys, 131 300m radius circles (survey sites) were delineated in >65% probability areas. Fifty-two were initially excluded due to access (>400m from track); 14 were too small (>5 ha), overlapped considerably with existing buffered records or had been harvested within the past 10 years. Sixty-five sites were considered available to survey, with 48 surveyed (74%).

Metric	Rationale	Assumptions	Source of Information	Methodology
The proportion of potential habitat in State forest that was surveyed	This measure will provide an indication of the proportion of the total area of potential habitat that has been surveyed after the LPAG recommendations were implemented (i.e. post February 2014). Survey effort (i.e. the total number of sites sampled for LBPs) is available for some but not all groups undertaking surveys. Where survey effort is available the total number of sampling sites will be used, where it is not available, just the known locations will be used. The resulting % figure will therefore underestimate the total area sampled but it will give an indication of the magnitude (e.g. has only 5% of the total area been sampled or is it closer to 50%). This will help in the interpretation of the likely proportion of the total population located and protected. To assess the extent of sampling coverage in the areas where the species is more likely to occur, the proportion of high probability area in predictive distribution models will be calculated. This includes the >30% probability of occurrence area from the ARI occupancy model (Lumsden *et al.* 2013) as areas predicted to have >30% probability of occurrence have a higher recorded occupancy rate than those with <30% probability of occurrence (with little differentiation between categories above >30%) (Nelson *et al.* 2015)	1. Survey effort is available for the ARI targeted surveys and VicForests pre-harvest surveys. 2. Survey effort is not available for the community group records or for most Existing records, only the sites where the species was detected. 3. Potential habitat is defined in the LPAG technical report (LPAG 2014a) as montane ash forest and snow gum woodland within the range of the species in the Central Highlands. This layer was developed using a combination of Statewide Forest Resource Inventory (SFRI) data (primarily available just for State forests) and an alternative dataset based on a non-tenure specific description of structural vegetation in Victoria (SVEG100) for parks and reserves. The species selected as potential habitat from these layers included: Alpine Ash *E. delegatensis*; Mountain Ash *E. regnans*; Shining Gum *E. nitens*; Snow Gum *E. pauciflora*; and Myrtle Beech *Nothofagus cunninghamii*). 4. Potential habitat is mapped for all areas of State forest (including SPZs).	• ARI targeted survey sites, VicForests pre-harvest survey sites, and the positive records from the Existing records, community groups and other organisations (user-created layer) • ARI occupancy model • LBP potential habitat layer • FORESTS. FMZ100_20131011	LBP potential habitat: 1. Use Create Fishnet tool to overlay 400 m x 400 m grid (approximately equivalent to a 200 m radius THEZ but with complete coverage) on entire species' distribution (CHRFA). 2. Assess grid cells in LBP potential habitat (montane ash forest or snow gum) only. 3. Assess grid cells in state forest only. 4. Grid cells are considered sampled if any survey point is located within that grid cell, recognising that not all of the cell is equally sampled. Cells are counted if containing at least 3 ha of LBP potential habitat. 5. Calculate proportion of potential habitat sampled, based on the number of grid cells sampled. Use "Selection" to select grid cells intersecting with LBP records. Tally number sampled. LBP occupancy model: 1. Use Create Fishnet tool to overlay 400 m x 400 m grid (approximately equivalent to a 200 m radius THEZ but with complete coverage) on entire species' distribution (CHRFA). 2. Assess grid cells in areas of > 30% predicted occupancy only. 3. Assess grid cells in state forest only. 4. Grid cells are considered sampled if any survey point is located within that grid cell, recognising that not all of the cell is equally sampled. Cells are counted if containing at least 3 ha of > 30% probability areas. 5. Calculate proportion of occupancy model sampled, based on the number of grid cells sampled. Use "Selection" to select grid cells intersecting with LBP records. Tally number sampled.

