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Introduction

Leadbeater's possum *Gymnobelideus leadbeateri* is a listed threatened species found mainly in montane ash and snowgum forests in the Central Highlands of Victoria, with a small occurrence in swamp forests in Yellingbo Nature Conservation Reserve. Threats to the species include wildfire, loss of hollow-bearing trees, and the harvesting of native forests. As a consequence, the species is a focus of sustainable forest management.

The species was nominated for re-listing as Critically Endangered under the *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) in 2013, from its previous category of endangered, with comments on the nomination requested by January 2014. Its listing category was raised from Endangered to Critically Endangered in May 2015, based on the recommendation of the Threatened Species Scientific Committee. An updated Draft Recovery Plan for the species was then prepared with input from stakeholders.

Over the period from 2013 to 2017, ABARES prepared briefing notes regarding the listing, conservation, recovery and management of Leadbeater's possum and the related issue of fire and forest harvesting. This publication brings together a series of these briefing notes.

The briefing notes are presented as written at the dates indicated, except that occasional minor or typographical errors have been corrected, URLs updated, intra- and inter-departmental references removed, and footnotes now include clarifying amendments. The briefing notes are individually paginated.

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>
> ABARES, 2016, *Leadbeater's possum: comments on Draft Recovery Plan.* ABARES Briefing Note, Canberra, February. CC BY 4.0.
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> ABARES, 2017, *Timber harvesting and fire risks and severity in Australia's native forests.* ABARES Briefing Note, Canberra, June. CC BY 4.0.

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Briefing Note

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19 December 2013

LEADBEATER'S POSSUM: LISTING ELIGIBILITY AND CONSERVATION ACTIONS

This briefing note considers the eligibility of Leadbeater's possum for listing as critically endangered under the *Environmental Protection and Biodiversity Conservation Act* (EPBC Act), following a nomination to this effect, and the necessary conservation actions for the species.

Key points

1) Leadbeater's possum is currently listed as endangered under the EPBC Act. The dependence of this species on regrowth forests containing old-growth elements (large, living or dead, hollow-bearing trees) results in populations that are dynamic over both space and time, and makes the species especially susceptible to an increased frequency and extent of wildfire.

2) The eligibility of Leadbeater's possum for listing as critically endangered, according to the categories selected in the nomination and based on the Guidelines for Assessing the Conservation Status of Native Species, requires evidence of a projected or actual reduction in population size or extent or habitat quality of ≥80% over any of three specified 14-year periods, where the causes of reduction persist or are not reversible or not understood.

3) Population projections do indicate that a significant decline in Leadbeater's possum populations commenced in the mid-1990s, with this decline predicted to continue for several decades. However, there is no evidence adduced in the listing nomination or available in reports of research performed more recently that suggests that the total Leadbeater's possum population has dropped or will drop by ≥80% over any of the indicated 14-year periods.

4) The causes of changes in the Leadbeater's possum population, including recent reductions, are well understood. Provided that historical mechanisms of species dispersal can be maintained and that the frequency and extent of wildfires do not increase above historical levels, populations are likely to increase in periods between major forest fires, although the timing of this depends on the age of the forest before the last fire.

5) Leadbeater's possum thus appears to lie above the threshold for listing as endangered under the EPBC Act, but below the threshold for listing as critically endangered. Current information is insufficient to determine population changes more precisely.

6) Conservation actions for Leadbeater's possum need to be carried out across the various forest types, tenures and uses in the range of the species. There is no evidence that increased reservation would assist conservation of the species; wildfire in forest reserves is as much a threat to the species as is wildfire in forest managed for other purposes. Population surveys, monitoring and analysis need to be undertaken across the range of the species, and not just in reserve areas such as those combined into the "Leadbeater's possum reserve".

7) Major appropriate conservation actions for Leadbeater's possum include:

   a) mitigation of potential fire impacts on the forests inhabited by Leadbeater's possum, such as through prescribed burning around these areas
   b) mapping of habitat known to be or likely to be suitable for the species over the next 20 years
   c) facilitation of the recovery of populations and colonisation of new suitable habitat, including by on-going research on animal dispersal and on the dynamics of hollow-bearing trees
   d) ensuring that forestry operations adopt silvicultural systems that retain current and potential future hollow-bearing trees, such as variable retention harvesting.

Listing criteria

The nomination of *Gymnobelideus leadbeateri* (Leadbeater's possum) for listing as critically endangered under the EPBC Act specifies eligibility under Criterion 1, A2 bc + A3 bc + A4 bc. Based on the Guidelines for Assessing the Conservation Status of Native Species according to the EPBC Act and EPBC Regulations 2000, authored by the Threatened Species Scientific Committee and provided with the nomination, these categories equate to:

> An observed, estimated, inferred or suspected population size reduction over the last 10 years or three generations, whichever is the longer**,** where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible**,** based on (and specifying) any of (a) to (e) under A1.

or

> A population size reduction, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

or

> An observed, estimated, inferred, projected or suspected population size reduction over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

and

> b) an index of abundance appropriate to the species
>
> c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

where the indicative extent of decline is ≥80%.

Three generations for this species is taken as 14 years[1], and the periods under consideration are further specified as 1999-2013 and 2008-2022. The above criteria can thus be combined and simplified as *a measured, inferred or projected reduction in population size or extent or habitat quality of ≥80%, occurring over the periods 1999-2013 or 2008-2022, where the causes of reduction persist or are not reversible or not understood*.

Habitat requirements

Leadbeater's possum is present in the Central Highlands of Victoria. Montane ash forest provides 88% by area of its currently understood total potential range, and snowgum woodland 12% by area; an outlying population at Yellingbo inhabits lowland swamp forest and provides 0.1% by area. The population in montane ash forest is reasonably well characterised, as is the much smaller population in lowland swamp forest. The snowgum woodland populations at and near Lake Mountain were killed in the 2009 fires, and that at Mt Baw Baw is not well known.

Habitat requirements of Leadbeater's possum across these forest types are:

- hollow-bearing trees for denning, with multiple such trees in each 1-3 hectare family territory. Trees need to be sufficiently large to accommodate a hollow approximately the size of a basketball, but with a narrow entrance to exclude predators. Most trees known to contain Leadbeater's possum dens are large old trees in old-growth forest, or large old dead stags resulting from a fire in old-growth forest.
- smooth-barked eucalypts for sap
- a dense mid-storey layer for secondary food (sap, gum and invertebrates) and for movement pathway, provided by wattle in montane ash forest, and tea-tree in snowgum woodland and lowland swamp forest.
- a cold, wet climate, with preference for moist, well-vegetated gullies on slopes facing south-east .

These requirements combine to make the optimal Leadbeater's possum habitat a regrowth forest with old-growth elements, and lead to the complex dependence of the species on fire. Fires in old-growth forest create dead large trees with hollows for nesting and also provide conditions for wattle growth, but kill Leadbeater's possum directly and also destroy both current and future hollow-bearing trees. Habitat for Leadbeater's possum is thus dynamic in both time and space, and this leads to the peculiar conservation challenges for this species.

Measuring population size and extent

There are currently two methods for surveying Leadbeater's possum populations: the older technique of stag-watching, and the more recent technique of call playback/thermal imaging/spot-lighting. Although the methods may detect similar trends in Leadbeater's possum populations, and similar impacts of fire, their results are not directly comparable, and data from the two methods cannot be aggregated to give population trends across combined sites or sample periods.

Stag-watching surveys have led to a large body of data on nest (den) tree requirements for the Leadbeater's possum populations monitored in this way, and demonstrated the impacts of fire on the species. In contrast, the call playback/thermal imaging/spot-lighting technique was

[1] Generation length is taken as 4.5 years in the nomination

developed for broad-scale population monitoring, and can be used at randomly selected sample sites across the range of the species. Although the call playback/thermal imaging/spot-lighting technique has not yet been used by a range of research groups or replicated over time, it appears to be the technique most suitable for estimating total Leadbeater's possum population size or extent, and trends.

Neither method has yet been used to estimate the total population of Leadbeater's possum, across the whole of its range and on forest of all tenures or management intent.

The recent development of the call playback/thermal imaging/spot-lighting technique by staff from the Arthur Rylah Institute for Environmental Research, Department of Environment and Primary Industries, Victoria, together with results of using the method across the Central Highlands and the modelling of populations in an area known as the Leadbeater's possum reserve, are described in Lumsden et al (2013)[2]. Presentations at a Leadbeater's Possum Stakeholder Engagement Workshop held in Sep-Oct 2013 also provided updates from the three main research groups working on Leadbeater's possum, including coverage of population trends[3].

The listing application presents well-accepted information on the life history and habitat of Leadbeater's possum and the impact of the 2009 fires. However, most of its population data derives from surveys using the stag-watching method on a set of long-term monitoring sites in the Central Highlands montane ash forests, scaling these data to estimate populations across the montane ash forest. The size of the population on Mt Baw Baw is acknowledged to be unknown.

At times, the listing application appears to assume that the measured population, and/or the population impacted by the 2009 fires, and/or the population in the high-quality habitat in the Leadbeater's possum reserve, represents the total population:

> The 2009 Black Saturday fire burnt 45% of high quality Leadbeater's Possum habitat. Post-fire the species has not been detected at burnt sites (Lindenmayer et al. 2013). Thus, the total population is likely to have been reduced by at least 45% following the 2009 fires.

The listing application does not present an estimate of total population numbers following the 2009 fires. The only total population estimates presented are for the main (montane ash) population (2000 mature individuals) and the minor Yellingbo population (200 individuals) before the 2009 fires:

> Menkhorst (2008) considered that there were about 2000 mature individuals in the main population, and 200 individuals at Yellingbo (the latter value is an overestimate – see below). This was prior to the fire in 2009 in large areas of montane ash forest and sub-alpine woodland.

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[2] Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadik TA, Smith SJ, Acevedo S, Cheers G, Jemison ML and Nicol MD (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, Vic. http://www.depi.vic.gov.au/__data/assets/pdf_file/0008/192932/DEPI_ARI_web.pdf

[3] Stakeholder Engagement Workshop presentations were available at http://www.depi.vic.gov.au/environment-and-wildlife/wildlife/leadbeaters-possum, titled:

- Findings from the New Strategic Approach to Biodiversity Management Research –Dr Lindy Lumsden, Arthur Rylah Institute for Environmental Research
- An overview of Leadbeater's Possum Biology –Dr Dan Harley, Wildlife Conservation & Science, Zoos Victoria
- Professor David Lindenmayer, Australian National University, summarises more than 30 years of research on Leadbeater's Possum and montane ash forest in Victoria's Central Highlands.

The call playback/thermal imaging/spot-lighting technique described in 2013 estimated a population *after* the 2009 fires of 1,500-5,500 colonies, 1,500-5,500 breeding females and 5,000-11,000 individuals from sampling across forest in the Central Highlands (Lumsden L, presentation at Leadbeater's Possum Stakeholder Engagement Workshop, 2013). This is a much larger number of individuals than estimated from the stag-watching technique. As noted above, determination of trends from comparison of numbers from the two techniques would be invalid, and the new data cannot be concluded to represent a population increase.

The more recent data and methodology from the Arthur Rylah Institute for Environmental Research, while a significant step forward and able to successfully identify a larger Leadbeater's possum population, still has not been used to sample the entire range of the species.