Metric	Rationale	Assumptions	Source of Information	Methodology
Number of ha protected by the THEZs that would not have otherwise been protected	This measures the area of forest protected by this action that would not have been protected under the previous policy and so could potentially have been harvested during this period or into the future. Areas within THEZs in SPZ and national parks/reserves are also calculated for comparison. The area of different disturbance histories within THEZs is calculated, to represent the amount of different age classes protected (e.g. 1939 fire regrowth, 1983 fire regrowth, timber harvesting regrowth etc.). Areas of potential mapped LBP habitat and those with a > 30% probability of occurrence from the ARI occupancy model within the THEZs will also be calculated.	1. Areas considered available for harvesting are those captured in VicForests' 2013 Available Resource layer. This includes all GMZ/SMZ minus modelled exclusions. 2. Comparisons are made based on the FMZ layer current at LPAG implementation (i.e. October 2013).	• LBPAG_BUFF_CHRFA FORESTS.FMZ100_20131011 • Available Resource 2013 CHRFA layer (RAAWSM2013a_AV2_CHRFA; VicForests supplied) • FORESTS.LASTLOG25 (to June 2016) • FIRE.LASTBURNT (to June 2016) • LBP_ZONE1A_VF • LBP Potential Habitat layer • ARI occupancy model	THEZ area in State forest – GMZ/SMZ: 1. Intersect LBPAG_BUFF_CHRFA and FMZ100_20131011 (definition query FMZ = GMZ or FMZ = SMZ). Calculate geometry. 2. Select and obtain statistics report to give sum of area for LBP DESC = Existing, Towards 200 and Beyond 200 THEZs. THEZ area in State forest – SPZ: 3. Intersect LBPAG_BUFF_CHRFA and FMZ100_20131011 (definition query FMZ = SPZ). Calculate geometry. 4. Do not include four THEZs accounted for in the Towards 200 and Beyond 200 timeframes: Apply definition query to output: "LBPBUFF_ID" <> 'RS305.1' AND "LBPBUFF_ID" <> 'RS355.1' AND "LBPBUFF_ID" <> 'RS361.1' AND "LBPBUFF_ID" <> 'RS193.1'. 5. Select and obtain statistics report to give sum of area for LBP DESC = Existing. Repeat for Towards 200 (adding the area of SPZ in the THEZ filtered out earlier: LBPBUFF_ID = RS193.1) and Beyond 200 (adding the area of SPZ in these THEZs filtered out earlier: LBPBUFF_ID = RS305.1, RS355.1 and RS361.1). THEZ area in National Park: 6. Intersect LBPAG_BUFF_CHRFA and FMZ100_20131011 (definition query FMZ = PRK). Calculate geometry. 7. Do not include two THEZs accounted for in the Towards 200 and Beyond 200 timeframes: Apply definition query to output: "LBPBUFF_ID" <> 'RS187.1' AND "LBPBUFF_ID" <> 'RS384.1'. 8. Select and obtain statistics report to give sum of area for LBP DESC = Existing and Reserve. Repeat for Towards 200 (adding the area of PRK in the THEZ filtered out earlier: LBPBUFF_ID = RS187.1) and Beyond 200 (adding the area of PRK in the THEZ filtered out earlier: LBPBUFF_ID = RS384.1). Repeat for THEZ area in Code of Forest Practice Available Resource area in THEZs: 1. Intersect LBPAG_BUFF_CHRFA and Available Resource. Calculate geometry. 2. Select and obtain statistics report to give sum of area for Ash and non-Ash areas of Available Resource.

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Comparison of the area protected by the THEZ action vs habitat protection through the Zone 1 prescription.	Prior to LPAG the only site- based prescription was on habitat through Zone 1A or 1B. A comparison with how much area was protected through these two actions will provide a measure of the relative effectiveness of the THEZ action.	1. The VicForests Zone1A layer will be used to represent the area of Zone 1 habitat protected. The area of Zone 1 habitat will be underestimated as areas designated as Zone 1 habitat that overlap with THEZs were not included in this layer. This layer is based on ground truthing areas scheduled for harvesting. 2. Zone 1A and 1B are defined in the survey standards (DELWP 2015).	• LBPAG_BUFF_CHRFA • VicForests-supplied "LBP_ZONE1A_VF"	Intersect LBPAG_BUFF_CHRFA and LBP_ZONE1A_VF. Calculate geometry, obtain sum of area with statistics report.