Long-term and short-term population changes: responses to fire and forest development

Leadbeater's possum is killed by fire of any intensity. Following the 2009 fires in the Victorian Central Highlands, no Leadbeater's possum were detected at any burnt site. A few Leadbeater's possum colonies did survive in some unburnt refugia within burnt areas, although these colonies may be very susceptible to predator pressure.

The 2009 fires thus had a substantial effect on the Leadbeater's possum population, directly removing the possum from 36% of its presumed range, including effectively all of the Lake Mountain population. A higher proportion (45%) of habitat in the recently declared Leadbeater's possum reserve was burnt (see references in Lumsden et al 2013).

The 2009 fires also impacted provision of the hollow-bearing trees in which Leadbeater's possum characteristically nest. On one hand, the burnt old-growth forest in the O'Shannassy catchment is predicted to become excellent habitat in 10-15 years time when a wattle understorey has developed under the overstorey of large dead trees. On the other hand, large areas of 1939 regrowth forest that were burnt in 2009 will now no longer grow on to old-growth status, and furthermore are believed not to have contained trees of sufficient size to produce dead stags with suitable hollows for Leadbeater's possum, and such areas will therefore not be suitable habitat for a long time.

Modelling of population size

Population Viability Analysis can bring together the habitat and demographic variables that influence a species, and predict trends in populations over time under a variety of assumptions. A recent Population Viability Analysis coordinated by the Arthur Rylah Institute for Environmental Research modelled the Leadbeater's possum population for 280 years in a particular part of its range (the 30,000 ha of the reserve system in the Central Highlands known as the Leadbeater's possum reserve).

The analysis requires a large number of assumptions about the biology of the species and forest development, and its main value may be to identify the critical variables for future research. Nevertheless, the analysis shows major multi-decadal trends that give context to the loss of habitat and populations in the 2009 fires. These trends track the development and loss of appropriate forest habitat (specifically hollow-bearing trees in forest that has had a sufficiently recent fire to contain a wattle understorey), overlaid with the direct impact of individual fires.

The Population Viability Analysis predicted that Leadbeater's possum populations in the Leadbeater's possum reserve area varied as follows:

- unknown level before the 1939 fires
- very low after the 1939 fires
- low until the 1970s, then increasing to a level considerably above the pre-1939 level with a peak around 3,500 adult females in the mid-1990s, then decreasing from around the year 2000
- halved in the 2009 fires
- now (2013) on a downward trajectory towards a low value (several hundred adult females) around the year 2070 because of continued loss of hollow-bearing trees
- commencement of recovery after the year 2070, assuming no further extensive fires over this time.

The analysis suggests that there was a peak of about 3,500 female adults (thus 3,500 colonies, and a proportionately higher total number of individuals) in the Leadbeater's possum reserve around the mid-1990s, and a minimum of about 750 female adults in the Leadbeater's possum reserve in about the year 2070. This is a predicted decrease of about 80% over 75 years. The decrease over the 14-year period from 1997 to 2011 (the 14-year period showing the largest decrease, and including the 2009 fires) is predicted to be around 50%.

Incorporation into the modelling of a potential future accelerated decline in hollow-bearing trees reduces the predicted minimum population size in the year 2070, as does incorporation of further large fires in the Leadbeater's possum reserve over this period.

The Leadbeater's possum reserve is a core part of the known range of the species but by no means its total range. Predictions for the entire Leadbeater's possum population could be buffered by simultaneous changes in populations in other parts of the total range of the species as forest develops, ages and burns in those areas.

Timber harvesting is not permitted in reserves through the Central Highlands, including in the Leadbeater's possum reserve. No data are available on the area of current or potential habitat that may be subject to harvesting operations over time, and thus the potential relative impact of forestry operations cannot be quantitatively assessed. Historical logging may have significantly reduced the number of hollow-bearing trees in some areas. Changes in Leadbeater's possum populations caused by forest development, ageing and fire occur across the range of the species independent of tenure or forest management.

In the context of the listing application, it can be concluded that the conditions underpinning the changes in Leadbeater's possum populations are well understood. The impacts of fire persist for many decades, but populations will increase at various times after fire depending on the nature of the forest that was burnt, successful dispersal into previously burnt areas, regrowth of wattle, and the overall frequency and extent of wildfires (the fire regime) across the Central Highlands.

Conservation actions

Major appropriate conservation actions for Leadbeater's possum need to be considered against the threats to this species.

Forest fire is a direct threat to the species. An altered fire regime also has the potential to affect the current and future supply of large trees suitable for forming hollows. Increasing the ability

to mitigate forest fire impacts on the forests inhabited by Leadbeater's possum and on the future habitat in the remaining unburnt stands of 1939 regrowth, such as through prescribed burning around these areas, is a key conservation action.

As a spatially dynamic species, Leadbeater's possum requires the ability to colonise new suitable forest habitat as this becomes available. Little is known about this ability, and how it may be constrained in the current fragmented forest and non-forest landscape. An understanding of population dynamics is needed to underpin appropriate management, and will require: on-going population monitoring across the entire range of the species; research on limitations to dispersal; research on how to successfully re-introduce the species to areas that have become suitable habitat; and an understanding of how to promote the persistence and development of hollows and hollow-bearing trees in areas of forest where these are the limiting factor for the species.

In this context, early spatially explicit population viability analysis undertaken by Lindenmayer and Possingham (1996)[4] associated a higher probability of persistence of Leadbeater's possum with forest blocks containing larger patches of old- growth forest, and highlighted the need for a number of such patches across the range of the species. Bekessy et al (2009)[5] provided a more recent example of the kind of spatially explicit population viability analysis that allows issues of dispersal dynamics, habitat fragmentation and conservation management (in this case, for the Tasmanian wedge-tailed eagle) to be addressed.

Forestry operations in actual or potential Leadbeater's possum habitat need to adopt silvicultural systems that retain current and potential future hollow-bearing trees, such as the variable retention harvesting approach used successfully in Tasmania. Fire-salvage harvesting is also likely to deplete the hollow-bearing tree resource.

Staff from the Arthur Rylah Institute for Environmental Research are on the record as noting that the Leadbeater's possum reserve alone is not sufficient to ensure the long-term persistence of the species (based on the Population Viability Analysis showing that the population in the reserve could drop below 500 adult females in certain circumstances). A similar point is made in the listing nomination:

> "the current reserve system is inadequate to conserve the species."
>
> "Recent modelling work strongly indicates that the existing reserve system is inadequate for Leadbeater's Possum, particularly in the advent of further wildfires in the Central Highlands of Victoria"

However, no evidence is adduced that an increase in the reserve system across the Central Highlands would enhance the conservation status of Leadbeater's possum. Indeed, populations in the reserve system were impacted as or more heavily by the 2009 fires as populations outside the reserve system, and the reserve system itself offers no protection from this major threat. An approach more likely to be successful with Leadbeater's possum, as with all mobile species, is integrated management across all tenures and forest management areas, including but not limited to the reserve system. This will require co-operation between forest reserve managers and production forest managers, as well as with researchers.

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[4] Lindenmayer DB, Possingham HP (1996) Ranking conservation and timber management options for Leadbeater's Possum in southeastern Australia using Population Viability Analysis. *Conservation Biology* 10: 235-251, and references therein

[5] Bekessy SA, Wintle BA, Gordon A, Fox JC, Chisholm R, Brown B, Regan T, Mooney N, Read SM, Burgman MA (2009) Modelling human impacts on the Tasmanian wedge-tailed eagle (*Aquila audax fleayi*). Biological Conservation 142: 2438-2448

Australian Government
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Briefing Note

Australian Bureau of Agricultural
and Resource Economics and Sciences

24 June 2015

LEADBEATER'S POSSUM: REVIEW OF CONSERVATION ADVICE AND SUGGESTIONS FOR RECOVERY PLAN

In April 2015, the Threatened Species Scientific Committee (TSSC) released Conservation Advice to list Leadbeater's possum as Critically Endangered under the *Environmental Protection and Biodiversity Conservation Act* (EPBC Act). This briefing note presents analysis of the basis of the revised listing assessment in the Conservation Advice, comments on its use of data, analyses the status of and justification for boxed text on p.33 of the Conservation Advice, and makes suggestions for inclusion in the recovery plan for the species.

Key points

1) Leadbeater's possum is only found in Victoria, and is dependent on regrowth forests containing old-growth elements. The size of Leadbeater's possum populations, and their location within the forest landscape, are very dependent on the historical fire regime, which makes the species difficult to manage. A conservation strategy for Leadbeater's possum combining habitat protection and habitat development has been applied through the 1998 Central Highlands Regional Forest Agreement (RFA) and the 1998 Central Highlands Forest Management Plan.

2) A predicted, significant decline in Leadbeater's possum populations commenced in the mid-1990s, due mainly to a progressive reduction in the availability of hollow-bearing trees. The 2009 fires then directly killed a proportion of the population in the Central Highlands, and destroyed a proportion of the species current and predicted future habitat. Substantial population decline is predicted to continue for several decades until mature trees develop in existing regrowth forest towards the latter part of this century.

3) The eligibility of Leadbeater's possum for relisting as Critically Endangered required evidence of a projected or actual reduction in population size or extent or habitat quality of ≥80% over specified 18-year periods (3 generations for the possum). The Conservation Advice found that the area of suitable habitat for Leadbeater's Possum reduced by 81-83% over the period 1995-2013, and predicted that the area of suitable habitat would reduce by a further 77-87% over the period 2013-2031 (a figure that was taken as exceeding the 80% threshold).

4) However, the assumptions and calculations used in the Conservation Advice to generate the above figures have not been peer-reviewed, some of the assumptions and scenarios are unrealistic, and some calculations contain errors. Several of the loss rates are applied over time periods other than the 18 years required as three generations of Leadbeater's possum. Multiple counting of losses occurs. The reason given to prefer the results of the analysis for Criterion A2a over the results of the analysis for Criterion A2b does not relate to difference between the calculations under these criteria. A rate of loss of hollows higher than the recently published figure is used, and unrealistic assumptions are made in regard to future fire areas (even allowing for the potential effects of climate change) and future forest harvesting (with harvesting assumed to occur even in reserves, for example). In addition, no consideration is given to any of the prescriptions applied to mitigate the impact of forest harvesting on Leadbeater's possum.

5) Recalculations presented in this briefing note utilise more realistic assumptions, select more likely scenarios from those developed in the Conservation Advice, and draw on published data. These recalculations show that the suitable habitat for Leadbeater's possum is likely to have reduced by 55-71% over the period 1995-2013, and that it is likely that the suitable habitat will reduce by a further 49-50% over the period 2013-2031[1].

6) Publications from key researchers on Leadbeater's possum are referenced in the Conservation Advice. However, a substantial portion of the numerical data used to estimate proportional reductions in suitable habitat is contained in 'Lindenmayer et al. (2014a) pers. comm.', and these data are not publically available.

7) The Conservation Advice also gave little consideration to the management and conservation actions implemented as a result of the Central Highlands RFA in 1997, and the actions identified in the Victorian Leadbeater's Possum Action Statement in 2014.

8) There is no evidence in the Conservation Advice itself, the Victorian government's 2014 Leadbeater's Possum Action Statement, or the 2014 reports of the Leadbeater's Possum Advisory Group, that ceasing timber harvesting would be, as expressed in the boxed text on page 33 of the Conservation Advice, "the most effective way to prevent further decline and rebuild the population". In every scenario addressed in the analyses in the Conservation Advice, harvesting is calculated as causing a far smaller loss of habitat than fire, or loss of hollows.

9) The Conservation Advice does not present evidence that an increase in the reserve system across the Central Highlands would enhance the conservation status of Leadbeater's possum. The Bayesian analysis presented in the Technical Report of the Leadbeater's Possum Action Group indicated that reservation of all Central Highlands forests gave no additional benefit over a package of other conservation and management actions.

10) An approach more likely to be successful with Leadbeater's possum, as with all mobile species, is integrated management across all tenures and forest management areas, including but not limited to the reserve system.

11) Retaining and updating the existing Leadbeater's Possum Recovery Plan, as recommended in the Conservation Advice, and incorporating the actions in the Victorian government's 2014

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[1] Calculated reductions in suitable habitat would be even smaller if expressed over 14 years (the period of time for three generations used in the relisting nomination) rather than over 18 years (the period of time for three generations used in the Listing Advice)

Leadbeater's Possum Action Statement, would provide a mechanism for compiling conservation actions appropriate to the various threats to the species. This briefing note lists key conservation actions that particularly need to be included in this updated recovery plan.

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Executive Summary

1) Leadbeater's possum has been relisted in 2015 as Critically Endangered under the *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) based on Conservation Advice provided by the Threatened Species Scientific Committee (TSSC 2015).

2) Leadbeater's possum depends on regrowth forests (with dense wattle understorey for foraging) containing old-growth elements (large, living or dead, hollow-bearing trees for nesting). The species thus requires a landscape with a certain fire regime (too few fires and the areas with wattle understorey will age and become depleted; too many fires and the number of trees with suitable hollows will decrease). This results in populations of the possum that vary greatly within the wider forest habitat of the species over a multi-decadal timescale, and makes the species both especially difficult to manage and susceptible to an increased frequency and extent of wildfire.

3) A strategy combining habitat protection and habitat development has been applied through the 1998 Central Highlands Regional Forest Agreement (Australian and Victorian Governments 1998) and 1998 Central Highlands Forest Management Plan (DNRE 1998), with the aim of ensuring the long-term conservation of Leadbeater's possum over the known range of the species.

   The Regional Forest Agreement resulted in all old-growth forests of the Ecological Vegetation Classes used by Leadbeater's possum being placed in the reserve system (as conservation reserves and Special Protection Zones (SPZs)), as part of the reserve targets for biodiversity conservation and in particular for conservation of Leadbeater's possum. As part of this process, all known Leadbeater's possum colonies were protected from harvesting, and management prescriptions in place to provide for and protect the development of future habitat were accredited.

   The 1998 Central Highlands Regional Forest Agreement also applied a strategy to develop future habitat and mitigate future risks to the conservation of Leadbeater's possum by protecting 85,000 ha of forest, 44% of the total ash eucalypt forest in the Central Highlands. These forests were located in conservation reserves and SPZs, and if not burnt would become more than 150 years old (and nesting habitat) by 2148. This strategy was implemented to help manage the risk caused by the significant anticipated gap in supply of suitable nest sites in hollow-bearing trees during the period 2050-2100, which was predicted to result from collapse of hollow-bearing stags resulting from the 1939 fire.

4) Currently, around 31% of ash forest and snowgum woodland suitable for Leadbeater's possum (62,600 ha) is available for timber harvesting. Harvesting operations follow the prescriptions that apply to Leadbeater's possum habitat, and to the retention of trees, which are set out in the code of practice, management plan, and associated action statements. Prior to the harvesting of a coupe in the Central Highlands, VicForests undertakes a desktop assessment of Leadbeater's possum habitat and values, undertakes transect walks and surveys of the coupe to identify values, implements targeted species surveys using external consultants, and undertakes follow-up research and monitoring. The prescriptions are designed to mitigate any impact of clearfelling on current Leadbeater's possum colonies and habitat, and provide for future hollows in Leadbeater's possum habitat. However, no strategy for effectiveness monitoring of the management prescriptions and strategies applying to Leadbeater's possum could be found in documentation.

These management arrangements were agreed to and accredited by the Australian Government in the 1998 Central Highlands Regional Forest Agreement, and have controlled timber harvesting to manage the conservation of Leadbeater's possum whilst providing resources to support a sustainable timber industry. Furthermore, these arrangements have been strengthened following the recommendations of the Leadbeater's Possum Advisory Group as captured in the 2014 Leadbeater's Possum Action Statement.

5) Currently, around 69% of ash forest and snowgum woodland suitable for Leadbeater's possum is excluded from timber harvesting, with 48% of ash forest and snowgum woodland suitable for Leadbeater's possum (98,500 ha of forest) in the conservation estate (conservation reserves and SPZs). However, little information could be found about improvements to knowledge on Leadbeater's possum and its habitat in the conservation estate through surveys and research. No information has been found about the performance of these national parks and reserves in terms of the conservation and management of Leadbeater's possum, even though performance monitoring and reporting was intended to be a component of the ecologically sustainable forest management system accredited by the Regional Forest Agreement.

   This paucity of information about the status of Leadbeater's possum on the conservation estate was not acknowledged in the Conservation Advice, and may have led to the focus of the Conservation Advice on forests available for timber harvesting and thus on the threat from harvesting.

6) Population estimates indicate that a significant decline in Leadbeater's possum populations commenced in the mid-1990s, due mainly to a reduction in the availability of hollow-bearing trees. This was followed by destruction of a large proportion of habitat in the 2009 fires, and the death of populations of Leadbeater's possum in the burnt areas. Substantial population decline is predicted to continue for several decades, driven mainly by further reduction in the availability of hollow-bearing trees until mature trees develop in existing regrowth forest towards the latter part of this century.

   The Leadbeater's Possum Advisory Group reported that the estimated Leadbeater's possum population size is sufficiently large to provide opportunities for recovery of the species during the next 70 years, assuming that required actions can be implemented soon enough and that threats can be adequately managed.

   Given the recently reported occurrence of Leadbeater's possum in logging regrowth (SEW 2014), it is important to determine quantitatively the habitat determinants underpinning this component of its distribution.

7) The eligibility of Leadbeater's possum for relisting as Critically Endangered required evidence of a projected or actual reduction in population size or extent or habitat quality of ≥80% over specified 18-year periods (3 generations for the possum). The Conservation Advice found that the area of suitable habitat for Leadbeater's Possum reduced by 81-83% over the period 1995-2013, and predicted that the area of suitable habitat would reduce by a further 77-87% over the period 2013-2031 (a figure that was taken as exceeding the 80% threshold). These calculations underpinned its relisting as Critically Endangered.

However, the calculations presented in the Conservation Advice are confounded by numerical errors and unrealistic assumptions and scenarios, and have not been peer-reviewed:

a) Several of the loss rates are applied over time periods other than the 18 years required as three generations of Leadbeater's possum.
b) Multiple counting of losses occurs.
c) The reason given to prefer the results of the analysis for Criterion A2a over the results of the analysis for Criterion A2b does not relate to difference between the calculations under these criteria.
d) A higher rate of future loss of hollows is used than the recently published figure.
e) Unrealistic assumptions are made in regard to future fire areas (even allowing for the potential effects of climate change) and in regard to future forest harvesting (with harvesting assumed to occur in reserves, for example).
f) No consideration is given to any of the prescriptions applied to mitigate the impact of forest harvesting on Leadbeater's possum.

8) When these errors are corrected, and more realistic assumptions and scenarios utilised, recalculations show that the suitable habitat for Leadbeater's possum is likely to have reduced by 55-71% over the period 1995-2013, and that the suitable habitat for Leadbeater's possum will likely reduce by a further 49-50% over the period 2013-2031.

9) A large number of publications from key researchers on Leadbeater's possum are referenced in the Conservation Advice. However, a substantial portion of the numerical data used in the Conservation Advice to estimate reductions in suitable habitat is contained in Lindenmayer et al. (2014a) pers. comm. – a reference that has not been published and is publically unavailable. This personal communication provides all the data used in Analysis A2a, and the data on loss of hollows (the top-ranked threat in terms of proportion of habitat affected) used in Analysis A2b and in Analysis A3.

Harvest projections provided by VicForests are also not publically available.

The Conservation Advice also gave little consideration to the management and conservation actions identified in the Victorian Leadbeater's Possum Action Statement in 2014.

10) There is no evidence in the Conservation Advice itself, or the Victorian government's 2014 Leadbeater's Possum Action Statement, that ceasing timber harvesting of mountain ash forest would be, as expressed in the boxed text on page 33 of the Conservation Advice, "the most effective way to prevent further decline and rebuild the population".

a) In every scenario addressed in the analyses in the Conservation Advice, harvesting is calculated as causing a far smaller loss of habitat than fire, or loss of hollows.
b) The required management actions listed in the Conservation Advice address only certain of the threats, and not timber harvesting.
c) Lindenmayer (2009, p.238) asserts that "the conservation of Leadbeater's Possum is a rare example where altered silvicultural systems (logging methods not based on traditional clearfelling) could significantly benefit the species".

11) The Conservation Advice does not present evidence that an increase in the reserve system across the Central Highlands would enhance the conservation status of Leadbeater's possum.

a) This is particularly the case given an apparent lack of knowledge and monitoring of how the existing reservation system is performing in terms of Leadbeater's possum conservation and management.
b) An approach more likely to be successful with Leadbeater's possum, as with all mobile species, is integrated management across all tenures and forest management areas, including but not limited to the reserve system.
c) The Bayesian analysis presented in the Technical Report of the Leadbeater's Possum Action Group indicated that reservation of all Central Highlands forests gave no additional benefit (as measured by the probability of "good" conservation status) to Leadbeater's possum over a package of other conservation and management actions.

12) The Conservation Advice recommends that the existing Leadbeater's Possum Recovery Plan be retained and updated, and this approach would provide an appropriate mechanism for incorporating conservation actions appropriate to the various threats to the species. The updated recovery plan should also incorporate all the recommendations in the Leadbeater's Possum Action Statement, including silvicultural prescriptions. Key conservation actions that particularly need to be incorporated in this updated recovery plan include:

a) Addressing the apparent deficiency of knowledge and information about Leadbeater's possum and its habitat on the conservation reserve estate (national parks and SPZs) and the performance of these reserves for the conservation and management of Leadbeater's possum, and determining the habitat determinants underpinning the recently reported occurrence of Leadbeater's possum in logging regrowth (SEW 2014).
b) Producing as a priority a comprehensive, accurate and current spatial layer showing the location of hollow-bearing trees across the range of Leadbeater's possum, for use in mapping the extent of Zone 1A or 1B Leadbeater's possum habitat and applying prescriptions associated with hollow-bearing trees.
c) Modelling suitable future habitat across both the reserve system and the production forest estate, utilising forest models that include response to recent fires, response to logging, and the rate of hollow-tree decline. This is essential for management planning in regard to Leadbeater's possum, including identifying forests for strategic placement of nest boxes or artificial hollows.
d) Facilitation of the recovery of populations and colonisation of new suitable habitat, including by on-going research on animal dispersal, the dynamics of hollow-bearing trees, the use of nest-boxes, and the creation of artificial hollows.
e) Facilitating management strategies in all tenures with current occupied Leadbeater's possum habitat to alleviate the loss of critical habitat features (hollow-bearing trees and dense acacia understorey) and to allow such management to prolong the suitability of current occupied habitat.
f) Investigating the use and strategic placement of "possum bridges" across roads and easements to see if these are able to facilitate movement of Leadbeater's possums and recolonisation of new forest habitat and alleviate threats posed by fragmentation.
g) Mitigation of potential future fire impacts on the forests inhabited by Leadbeater's possum, such as through prescribed burning around these areas, especially in consideration of projected climate-change scenarios.

h) Management of feral cat populations to increase the likelihood of maintaining populations of Leadbeater's possum in fire refugia, and facilitating the recolonisation of new suitable habitat.