Indirect benefits based on protection of surrounding habitat that is no longer viable or accessible for harvesting due to THEZs	There will be indirect benefits to Leadbeater's Possum through areas being effectively, although not formally, protected where there are fragments of habitat surrounding THEZs that are unviable to harvest or inaccessible. Although is not known if this additional area is occupied by a colony, there are benefits from an increase in size of the protected area, providing a larger buffer around the colony and increasing connectivity to adjacent colonies.	1. This area will be the same as VicForests uses to assess indirect impacts on the timber industry. 2. VicForests classifies fragments as areas less than 5 ha in size that are more than 40 m from viable, accessible timber stands. 3. As these areas are not formally zoned, or included in the VicForests Reserve layer, their status could change in the future.	• VicForests –supplied layer "Fragment_LBP" • ARI occupancy model	Total area: - Add field, calculate geometry and obtain sum of area with statistics report. Proportion of fragments that are > 30 % probability of occupancy: - Intersect "Fragment_LBP" with occupancy model (definition query GRIDCODE <> 1). - In output, re-calculate geometry and obtain sum of area with statistics report. - Divide this figure by the total area in the "Fragment_LBP" layer
Evaluating the effectiveness of the additional protection of the 200 m timber harvesting exclusion zones in supporting the recovery of Leadbeater's Possum				
Proportion of the estimated total number of colonies occurring in State forest that has been protected by the timber harvesting exclusion zones	As part of the LPAG process, the number of LBP colonies in the Central Highlands was estimated, developed by extrapolating from the number of LBP detections at 180 randomly selected sites surveyed throughout the species range in 2012. A number of key factors and assumptions that impacted this estimate, leading to a high degree of uncertainty and hence a range in the estimates.	1. Assumptions in developing the population estimates are provided in the LPAG recommendations report (based on different detection rates in State forest and national park, and in areas burnt and not burnt in 2009, imperfect detectability, and differing estimates of effective survey area, i.e. distance from which animals were drawn into the call playback method).	•	It is not possible to reassess population numbers from the recent increased number of new records as the targeted nature of the sampling that yielded these records precludes extrapolation across the whole range.

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Reduction in extinction risk estimated in the 2013 PVA analysis, by adding the area of the new THEZs to the existing LBP reserve	PVAs can be used as a conservation tool to provide an assessment of extinction risk. The PVA developed in 2013 (Lumsden *et al.* 2013 and Todd *et al*. 2016) calculated the minimum population size risk curves for adult females (which is equivalent to a colony) within the LBP reserve system, an area set aside specifically for the protection of LBP (Smith and Morey 2001, DEPI 2014). Adding the additional areas now protected by the THEZs, also specifically reserved for LBPs, and rerunning the risk curves will indicate the level of reduced extinction risk resulting from these additional areas.	1. The PVA has a range of assumptions as outlined in Lumsden *et al.* (2013) and Todd *et al.* (2016). 2. The first part of this PVA related explicitly to the 30,520 ha Leadbeater's Possum Reserve system, where it is unknown how much of the area is occupied by the species, in comparison to knowing that at least part of each THEZ is occupied. 3. The original PVA assumed all post-1978 harvested areas were unsuitable nesting habitat for LBPs, and so were excluded from calculations; however, recent sampling shows substantial use by LBPs for foraging in some of these areas. Differentiating between nesting and foraging habitat in future models would be useful. 4. The model does not assume all the LBP reserve is occupied. The reserve provides for a certain number of possible colonies, which is affected by the historical fire disturbance. Even after accounting for fire disturbance, the remaining possible colonies are not necessarily all occupied. It is a stochastic model, where some trajectories will produce outcomes where all or nearly all possible colonies are occupied, however of most interest is those trajectories at the other end of the scale, hence the focus on the distribution of the minimum number of female adults. 5. The model is highly sensitive to the density of LBPs and the size of territories, and these parameters may be highly variable. 6. The original model when predicting	• LBP PVA (Todd *et al.* (2016))	A population model was developed to evaluate if the Leadbeater's Possum reserve system was sufficient to support the long-term conservation of the species, or if additional strategies were required (Todd *et al*. 2016). Todd *et al*. (2016) defined reserve effectiveness for Leadbeater's Possum to be when there was no more than a 5% probability of the population falling to (or below) 500 adult females in 40 generations (equivalent to 200 years). The risk of extinction was assessed for the reserve system factoring in the historical fire disturbance and different future disturbance scenarios. Survival and fecundity rates used in the model were taken from previously-developed population models (Lindenmayer *et al.