13) These conservation actions for Leadbeater's possum need to be carried out across the various forest types, tenures and uses in the range of the species in an integrated management approach. Population surveys, monitoring, analysis and modelling need to be undertaken across the range of the species, including both reserve areas and forest available for timber production. Management actions, monitoring and reporting need to apply equally to the reserve system as to the estate available for timber harvesting. Management of populations of Leadbeater's possum over the coming decades, and provision of suitable habitat, will therefore require co-operation between forest reserve managers and production forest managers, and co-operation between researchers in the various interested agencies.

Approach taken in ABARES review of the 2015 Conservation Advice

ABARES reviewed the Threatened Species Scientific Committee Conservation Advice on Leadbeater's Possum (TSSC 2015), supporting documentation including the nomination, the scientific literature, and the body of work that resulted in the Victorian Action Statement on Leadbeater's possum (DEPI 2014a).

The approach ABARES has taken in this review is to analyse the Conservation Advice as follows:

- a description of the habitat requirements and management of Leadbeater's possum, an analysis of the status and implementation of the management systems and prescriptions put in place in the Central Highlands Regional Forest Agreement and the Central Highlands Forest Management Plan, and the impacts on the 2009 fires on populations and habitat of Leadbeater's possum
- a critique of the calculations and numerical approaches underpinning the recommendation to relist Leadbeater's possum as Critically Endangered, detailed in Appendix A, as well as the use of data in the Conservation Advice
- a critique of the recommendations of the Conservation Advice in regard to suggested conservation arrangements for managing Leadbeater's possum.

Habitat requirements and habitat management

General ecology

Leadbeater's possum was discovered in the late 19th century and is a habitat specialist in the wet or damp forests of the Central Highlands of Victoria, with a well-understood life history (CVRFASC 1997a). It was considered to be extinct by the middle of the 20th century, was rediscovered in 1961, and populations increased during the latter part of the 20th century (Attiwill and Fewing 2001, Lumsden et al. 2013). Montane ash forest (dominated by mountain ash *Eucalyptus regnans*, alpine ash *E. delegatensis*, and shining gum *E. nitens*, in Montane Damp Forest, Montane Wet Forest and Wet Forest ecological vegetation classes (EVCs)) provides 88% by area of the currently understood total potential range of Leadbeater's possum, and snowgum woodland in the Subalpine Woodland EVC provides 12% by area; an outlying population at Yellingbo inhabits lowland swamp forest, a variant of Riparian Forest EVC, which provides 0.1%

by area (data in presentations from experts at a Leadbeater's Possum Stakeholder Engagement Workshop held in September-October2013; SEW 2014).

These three habitat types, montane ash forest, snowgum woodland and lowland swamp forest, and within these the specific habitat of Leadbeater's possum, were known at the time (1996-98) that the Victorian Central Highlands Regional Forest Agreement (Australian and Victorian Governments 1998) was being formulated. The population in montane ash forest is reasonably well characterised, as is the much smaller population in lowland swamp forest. The snowgum woodland populations at and near Lake Mountain were killed in the 2009 fires (LPAG 2014a), and the populations at Mt Baw Baw are not well known.

Habitat requirements

Habitat requirements of Leadbeater's possum across these forest types (Lindenmayer 1989, CVRFASC 1997a, Macfarlane et al 1997, LPAG 2014a, TSSC 2015) are:

- hollow-bearing trees for denning, with multiple such trees in each 1-3 hectare family territory. Trees need to be sufficiently large to accommodate a hollow approximately the size of a basketball, but with a narrow entrance to exclude predators. Most trees known to contain Leadbeater's possum dens are large old trees in old-growth forest, or large old dead stags in regrowth forest resulting from a fire in previous old-growth forest. Nest-tree abundance and distribution is a critical factor determining habitat quality
- forest stands with a predominance of smooth-barked eucalypts with large amounts of decorticating bark
- a dense mid-storey layer for secondary food (sap, gum and invertebrates) and for unrestricted movement, provided by wattle in montane ash forest, and tea-tree in snowgum woodland and lowland swamp forest
- a cold, wet climate, with preference for moist, well-vegetated gullies on slopes facing south-east.

These requirements combine to make the optimal Leadbeater's possum habitat a regrowth forest with old-growth elements, and lead to the complex dependence of the species on fire (CVRFASC 1997a, DNRE 1998). Optimum habitat was identified as "young regenerating or uneven-aged ash-eucalypt forest that contains both wattles and an ample supply of old hollow trees" (Macfarlane et al. 1997 based on Lindenmayer et al. (1991)), and this description remains current. Fires in old-growth forest create dead large trees with hollows for nesting and also provide conditions for subsequent wattle growth, but kill Leadbeater's possum directly and also destroy both current and future hollow-bearing trees. For example, optimum habitat was provided as a result of the 1939 fires, which burnt approximately 84% of the Central Highlands ash eucalypt forests but promoted regrowth of eucalypts and a dense wattle understorey, and (because they predominantly burnt old-growth forest) provided suitable densities of dead hollow-bearing trees (Attiwill and Fewings 2001). Habitat for Leadbeater's possum is thus dynamic in both time and space, with the possum needing to recolonise its preferred habitat after fire, and this leads to the peculiar conservation challenges for this species.

This challenge is well documented in the Comprehensive Regional Assessment documents (CVRFASC 1997a, b, c) leading into the Victorian Central Highlands Regional Forest Agreement signed in 1998.

The fire-killed mature forest and resultant regrowth from the 1939 fires provided abundant feeding and nesting habitat for Leadbeater's possum from 1966 to 1996. However, in the early

1990s it was recognised that the extent of Leadbeater's possum habitat was diminishing as the relatively short-lived wattle understorey began to degrade, but especially as the fire-killed nest trees progressively decayed and fell, giving a gap in the availability and supply of nest trees until after 2090 (Attiwill and Fewings 2001). In the next 50-100 years, therefore, the availability of nest/den trees for Leadbeater's possum will be significantly diminished. Garnett et al. (2003, p.3) (see Appendix B) summarise this as follows in the Action Statement "Loss of hollow-bearing trees from Victorian native forests and woodlands":

> "Severe wildfires can reduce numbers of hollows by killing most of a particular cohort of trees, resulting in a relatively even-aged regrowth with a few old or dead trees. This may create a temporary abundance of hollows as large, fire-killed trees decay, but over the following decades these trees are likely to collapse more quickly than new hollows are formed. This is currently happening in the Central Highlands, where most trees in 65% of the montane ash forests were killed by wildfire in 1939 (Noble 1977; Smith & Woodgate 1985). The subsequent loss of dead hollow-bearing trees in these forests has been estimated at 3.6% per year, as measured over a five year period in the 1980s (Lindenmayer et al. 1990a). Most remaining stags with hollows will collapse in the next 75 years, leaving a period of at least 50 years when there will be a shortage of hollows for Leadbeater's Possum and other arboreal marsupials (Smith and Lindenmayer 1988; Lindenmayer et al. 1990a). The problem exists because trees that germinated after the 1939 fires are not yet old enough to develop hollows."

It was also recognised that loss of future potential nest trees in Leadbeater's possum habitat due to timber harvesting would further reduce the ability of the species to survive (CVRFASC 1997a). The conundrum recognised at the time was "Even if timber harvesting were excluded from the regrowth ash forests, they will not be capable of providing suitable nest sites for a further 150 years - assuming that Ash trees must be about 200 years old before they can provide suitable nest sites. It therefore follows that the existing older-aged forest must continue to provide habitat for at least another 150 years" (p. 89, CVRFASC 1997a). The only way to plan and manage the long-term survival of Leadbeater's possum was an integrated approach across both conservation reserves and production forests spatially and temporally to 2100 (CVRFASC 1997a, DNRE 1998, Attiwill and Fewings 2001). The future shortage of hollow-bearing trees recognised in the 1990s has been predicted to be most severe from 2064 to 2084 and to persist beyond 2100 (Lumsden et al. 2013, LPAG 2014a, b), and remains as a critical habitat issue and determinant of population size.

Management of Leadbeater's possum under the Central Highlands Regional Forest Agreement

Wildfire and uncontrolled (unmanaged) timber harvesting were identified in 1997 as major threats to Leadbeater's possum. Climate change and planned fire were identified as moderate threats, with predation and roading considered as minor threats (CVRFASC 1997a). Harvested forests were known to maintain Leadbeater's possum populations if an adequate density of nesting trees was retained (Lindenmayer 1992). The approach articulated by Menkhorst and Lumsden (1995) was implemented: "The only way to plan for the longterm survival of Leadbeater's possum is through timely implementation of active and adaptive management strategies, further research and close liaison between wildlife biologists and forest managers." As a consequence, systems and processes were put in place in an integrated manner to manage the risks and threats to the conservation of Leadbeater's possum, including impacts posed by timber harvesting. These were addressed in the arrangements that underpinned the 1998 Victorian Central Highlands Regional Forest Agreement (Australian and Victorian Governments 1998) and 1997 Leadbeater's Possum Recovery Plan (Macfarlane et al. 1997).

The Regional Forest Agreement resulted in all old-growth forests of the EVCs used by Leadbeater's possum (5,670 ha of montane ash old-growth forest comprising Damp Forest, Wet Forest and Montane Damp Forest EVCs; 130 ha of Riparian Forest; and 3 ha of Sub-alpine Woodland; p.21, CVRFASC 1997c) being placed in the reserve system (conservation reserves and Special Protection Zones (SPZs)) as part of the achievement of JANIS targets (JANIS 1997) for biodiversity conservation and in particular for Leadbeater's possum. LPAG (2014a; p. 9) reports that "All old growth ash stands have been protected from harvesting in the Central Highlands for over 20 years". An analysis[2] of Leadbeater's possum records showed that 55% of records were in conservation reserves and 4% were in Special Management Zones and Code of Forest Practice exclusions. Of the 23,900 ha of older-aged montane ash forest, around 10,000 ha was in the Yarra Ranges National Park, and the remainder in State Forest was placed in the Special Protection Zone and excluded from harvesting. All of this older montane ash forest was classed as Zone 1A possum habitat (CVRFASC 1997a).

Regional management prescriptions for timber operations based on the Leadbeater's Possum Action Statement 1995 and the 1997 Recovery Plan (Macfarlane et al. 1995, 1997) were implemented through the Central Highlands Forest Management Plan, the codes of forest practices system, and commitments made in Victorian Central Highlands Regional Forest Agreement, with the over-arching goal of achieving ecologically sustainable forest management. These implementation mechanisms were accredited in the Regional Forest Agreement (Victoria and the Commonwealth 1998). The Regional Forest Agreement, consequent Forest Management Plan, and plans to cover the reserve system, provided a robust system and integrated approach in managing Leadbeater's possum. Management prescriptions applying to Leadbeater's possum habitat zones are described in Box 1, Table 1, and Appendix C. Timber harvesting codes are informed by, and must comply with, relevant policy documents including policies relating to specific forest values such as threatened species, guidelines and strategies within forest management plans made under the *Forest Act 1958*, and Action Statements made under the *Flora and Fauna Guarantee Act 1988* (DNRE 1996, DSE 2007, DEPI 2014b). The Victorian Code of Forest Practices for Timber Production (DNRE 1996[3]) specified the need to retain an appropriate number and configuration of habitat trees, to provide for the replacement of old hollow-bearing trees within and around coupes, and to protect these trees during harvesting and subsequent management.

Specific management guidelines for the retention of hollow-bearing trees on timber harvesting coupes in the Central Highlands, and particularly in ash forest, applied through the Victorian Central Highlands Forest Management Plan (see Appendix D). These guidelines, contained in Table 1 and Appendices C and D, were based on the incorporation of findings summarised in Lindenmayer (1992) and the approach of Macfarlane et al. (1995) and Menkhorst and Lumsden (1995). Already at that time there was a recognised need to use modified timber harvesting prescriptions, modified logging rotation lengths and modified silvicultural systems to enable the retention of a suitable density and configuration of habitat trees, and a recognised need to ensure a continuous supply of trees able to become trees that would meet the habitat requirements of arboreal marsupials, particularly Leadbeater's possum, while meeting forest industry needs. These requirements were incorporated into planning documents.

Zone 1A habitat only occurs in the reserve system (conservation reserves and SPZ), and 27,000 ha of this (Table 2) was identified as critical habitat for Leadbeater's possum (CVRFASC

[2] Refer to Table 6.3 and associated notes in CVRFASC (1997a)

[3] Note the Code has had subsequent revisions in 2007 (DSE 2007) and 2014 (DEPI 2014b).

1997b, c). Zone 1B habitat was identified as good habitat as long as critical features (density of hollow-bearing trees and wattle density) of the habitat remain. The aim of the management of Leadbeater's possum was to divide the montane ash forest within the known range of Leadbeater's possum into 21 Leadbeater's Possum Management Units (LMUs; refer to Table 2 and Map 4 in Appendix D); retain at least 600 ha of Zone 1A ash forest in patches of 50-100 ha in each LMU; and, where 600 ha of retained forest could not be achieved using Zones 1A and 1B forest, to identify and plan to retain patches of 1939 regrowth forest that will develop suitable nesting trees in 50-100 years (Attiwill and Fewings 2001). It was intended that Zone 1 A habitat in conservation reserves and SPZs (84,800 ha: CVRFASC 1997a, p.101) be protected in reserves so that if not burnt it would become more than 150 years old by 2148 and potential Leadbeater's possum habitat (DNRE 1998; see Figure 3.1 in Appendix D; Lindenmayer and Possingham 1995). This strategy was applied to develop future habitat and mitigate future risks to the conservation of Leadbeater's possum. The goal was to ensure that, by 2100, 44% of the total ash eucalypt forest in the Central Highlands that was located in conservation reserves and SPZs would be over 150 years old (CVRFASC 1997a, Appendix E). This strategy was implemented to help manage the risk of the significant anticipated gap in supply of suitable nest sites in hollow-bearing trees during the period 2050-2100 (Appendix E) and to spread the risk posed by future wildfire (Lindenmayer and Possingham 1995).

Table 1 Leadbeater's possum habitat zones on multiple-use public native forest tenure

Zone	Forest type and density of hollow-bearing trees[1]	Hollow-bearing tree[1] type	Wattle density[2]	Management
1A	Mature ash forest (>120 years old) and mixed-aged ash forest where oldest age class is mature (>120 years old) Regrowth ash forest with ≥ 12[3] hollow bearing trees per 3 ha in patches ≥ 3 ha	Living trees containing hollows	n/a	Special Protection Zone (harvest exclusion and is conservation reserve)
1B	Regrowth ash forest with ≥ 12 hollow bearing trees per 3 ha in patches ≥ 10 ha	Dead or living trees containing hollows	> 5 m^2/ha	General Management Zone but excluded from timber harvesting while Zone 1B attributes remain (Action 7 prescriptions[4] apply when attributes fall below threshold).
2	Regrowth ash forest of varying age Regrowth ash forest with features of Zones 1A and 1B but below the patch size thresholds	n/a	n/a	General Management Zone (Action 7 prescriptions[4] apply)

Source: Macfarlane et al. (1997), DNRE (1998).

Notes:

[1] Hollow-bearing trees are Mountain Ash, Alpine Ash or Shining Gum, either living or dead.

[2] Density is expressed as basal area - the sum of the cross-sectional area of the boles of the trees. Basal area is the combined total of *Acacia dealbata*, *A. obliquinervia* or *A. frigescens*.

[3] The number of hollow-bearing trees for Zone 1A was reduced to 10 hollow-bearing trees per 3 ha in 2014 following recommendations from the Leadbeater's Possum Advisory Group and resultant changes to the Action Statement for Leadbeater's Possum (DEPI 2014, DELWP 2015).

[4] See Appendix C for Action 7 prescriptions

≥, greater than or equal to; >, greater than

The approach to managing and conserving Leadbeater's possum was articulated in the biodiversity report (see Appendix E) associated with the Central Highland's Comprehensive Regional Assessment. The strategy incorporated into the Central Highlands Regional Forest Agreement and Forest Management Plan involved a combination of habitat protection and habitat development, and was applied with the aim of ensuring the long-term conservation of Leadbeater's possum over the known range of the species. Prescriptions were implemented in

State forest in areas subject to harvesting when high-quality Leadbeater's possum habitat was identified (LPAG 2014a). All known colonies were protected from harvesting, and management prescriptions were in place to provide future habitat (Box 1). However, a deficiency identified by LPAG (2014a) was that there were no measures specifically focused on the identification and protection of currently unknown colonies.

Table 2 Area of Leadbeater's possum Zone 1A habitat by Leadbeater's Possum Management Unit

Forest Management blocks within Leadbeater's Possum Management Units (LMU)	Area of ash eucalypt forest in that LMU (ha)	Zone 1A Leadbeater's Possum habitat in that LMU[1] (ha)
Easton, Red Jacket, Goulburn, Mt Matlock, Deer Hound	7,743	253
Bells, Cascade, Baw Baw	8,802	831
East and West Tyers, Lady	5,413	1,395
Thomson, Tanjil	9,156	431
Toorongo, Rowleys	7,829	112
Upper Yarra	14,941	285
Brimbonga, Loch	8,345	1,199
Ada, Bennie	7,935	819
Upper Bunyip, Pioneer, Labertouche, Tarago, Lavery	7,313	552
Mississippi, Tarrango, Little Yarra	6,246	1,279
Yuonga	6,114	1,720
Watts	11,415	3,438
Yea River, Kalatha	3,954	690
Murrindindi, Yellowdindi, Mohican East and West, Narbethong, Robbies	6,262	221
Acheron, Steavenson	8,248	1,316
O'Shannassy	11,661	7,115
Upper Taggerty	5,705	1,405
Cathedral, Rubicon	8,638	608
Royston, Snobs, Torbreck, Taponga	9,323	967
Manango, Torbreck River, Stockmans, Gum Top	7,462	2,316
Oaks, Frenchmans, Big River	4,265	49
Sub-total	**166,770**	**27,001**
Central Highlands ash eucalypt outside of any LMU	14,230	0
Total Central Highlands ash eucalypt	**181,000**[2]	**27,001**

Source Appendix L, p.121 of Central Highlands Forest Management Plan (DNRE 1998)
Notes:
[1] Leadbeater's Possum Zone 1A habitat as assessed from aerial photographs on the basis of stag density, or modelled using growth stage mapping and ash-eucalypt forest mapping.
[2] Total from p.23 Central Highlands Forest Management Plan (DNRE 1998).

Box 1 Quote from Central Highlands Biodiversity Report

"Management actions include: the establishment of a zoning system with specific prescriptions relating to the assessment of habitat, size and shape of coupes, buffer establishment and the protection of all hollow-bearing trees regardless of zoning classification. All known colonies are to be protected and other management activities including roading and reforestation are to be addressed. Intended management actions outlined in the Action Statement include: establishment of 21 Leadbeater's Possum Management Units, resource assessment surveys to determine the extent and distribution of current optimum and potentially optimum habitat, a revision of the current zoning system to reflect habitat changes over time, logging coupe assessment, retention of buffer strips, protection of hollow trees, salvage logging plans, operational trials of retained overwood silvicultural systems, reserve establishment, continuation of research to assist and improve long-term conservation, captive management planning, social and economic planning and continuation of community education (Macfarlane et al. 1995)."

Source: CVRFASC 1997a, p.246; see Appendix E

Management plans applying to national parks are also important in managing Leadbeater's possum and its habitat. LPAG (2014a, pp.16-17) describes their importance as:

> "15-year park management plans, which articulate the vision, goals, measures and long term strategies for parks, and adopt a landscape-wide, multi-scale approach to their management. This is considered fundamental for achieving optimal outcomes for species such as Leadbeater's Possum, which only occurs in small patches of suitable habitat in parks. They also include a conservation action plan that specifies the desired condition of natural assets in a park, acceptable level of threat to these assets, and practices used for managing these threats. These can be adjusted to changing circumstances and new information in order to ensure optimal conservation and protection of species, including Leadbeater's Possum."

The forest management systems, processes and prescriptions applying to the conservation management of Leadbeater's possum were accredited in the Central Highlands Regional Forest Agreement. LPAG (2014a: pp.17-18) describes these arrangements as[4]

> "The RFAs formally accredit Victoria's State forest management arrangements, including relevant Forest Management Plans, the FFG Act and the processes established by the Code of Forest Practices for Timber Production (2007). RFAs are recognised under the EPBC Act. Timber harvesting operations undertaken within the requirements of an RFA are exempt from the environmental approval requirements which might otherwise apply under the EPBC Act. Instead the obligations and arrangements accredited by the RFA apply. The Central Highlands Regional Forest Agreement was concluded in March 1998 and is due for renegotiation in 2018.
>
> ... Forest Management Plans (FMPs) are required under the Victorian Forests Act 1958. They are also a requirement of Regional Forest Agreements and the Code of Forest Practice. FMPs, the forest management zoning schemes established under FMPs, and prescriptions contained in FMPs for the conservation and protection of biodiversity (including their process for review) form an important part of Victoria's accredited forest management arrangements.
>
> The Central Highlands Forest Management Plan was completed in May 1998 (CHFMP). The plan was to apply until 2008 or until other circumstances warranted a major review. It has not yet been reviewed and is considered to still be in place. A zoning review of the Central Highlands is currently underway. The CHFMP provides for the balanced use and care of the Central Highlands State forests and provides a framework in which the area's timber industry can continue to confidently invest while providing protection for the natural and cultural values of the forest. It achieves this by establishing a system of forest management zones that sets priorities and permitted uses for different parts of the forest.
>
> ... It also provides a series of management guidelines, prescriptions and actions for the management of all aspects of Central Highlands State forests. The CHFMP also provides

[4] "…" indicate where text has been omitted from the quote

guidance for and circumstances in which the zoning scheme, guidelines and prescriptions can be amended to adapt to changing circumstances and new information. Management prescriptions for Leadbeater's Possum habitat zones are outlined in the CHFMP and seek to give effect to the 1995 Leadbeater's Possum Action Statement.