* 1993; Lindenmayer and Lacy 1995; Lindenmayer and Possingham 1995a, b). Scenarios developed to examine the impact of past bushfires were based upon fire models by Lindenmayer and Possingham (1995a, 1995b). These models showed major population fluctuations in response to these fires. Of the fires examined (i.e., 1939, 1983, 1990, 2007, 2009), the 1939 and 2009 fires were the most widespread and burnt the greatest area. In 1939, the majority of the Central Highlands was severely affected by fire (The Commonwealth of Australia and Department of Natural Resources and Environment 1997), while in 2009, 36% of ash forests in the Central Highlands was burnt, including 45% of the Leadbeater's Possum reserve system (S. Smith, DELWP, unpublished data using all fire severities). The Leadbeater's Possum model is a stochastic population model and each run of the model produces a different trajectory of the number of adult females. To assess risk, the minimum population size of adult females is recorded from each trajectory. The collection of minimum population sizes of adult females forms a distribution of minimum population sizes and is a summary of the extreme dynamics (Burgman *et al*. 1993; Todd *et al*. 2008) of the adult female population. Plotting the associated normalised cumulative frequency distribution produces a graph of probabilities versus population size called the minimum population size risk curve. Risk curves represents both the chance of extinction (probability of falling to zero) and the chance of falling below some non-zero population threshold or quasi-extinction (Burgman *et al*. 1993). Additionally, risk

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		into the future included an increased rate of loss of hollow-bearing trees. This assumption was valid during the period prior to the development of the model (based on Lindenmayer et al.) but it appears that the rate of loss of hollow-bearing trees may have slowed, and so only future fire predictions were modelled when predicting future disturbances.		curves can be readily compared and assessed in terms of increasing or decreasing risk by a shift to the left or right respectively (Koehn and Todd 2012; Todd *et al*. 2002). Calculating the expected value of the minimum population size risk curve provides a metric for scenario comparison (McCarthy and Thompson 2001; Todd *et al*. 2005). The expected value of the minimum population size distribution for adult females was used as a measure of risk. In addition, the quasi-extinction threshold, with a 5% probability of the adult female population size being less than or equal to the threshold, was reported as well as the probability for the quasi-extinction threshold of 500 or less adult females. Another method to examine the change in risk is to use the definition of reserve effectiveness posited by Todd *et al*. (2016); if the reserve is effective then the risk curve either passes through the point (500 adult females, 0.05 probability) or to the right of this point.
Assessment of extinction risk to each colony - geographic spread of THEZs, based on the number (and %) of colonies in each Leadbeater's Possum Management Unit and in each of the metapopulations used for the PVA analysis, and an accumulation curve showing increase in geographic spread over time as more colonies have been protected.	There is a greater extinction risk if all the newly protected colonies are in a localised area and hence could be impacted by a single bushfire. A measure of how geographically spread the newly protected colonies are, is based on their spread across the Leadbeater's Possum Management Units (LMUs), which divide the species range into 21 units (DEPI 2014), or across the 6 metapopulations (described in Lumsden *et al.* 2013 and Todd *et al.* 2016). Bushfire simulation risk modelling will be used to interpret this metric (Leadbeater's Possum Fuel Management report, DELWP 2015/16).	1. One 200m radius THEZ = one colony. 2. LMUs (n = 21) 10, 11 & 14 are entirely NP. 3. THEZ overlapping more than one LMU were assigned to whichever one it overlapped with most.	• LBPAG_BUFF_CHRFA • LMU_all_VG94 • "Individual_colonies_ExRes" layer • Metapopulation layer "LBP G1-G6_RegionsBoundaries"	Accumulation curves showing the change in geographic spread are calculated based on the change in the number of THEZs within the 21 LMUs and the 6 Metapopulations. A range of thresholds are set for each LMU/Metapopulation (ie. 5 colonies, 10 colonies, 15 colonies). How many LMUs/Metapopulations meet this threshold for increasing pool of 50 buffers will be tallied and an accumulation curve produced showing how this changes as THEZs increase in the landscape. LMUs: Spatial join LBPAG_BUFF_CHRFA, "Individual_colonies_ExRes" and LMU_all_VG94. Export into Excel. Use Rand() to randomly sort THEZs. Extract data for THEZs by 50 buffer intervals, use pivot tables to count number of THEZs in each LMU. Tally these for each threshold to create the accumulation curve. Metapopulations: Spatial join LBPAG_BUFF_CHRFA and "LBP G1-G6_Regions_Boundaries". Export into Excel. Use Rand() to randomly sort THEZs. Extract data for THEZs by 50 buffer intervals, use pivot tables to count number of THEZs in each Metapopulation. Tally these for each threshold to create the accumulation curve.