Additional habitat for Leadbeater's Possum is protected in other areas of State forests through prescriptions in the CHFMP."

Progress in forest management systems from signing the 1998 Regional Forest Agreement to 2008

The Victorian Central Highlands Forest Management Plan (DNRE 1998) reflected the outcomes of the Regional Forest Agreement. Management Plans covering national parks and reserves were finalised over the period to 2005 (DEPI 2014a). Where applicable to the management of these reserves, these plans provided guidance on the management and monitoring of Leadbeater's possum. The Yellingbo Nature Conservation Reserve, Baw Baw National Park and Yarra Ranges National Park Management Plans (Parks Victoria 2002, 2004, 2005) describe the conservation of Leadbeater's Possum and its habitat as a priority (DEPI 2014a). LPAG (2014a) reports that a detailed conservation action plan for the Central Highlands parks is scheduled to commence in 2014/15. No information has been found about how well these national parks and reserves are performing in terms of the conservation and management of Leadbeater's possum, even though performance monitoring and reporting was intended to be a component of the ecologically sustainable forest management system of the Regional Forest Agreement (ESFM, CVRFASC 1997c, p.48).

The loss of hollow-bearing trees has been well recognised, and resulted in a Flora and Fauna Guarantee Act 1988 Action Statement that provided guidance on the conservation and retention of hollow-bearing trees (Garnett et al. 2003). The statement (p.3) includes the following guidance (see Appendix B):

"Key mechanisms for conserving habitat features including hollow-bearing trees within State forest are:

- exclusion or modification of timber harvesting and other disturbances through the application of forest management zones, and/or
- application of prescriptions (rules) governing the way in which these activities are carried out to minimise impacts on habitat values. Forest management zones and prescriptions for the retention of wildlife habitat in State forests are specified in Forest Management Plans and Regional Forest Management Prescriptions, in accordance with the 'Code of Forest Practices for Timber Production' (CFPTP-NRE 1996). Prescriptions vary according to region and forest type.

In relation to hollow-dependent species, the critical factors to consider when developing prescriptions include:

- the habitat requirements of fauna species and their prey, including minimum number, size and type, location of hollow, preferred species and location within the landscape;
- the distribution of hollow-bearing trees taking into account dispersal distances of fauna species;
- the growth stages of the forest to plan for adequate recruitment of hollow-bearing trees over time;
- the forest in the context of the surrounding landscape and existing habitat;
- silvicultural considerations, including adequate regeneration response, and
- operational considerations, including occupational health and safety."

Forest regenerating from fire and logging can provide future habitat, as long as there are sufficient hollows present. Around 62,600 ha of ash forest is available for timber harvesting in the Central Highlands, and harvesting operations follow the prescriptions set out in the code of

practice and management plan, of particular relevance being those prescriptions associated with the retention of trees and Leadbeater's possum habitat. Prior to harvesting operations, VicForests staff survey areas proposed for harvest to identify a range of environmental values and Leadbeater's possum Zone 1A and 1B habitat (LPAG 2014a). VicForests applies the following protocols to coupe harvests in the Central Highlands: a desktop assessment of potential values that includes Leadbeater's possum habitat[5], transect walking and surveys to identify values in the coupe, targeted species surveys using external consultants, and follow-up research and monitoring (Ryan and Powell 2015). Impacts of timber harvesting are known and summarised in DEPI (2014a). Regular audits of compliance with the Code of Practice and management prescriptions (implementation monitoring) have shown good compliance, and where deficiencies are picked up in audits these deficiencies have been remedied[6]. No issue has been reported in these audits in regard to harvesting not being managed around, or excluded from, known colonies and habitats of Leadbeater's possum. As LPAG (2014a, p.25) reports "Regular auditing ensures procedures and staff are up-to-date with all regulatory requirements and it encourages innovation and fresh approaches to ongoing system improvements and practices."

Significant amounts of data relating to the ecology and conservation management and planning of Leadbeater's possum has been collected from the 1980s to the present (Smith 1984, Lindenmayer 1989, AHC and DCHR 1994, CVRFASC 1997a, Lindenmayer and colleagues[7], Lumsden et al. 2013, LPAG 2014a). New data have been accumulated in regards to rates of hollow loss, immediate impacts of fire on the possum, new survey techniques (call play-back, thermal imaging, installed automatic cameras) showing much wider distribution of the possum as well as susceptibility to cats, improved design and trial of nest-boxes, and trial design and implementation of artificial hollows (DEPI 2014a), but this has not resulted in substantial change to the management prescriptions for Leadbeater's possum in logged forest since the knowledge used by Macfarlane et al. (1995) and the biodiversity report (CVRFASC 1997a) (DEPI 2014a). No information about effectiveness monitoring of management prescriptions and strategies applying to Leadbeater's possum could be found. Little information could be found about improvements to knowledge of Leadbeater's possum and its habitat in the conservation estate (conservation reserves and SPZs) through surveys and research. Management arrangements for Leadbeater's possum since 1995 outlined in Box 1 above, and arrangements for management of the loss of hollows in Garnett et al (2003), have been in place for many years, so it is unclear how logging could have affected Leadbeater's possum over this time. It is also unclear how the impact of logging reported in the Conservation Advice[8] could have come about; it is ABARES understanding that silvicultural prescriptions are designed to mitigate any impact

[5] Including a review of available maps, surveys, reports and other information

[6] The Department of Environment and Primary Industries (DEPI) was the environmental regulator for commercial timber harvesting activities in Victoria's State forests until the recent departmental name change to the Department of Environment, Land, Water and Planning. VicForests is the managing authority responsible for planning and overseeing timber harvesting operations conducted on public land in Victoria. Audits are undertaken periodically to check compliance with the regulatory requirements in the *Code of Practice for Timber Production 2014*. Audit reports and Victorian departmental responses are at http://www.depi.vic.gov.au/forestry-and-land-use/timber-production/timber-harvesting-regulation/monitoring-compliance-and-auditing

[7] Refers to the body of work principally associated with David Lindenmayer, his students and collaborators, as well as the work of Andrew Smith, Grahame Suckling, Lindy Lumsden, Malcolm Macfarlane, Peter Menkhorst, Jill Smith and Kim Lowe dating from the 1980s to the present.

[8] Table 1 of the Conservation Advice (TSSC 2015, p. 43) reports 1,027 ha of suitable habitat lost due to harvesting, citing Lindenmayer et al. (2014a) pers. comm. as the source.

of clearfelling on current Leadbeater's possum colonies and habitat and on the provision of future hollows in Leadbeater's possum habitat.

The Statewide Forest Resource Inventory (SFRI) was completed for State forests in the Central Highlands by 2005, however it was not completed for the reserve system as envisaged in the Regional Forest Agreement. This deficiency was recognised by Lumsden et al. (2013) in their survey, modelling and prediction of Leadbeater's possum populations in 2012, as they found that habitat attribute data were limited in conservation reserves.

Leadbeater's possum is susceptible to predation by feral cats. The extent of predation depends upon cat density and the extent to which Leadbeater's possum is able to remain active entirely in the upper canopies of forested habitats (Dickman 1996). Generally Leadbeater's possum requires a well-connected and dense understorey to allow rapid movement between nest trees without needing to come to the ground. If the density of cats increases and/or habitats change such that the possum moves into the predation zone of cats, then it becomes more susceptible to cat predation. Predation was identified as a low threat to Leadbeater's possum in 1997, but cats were identified as a potential threat (CVRFASC 1997a) and incorporated into actions in the Central Highlands Forest Management Plan (DNRE 1998). Because of habitat changes (including from fire) and possible increases in cat density since this date, the level of threat has likely increased. Lumsden (pers. comm. to Research Working Group 4, Marysville, 2013) reported increased cat predation of possums associated with fire refugia, suggesting that cat predation may impact particularly on possums as they move out from refugia to colonise new areas of forest as these become habitat. However the threat of cats has not been considered in the 2014 Action Plan or 2015 Conservation Advice. DoE (2015a, b) discusses the threat and management of feral cats in ways applicable to managing cats in Leadbeater's possum habitat.

It is unclear from Regional Forest Agreements review documentation (Wallace 2010, DEPI 2014c) how and if Leadbeater's possum has been incorporated as an "other forest value" into the Victorian forest management modelling system (Integrated Forest Planning System, IFPS; replaced by the Woodstock suite of tools in 2005) as envisaged in the Central Highlands Forest Management Plan (DNRE 1998, p.78; see Appendix D). Review documentation has not explicitly analysed the improvement and performance of the systems associated with ecologically sustainable forest management as outlined in Chapter 5 of the Central Highlands RFA Directions Report (CVRFASC 1997c) and referenced in the accreditation sections of the Regional Forest Agreement (Sections 48 and 49, Central Highlands RFA, Victoria and the Commonwealth 1998).

Lindenmayer (2009) reports on research in Victoria into the variable retention harvest system as an alternative silvicultural system to clearfelling. This research, undertaken jointly by Victorian government agencies and the Australian National University, commenced in 2003. An objective of the research was to investigate how to create more areas of multi-aged forest and thereby reduce the time taken for regenerating forest to become suitable habitat for species like Leadbeater's possum. Similar research on retention forestry has been undertaken in Tasmania (Neyland et al. 2012) and internationally (Mori and Kitagawa 2014). The research in Victoria supported requirements of the Leadbeater's Possum Recovery Plan (Action 7.6 alternative silvicultural systems; Macfarlane et al. 1997) (see Appendix C) and the Central Highlands Forest Management Plan (retained overwood silviculture system; DNRE 1998) (see Appendix D). Six years into the study the forests where the alternative silvicultural system was being applied were impacted by the 2009 fire. While the effectiveness of altered silvicultural systems for biodiversity conservation was not demonstrated in the Victorian research, preliminary results appeared positive (Box 2). Implementation of retention harvesting in regrowth forests is

included in the recommendations of the Leadbeater's Possum Advisory Group (LPAG 2014b) and in the updated Leadbeater's Possum Action Plan (DEPI 2014a).

Box 2 Alternative silviculture and Leadbeater's possum

"However a key issue was that the retained islands in the VHRS were not intended to retain viable populations of particular species. Rather, the aim was to promote the future structural complexity of logged and regenerated forests, for example, 10-40 years following harvesting, and thus improve the habitat quality of regrowth forests for otherwise logging-sensitive species such as Leadbeater's Possum. Indeed, data on the habitat requirements of Leadbeater's Possum and other vertebrate species in Mountain Ash forests suggest that the VHRS had the potential to actually create suitable habitat. Hence, as indicated by Smith et al. (1985) and Lindenmayer (1994a), the conservation of Leadbeater's Possum is a rare example where altered silvicultural systems (logging methods not based on traditional clearfelling) could significantly benefit the species."

Source: Lindenmayer (2009, pp.237-8). VHRS, variable retention harvest system. Refer to source publication for embedded references.