Metric	Rationale	Assumptions	Source of Information	Methodology
Assessment of extinction risk to each colony - % protected forest in landscape context (e.g. within 1km radius).	The long term survival of individuals/colonies is likely to be greater if more habitat is protected within the surrounding area, by providing additional habitat, greater connectivity, more colonies.	Calculated for the 495 discrete colonies	• LBPAG_SITES_CHRFA • "Individual_colonies_ExRes" layer • FORESTS.FMZ100_20131011 • FORESTS.FMZ100 (v. 5/12/2016)	1. Apply definition query to LBPAG_SITES_CHRFA to show only sites that are considered centroids of individual colonies. This is the centroid of all TT and BT buffers, and the list of UNIQUE_IDs captured in the layer "Individual_colonies_ExRes". Total will be 495. 2. Buffer these 495 sites to 1km. 3. Create new layer 'BT_buffers_not_yet_SPZ' to account for area buffered by a 'Beyond 200' record but not yet migrated into SPZ in FMZ100. 4. Intersect the 1km buffer output with FMZ100 (definition query FMZ = PRK or SPZ) (v. 20131011 and v.20161205) and 'BT_buffers_not_yet_SPZ'. 5. In each of the three intersect attribute tables, re-calculate geometry. 6. Export the attribute tables of the three intersects to Excel. Combine the FMZ100v.20161205 and BT_not_yet_SPZ intersect outputs. 7. Pivot table to sum the area protected within each 1km buffer, pre- LPAG (PRK and SPZ in FMZ100 v.20131011) and up at the point of the review (PRK and SPZ in FMZ100 v.20161205 + BT_buffers_not_yet_SPZ)
Assessment of extinction risk to each colony - average number of colonies in a cluster of colonies and an accumulation curve showing change in cluster size over time as new THEZs added.	Clusters of protected LBP colonies can mitigate against isolation and provide for 'neighbourhoods' rather than individual colonies. The average number of colonies within a cluster will provide an indication of how large these clusters are. An accumulation curve will show how these clusters changed in size over time.	1. One THEZ = one colony. 2. A 'cluster' of colonies is comprised of a minimum number of two THEZs, where THEZ edges are < 100 m from the edge of another THEZ 3. Includes all categories of records ('Existing', 'Towards 200', 'Beyond 200' and 'Reserves').	• LBPAG_SITES_CHRFA • LBPAG_BUFF_CHRFA	1. There are 470 unique polygon records in LBPAG_BUFF_CHRFA 2. Dissolve connected polygons. This creates 357 unique groups of THEZs 3. Run Generate Near Table specifying search distance of 100 m, including XY start and end coordinates 4. Convert XY start and end coordinates to lines 5. Buffer by 5 m 6. Merge buffer connections with LBP buffers (output – step 2) 7. Dissolve all connected polygons 8. Ignore single LBP buffers 9. Extract all valid clusters from step 8 and add CLUSTERID to each of these 10. Run spatial join against unique LBP sites

Metric	Rationale	Assumptions	Source of Information	Methodology
Assessment of extinction risk to each colony based on future habitat suitability in THEZs based on two key habitat features: - estimate of live hollow-bearing tree density and ratio of live to dead hollow-bearing trees (HBTs); and - estimate of Acacia longevity.	Dead stags remaining from the 1939 bushfires are continuing to collapse and it is predicted that these will be lost completely within coming decades. Once these are gone, hollows will be provided mainly by the current live HBTs. Where HBT data is available (i.e. from ARI targeted survey sites), the density of live HBTs and the ratio of live to dead HBTs will provide an indication of nesting resources into the future. Acacia senesces as it ages, reducing foraging resources. Where stand age data is available, the longevity of remaining Acacia resources is calculated to provide an indication of future foraging resources.	1. Hollow-bearing tree data is available only for the ARI targeted survey sites. This metric is based on the 148 sites with LBP detections 2014-2016.). Although the site selection for this work was not random, in just considering the sites where LBPs were recorded it is reflective of at least a subset of where colonies are located, and how the hollow availability are likely to change over time. 2. Data on Acacia density will be extracted from ARI targeted survey site habitat data.	• ARI Leadbeater's Possum targeted surveys habitat data 2014-2016	Pivot table in Excel. Report Filter parameters: LBP = 1 HBT inside 1 ha sampling grid = 1 Hollows observed in tree = 1 Species = all Row labels: Site Column labels: Tree form Values: Count of Tree form Group forms 0.5-2 (Live HBTs) and 3-8 (Dead HBTs), average totals for each group to obtain the number of live trees and the mean ratio of live to dead hollow-bearing trees for ARI targeted survey sites where Leadbeater's Possums were detected