Management of Leadbeater's possum since 2008

The system of retained Leadbeater's possum habitat (27,000 ha) identified and protected as part of the Central Highlands Forest Management Plan (NRE 1998) was an important element in managing the possum. In 2008, a Leadbeater's Possum Reserve System was agreed upon, protecting priority areas of habitat. When this reserve was established in February 2009, it comprised 30,500 ha of high-quality Leadbeater's possum habitat. A total of 127 patches greater than 50 ha in size and containing predominantly old-growth ash forest were incorporated into the reserve system. Areas of old-growth forest were primarily selected because these were likely to provide suitable habitat into the future, compared to areas of 1939 regrowth where the dead hollow-bearing trees were collapsing over time. This new reserve system was based on the earlier reservation of Leadbeater's possum critical habitat (Zone 1A Leadbeater's possum habitat, Table 2). The 127 patches were spread across the range of the species to reduce the risk of large areas being rendered unsuitable due to subsequent wildfire. Areas to be included in the reserve system were assessed independent of their public tenure status. The majority of the reserves (85%) were located in areas that were in formal parks and reserves or existing SPZs within State forest (58% in parks and reserves and 27% in SPZs). Less than 3,000 ha fell within areas available for timber harvesting, reducing to 2,500 ha when unproductive forest was removed; in 2008, these areas were converted to SPZs excluded from timber harvesting (Lumsden et al. 2013, DEPI 2014a).

LPAG (2014a) reported 204,400 ha of potential Leadbeater's possum habitat within the range of the species in the Central Highlands, comprised of 96% ash forest and 4% snowgum woodland. In the Conservation Advice, the 204,400 ha of potential Leadbeater's possum habitat was identified as "suitable forest" for Leadbeater's possum. The lowland floodplain forest habitat used by Leadbeater's possum at Yellingbo is 50 ha. Of the ash forest and snowgum woodland potential habitat, 69% is located in national parks, conservation reserves and State forest SPZs (including the 30,500 ha Leadbeater's Possum Reserve System) or areas excluded from harvesting due to biodiversity and regulatory reasons (Table 3). Other areas of high-quality Leadbeater's possum habitat are excluded from harvesting due to VicForests operational constraints and prescriptions (e.g. Leadbeater's possum habitat zones and prescriptions).

Lumsden et al. (2013) provides estimates of Leadbeater's possum occupancy across conservation reserves and State forest in 2012 using probability models and habitat attributes, based upon a wide set of survey sites across the range of the possum. Modelling of occupancy considered the effects of the 2009 fire. The area of occupancy is reported (Table 4) to be higher in State forest compared with in conservation reserves (including the Leadbeater's Possum

Reserve System). The area modelled as occupied by Leadbeater's possum in State forest includes Zone 1B and 2 habitat; however, the species can also be found in habitat with fewer hollow-bearing trees than the number required to qualify as Zones 1A and 1B (DEPI 2014a).

Table 3 presents the area of the potential Leadbeater's possum habitat reserved and the area available for timber harvesting in the Central Highlands.

Table 3 Area of potential Leadbeater's possum habitat reserved and available for timber harvesting within the range of Leadbeater's possum in the Central Highlands.

Type	Area in hectares	Proportion of range (%)
Area of potential habitat within the range of Leadbeater's possum in the Central Highlands (all ash forests and snowgum woodlands)	204,400	100
National parks and formal reserves	69,200	34
Special Protection Zones (SPZs) – reserves in State forest managed for a range of environmental reasons, including Leadbeater's possum	29,300	14
State forest available for timber harvesting but excluded from harvesting due to biodiversity, regulatory, operational and prescriptive reasons (operational exclusions)	43,300[1]	21
State forest potentially available for timber harvesting (gross harvest area)	62,600	31
Net harvestable area in the 62,600 ha available for timber harvesting[2]	40,988[3]	20
Area of potential habitat that was burnt in 2009	68,000	33[4]
Conservation reserves (national parks, formal reserves and SPZs)	98,500	48

Notes:
1 Exclusions due to operational and prescriptive reasons are estimates only (LPAG 2014a).
2 Net harvestable area: The actual area of the forest harvested (i.e. the area remaining once all of the excluded areas are removed from the Gross Coupe Area). The net harvestable area is generally between 50–70% of the Gross Coupe Area. In other words, 30–50% of the forest within the Gross Coupe Area is generally retained for habitat and other values (LPAG 2014a, p.25).
3 Applying a 34.5% ratio based on historical estimates of unmapped field-validated prescription constraints (including code exclusions and Leadbeater's possum prescriptions) and derived from figures used to calculate the area of State forest potentially available for timber harvesting as discussed in LPAG 2014a (p.59)
4 LPAG (2014a, p.11) reports 34%, but 68,000 ha is 33% of 204,400 ha. This figure is also different from that reported by LPAG (2014b, Appendix 4): 28,400 ha high severity, 26,900 ha low to moderate severity, total burnt 55,300 ha, equalling 27%.
Source: Adapted from Table 1 in LPAG (2014a)

Table 4 Area of predicted Leadbeater's possum habitat in conservation reserves (parks and reserves, including the Leadbeater's Possum Reserve System) and in state forest at two predicted levels of occupancy after the 2009 fire

Probability rate	Conservation reserves ha (%)	State forest ha (%)	Total (ha)
> 50% probability of occupancy	15,243 (43%)	20,521 (57%)	35,764 (100%)
> 30% probability of occupancy	32,582 (35%)	61,243 (65%)	93,825 (100%)

Note: No tabular information on the areas of 65% and 85% probability occupancy could be found, although 65% occupancy is used in the new prescriptions.
Source: Lumsden et al. (2013, p.25); % figures calculated and included for this briefing note.

The updated Leadbeater's Possum Action Plan (DEPI 2014a) outlines strategies that have previously been used to maintain or manage Leadbeater's possum colonies:

- Supplementary feeding trials in 2009-2011 following the 2009 wildfire in the Central Highlands was successfully applied in refugia areas to support populations.

- Nest boxes have been used to increase den site availability in lowland swamp forest at Yellingbo and in sub-alpine woodland at Lake Mountain and Mount Bullfight; the success of nest boxes has been variable in montane ash forest. The nest box strategy is used strategically to supplement den sites and reduce the likelihood of territory abandonment from hollow-tree loss, and also to reduce the risk of habitat impacts caused by further wildfire.
- Translocations to new areas have been trialled and found unsuccessful to date for a range of reasons.
- Research into alternative harvesting silviculture regimes (retention harvesting) and the impact on fauna and fauna habitat, including retention of habitat components to support Leadbeater's possum, commenced in 2003. The research sites were affected by the 2009 fires as discussed in Lindenmayer (2009).

Two further actions are being taken in addition to the above:

- As an alternative to nest-boxes, artificial hollows have been created in regrowth forest resulting from the 1939 fires, with a current research trial involving four hollows at each of four sites being monitored by automatic cameras.
- Concurrently, VicForests is implementing 'retention regrowth silviculture' developed from the Tasmanian Variable Retention prescriptions as a replacement for clearfelling in montane ash forests across the Central Highlands.

Appendix F contains an extract of the Actions arising from the updated Leadbeater's Possum Action Statement (DEPI 2014a). There is significant commonality between the actions outlined in the new Action Plan and the actions and guidelines associated with the 1997 Recovery Plan, Central Highlands Forest Management Plan and Regional Forest Agreement. The effectiveness of actions outlined in the new Action Statement will be reviewed in 2017. The Victorian Government (2014) reported on implementation after six months; Appendix G provides an extract of these implementation details. The Plan incorporated strategies proposed in Lindenmayer et al. (2013).

As a consequence of the population reduction of Leadbeater's possum following the 2009 fires, management prescriptions applying to Leadbeater's possum changed in 2014 (refer to Appendix F for a detailed description and explanation of changes). These changes included:

- A 200 metre radius (12.57 ha) timber harvesting exclusion zone (SPZ) centred on verified colonies (DELWP 2015).
- Delay harvesting of areas until June 2016 where the ARI 2013 occupancy model (Lumsden et al. 2013) predicts a high probability of occupancy (greater than 0.65 probability), and undertake targeted surveys of Leadbeater's possum in such areas associated with VicForests' harvest plan.
- Change the definition of Zone 1A habitat from 12 hollow-bearing trees per 3 ha to 10 hollow-bearing trees per 3 ha in patches greater than 3 ha.
- Special attention should be given to the protection of currently living nest trees. Protective measures to aid the continuing survival of nest trees on logging coupes should be used, including the use of fire retardants and the provision of fire breaks around such trees. Hollow-bearing trees should not be felled for seed collection.
- Undertake an inventory to improve the understanding of the extent of Zone 1A habitat, building upon previous assessments. There is currently no spatial layer that maps the extent and distribution of Zone 1A habitat across the range of Leadbeater's Possum, due to the difficulty in remotely mapping mature or senescent hollow-bearing trees.

- Protect from timber harvesting operations at least 30% of the ash forest in each Leadbeater's Possum Management Unit (LMU) within the range of Leadbeater's possum to allow this forest to develop into old-growth forest. An additional 274 hectares of ash forest would be required to be protected in two LMUs.
- From July 2014, apply retention harvesting in at least 50% of the area of ash harvested within the Leadbeater's possum range. Specific silvicultural guidelines for retention harvesting are still to be developed and implemented.
- Investigate alternatives to high-intensity regeneration burns linked to post-burn retention harvest criteria.
- Developing strategies applying to the management of fire, translocation and reestablishment of populations, and research into accelerated hollow development and use of nest boxes.

The Leadbeater's Possum Advisory Group (LPAG) undertook a considered analysis (LPAG 2014a, b). However, given its terms of reference (LPAG 2014b, pp.22-23), its approach was primarily to focus on the 62,600 ha of potential Leadbeater's possum habitat available for timber harvesting, which is 31% of the total potential habitat (Table 3). The remaining 69% of potential Leadbeater's habitat, which includes a component of 48% on the conservation estate, was given secondary consideration. LPAG therefore proposed a package of actions primarily (but not exclusively) focused on the management of Leadbeater's possum in forests available for timber harvesting. This translated into the actions in the updated Leadbeater's Possum Action Statement (DEPI 2014a). As an example, the action requiring new surveys for Leadbeater's possum colonies appears to be concentrated on forests available for harvesting rather than across the whole of its potential habitat (LPAG 2014a).

While some of the actions proposed in LPAG (2014b) and presented in DEPI (2014a) relate to the conservation estate (conservation reserves and SPZs), there is a deficiency in the knowledge base on conservation reserves and the performance of these reserves for the conservation and management of Leadbeater's possum. The importance of the 69% of potential Leadbeater's habitat outside of the forests available for harvesting appears to be relatively unknown or not reported. This paucity of information was not acknowledged in the Conservation Advice (TSSC 2015), and may have led to the focus of the Conservation Advice on forests available for timber harvesting, and thus to the focus on the threat from harvesting.

The updated recovery plan recommended in the Conservation Advice needs to address the deficiency of knowledge and information about Leadbeater's possum and its habitat on conservation reserves, and about the performance of these reserves for the conservation and management of Leadbeater's possum. For example, LPAG (2014a, p.61) highlights the following issue:

> "There is no comprehensive, current spatial layer showing the location of hollow-bearing trees across the range of Leadbeater's Possum. As a result it is not possible to map the extent of Zone 1A or 1B Leadbeater's Possum habitat, nor assess how the area would vary under different definitions of Zone 1 habitat. As protecting high-quality Leadbeater's Possum habitat is a key action to support the recovery of Leadbeater's Possum, it was important to have a way of at least broadly assessing potential actions relating to habitat zones."

Such information is fundamentally important for the conservation management and recovery of Leadbeater's possum. The production of accurate spatial information across the entire potential habitat for Leadbeater's possum needs to be a priority, and this should be included as an action in the updated recovery plan.

Long-term and short-term population changes: responses to 2009 fire and forest development

Leadbeater's possum is killed by fire and its habitat changes under any fire intensity. Following the 2009 fires in the Victorian Central Highlands, no Leadbeater's possum were detected at any burnt site (LPAG 2014a, SEW 2014). A few Leadbeater's possum colonies did survive in some unburnt refugia within burnt areas, although these colonies may be susceptible to predator pressure.

The 2009 fires thus had a substantial effect on the Leadbeater's possum population, directly removing the possum from forests where it was known to occur, including effectively all of the Lake Mountain population, and burning 33% of the 204,400 ha of potential Leadbeater's possum habitat (Table 3). Lumsden et al. (2013) reports 36% of potential ash forest habitat being burnt. A higher proportion (45%) of habitat in the Leadbeater's Possum Reserve System was burnt (see references in Lumsden et al. 2013).

The 2009 fires also significantly impacted the provision of the hollow-bearing trees in which Leadbeater's possum nest. On one hand, the burnt old-growth forest in the O'Shannassy catchment is predicted to become excellent habitat in 10-15 years time when a wattle understorey has developed under the overstorey of large dead trees (SEW 2014). On the other hand, large areas of 1939 regrowth forest that were burnt in 2009 will now no longer grow on to old-growth status, and furthermore are believed not to have contained trees of sufficient size to produce dead stags with suitable hollows for Leadbeater's possum: such areas will therefore not be suitable habitat for a long time without management intervention.

Survey techniques: Measuring population size and extent

Leadbeater's possum is nocturnal, shy, fast-moving and usually confined to the forest canopy, sub-canopy or understorey, and its habitat can make it very difficult to observe. DELWP (2015) provides a good description of the advantages and disadvantages of the survey techniques used for Leadbeater's possum. There are currently two methods: the older technique of stag-watching, which is very labour intensive, and the more recent technique of call playback/thermal imaging/spot-lighting (DELWP 2015). Although the methods may detect similar trends in Leadbeater's possum populations, and similar impacts of fire, their results are not directly comparable, and data from the two methods cannot be aggregated to give population trends across combined sites or sample periods or provide an accurate estimate of total spatial distribution. Neither method has yet been used to estimate the total population of Leadbeater's possum, across the whole of its range and on forest of all tenures or management intent.

Stag-watching surveys have been used by Lindenmayer and colleagues (DELWP 2015). This work led to a large body of data on nest (den) tree requirements for the Leadbeater's possum populations monitored in this way, and demonstrated the impacts of fire on the species. In contrast, the call playback/thermal imaging/spot-lighting technique was developed for broad-scale population monitoring of the possum by the Arthur Rylah Institute for Environmental Research (ARI) and described by Lumsden et al. (2013), and can be used at randomly selected sample sites across the range of the species.

Although the call playback/thermal imaging/spot-lighting technique has not yet been used by a range of research groups or replicated over time, it appears for the above reasons to be the technique most suitable for estimating total Leadbeater's possum population size or extent, and

trends. It has however been suggested that call playback may attract individuals from outside their home range (TSSC 2015). Call playback/thermal imaging/spot-lighting has been used to monitor and model populations in the Leadbeater's Possum Reserve system and more generally in broad-scale surveys in 2012. Possums were found in fire refugia areas (>10 ha) and in ash eucalypt and snowgum communities, but not in any areas burnt in the 2009 fires. Lumsden et al. (2013, p.13) report key results of their survey of ash forest as follows:

> "Within ash forests, Leadbeater's Possums were detected in sites varied in age and disturbance history and included old growth stands, multi-aged stands, fire regrowth from wildfires in 1939 and 1983, and logging regrowth 10 – 45 years post-harvest. Sites were generally structurally complex with well-developed tall shrub and tree layers including one or more species of wattle (*Acacia dealbata, A. frigescens, A. obliquinervia*)."

There is no indication of the number of records located in logging regrowth. As Lumsden (SEW 2014) and Lindenmayer (SEW 2014) have reported the occurrence of Leadbeater's possum in logging regrowth, it is important to determine quantitatively the distribution of the species in logging regrowth, and understand the habitat determinants underpinning this distribution.

Presentations at a Leadbeater's Possum Stakeholder Engagement Workshop held in Sep-Oct 2013 (SEW 2014) also provided updates from the three main research groups working on Leadbeater's possum, including coverage of population trends.

The 2013 listing application and the 2015 Conservation Advice (TSSC 2015) present well-accepted information on the life history and habitat of Leadbeater's possum and the impact of the 2009 fires. Population data derived from surveys using the stag-watching method on a set of long-term monitoring sites in the Central Highlands montane ash forests was scaled and used to estimate populations across the montane ash forest. The size of the population on Mt Baw Baw is acknowledged to be unknown.

However, at times the 2013 listing application and the 2015 Conservation Advice appear to assume that the measured population, and/or the population impacted by the 2009 fires, and/or the population in the high-quality habitat in the Leadbeater's Possum Reserve System, represents the total population. For example:

> "The 2009 Black Saturday fire burnt 45% of high quality Leadbeater's Possum habitat (...). Post-fire the species has not been detected at burnt sites (Lindenmayer et al. 2013). Thus, the total population is likely to have been reduced by at least 45% following the 2009 fires."[9]

whereas, as shown on Table 3, the area of total potential habitat that was burnt in the 2009 fires was 33%[10].

The listing application and Conservation Advice do not present an estimate of total population numbers following the 2009 fires.

The only total population estimates presented are for the main (montane ash) population (2000 mature individuals) and the minor Yellingbo population (200 individuals) before the 2009 fires, as reported by Menkhorst (2008), but before use of the call playback/thermal imaging/spot-lighting survey method. The Conservation Advice also reports the "crude" estimate of Lindenmayer et al. (pers. comm. 2014a) of a total population of 3,125 animals based

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[9] Page 7 Nomination Form –Leadbeater's possum 2013/14; embedded reference not in reference list. Redacted text excluded as (...). http://www.environment.gov.au/system/files/pages/d6892718-d1f0-4ca9-acbc-682ba441116f/files/gymnobelideus-leadbeateri-nomination-form.pdf

[10] Reported by LPAG (2014a) as 34%.

on an estimated 2,225 ha of suitable habitat and the long-term mean abundance of animals in suitable forest of 1.4 animals/ha (TSSC 2015).

However, the call playback/thermal imaging/spot-lighting technique described in 2013 (Lumsden et al. 2013, DELWP 2015) estimated a population after the 2009 fires of 1,500-5,500 colonies, 1,500-5,500 breeding females and 5,000-11,000 individuals, from sampling across forest in the Central Highlands (Lumsden L, presentation at Leadbeater's Possum Stakeholder Engagement Workshop, SEW 2014). This is a much larger number of individuals than estimated from the stag-watching technique, but the new method, while a significant step forward, has not been used to sample the entire range of the species (Lumsden et al. 2013).

As noted above, determination of trends from comparison of numbers from the two techniques would be invalid, and the new data from Lumsden et al. (2013) cannot be concluded to represent a population increase, even if it is a more accurate measure. The Conservation Advice (TSSC 2015) acknowledges that these population data are estimates.

Modelling of population size

Population Viability Analysis (PVA) can bring together the habitat and demographic variables that influence a species, and predict trends in populations over time under a variety of assumptions. A recent PVA (Lumsden et al. 2013) modelled the Leadbeater's possum population for 280 years in the 30,000 ha of the reserve system in the Central Highlands known as the Leadbeater's Possum Reserve System. Leadbeater's possum populations occurring outside of the Leadbeater's Possum Reserve System were not included in the PVA assessment.

The analysis requires a large number of assumptions about the biology of the species and forest development, and its main value may be to identify the critical variables for future research. Nevertheless, the analysis shows major multi-decadal trends that give context to the loss of habitat and populations in the 2009 fires. These trends track the development and loss of appropriate forest habitat (specifically hollow-bearing trees in forest that has had a sufficiently recent fire to contain a wattle understorey), overlaid with the direct impact of individual fires.

The analysis showed that Leadbeater's possum populations in the Leadbeater's Possum Reserve System varied as follows:

- unknown population level before the 1939 fires
- very low population after the 1939 fires
- low population until the 1970s, then increasing to a level higher than the estimated pre-1939 level with a peak around 3,500 adult females in the mid-1990s, then decreasing in population since the year 2000
- population halved as a result of the 2009 fires
- population continues to decline towards a low value (several hundred adult females) around the year 2070 because of continued loss of hollow-bearing trees
- population starts to recover after the year 2070, assuming no further extensive fires over this time.

The analysis suggests that there was a peak of about 3,500 female adults (thus 3,500 colonies, and a proportionately higher total number of individuals) in the Leadbeater's Possum Reserve System around the mid-1990s, and predicts a minimum of about 750 female adults in the Leadbeater's Possum Reserve System in about the year 2070. This is a predicted decrease of

about 80% over 75 years. The decrease over the 14-year period from 1997 to 2011 (the 14-year period showing the largest decrease, and including the 2009 fires) is predicted to be around 50%.

Incorporation into the modelling of a potential future accelerated decline in hollow-bearing trees reduces the predicted minimum population size in the year 2070, as does incorporation of further large fires in the Leadbeater's Possum Reserve System over this period. Lumsden et al. (2013) noted that "The population is highly sensitive to an accelerated loss of hollow-bearing trees and future wildfires."

The Leadbeater's Possum Reserve System is a core part of the known range of the species but by no means its total range. Predictions for entire Leadbeater's possum population could be buffered by simultaneous changes in populations in other parts of the total range of the species as forest develops, ages and burns in those areas.

Timber harvesting is not permitted in reserves through the Central Highlands, including in the Leadbeater's Possum Reserve System. No data were incorporated into the PVA on the area of current or potential habitat that may be subject to harvesting operations over time, and thus the potential relative impact of forestry operations cannot be quantitatively assessed from the PVA model. Historical logging, especially salvage logging dating from 1939, may have significantly reduced the number of hollow-bearing trees in some areas. Changes in Leadbeater's possum populations caused by forest development, ageing and fire occur across the range of the species independent of tenure or forest management.

It can be concluded that the conditions underpinning the changes in Leadbeater's possum populations are well understood. The population trends shown in the PVA mostly result from the shortage of hollow-bearing trees that is predicted to occur from 2064 to 2084 and to persist beyond 2100, as discussed previously. The impacts of fire also persist for many decades, but Leadbeater's possum populations will increase at various times after fire depending on the nature of the forest that was burnt, successful dispersal into previously burnt areas, regrowth of wattle, and the overall frequency and extent of wildfires (the fire regime) across the Central Highlands.

LPAG (2014a, p.13) provided the following comment on the notable and anticipated decline in Leadbeater's possum over the next 70 years: "it is considered that the estimated population size is large enough to provide opportunities for recovery of the species during this period, assuming that required actions can be implemented soon enough and that threats can be adequately managed."

Critique of the calculations and numerical approaches in the Conservation Advice

In Conservation Advice issued 22 April 2015 (TSSC 2015), Leadbeater's Possum was listed by the Threatened Species Scientific Committee (TSSC) as Critically Endangered under Criterion A2(C) and Criterion A3(C), but not various other criteria (Box 3).

Box 3 Extracts from 2015 Conservation Advice in regards to Leadbeater's Possum

p.1

Conservation status – Critically Endangered (Criterion 1:A2(c), A3(c))

Leadbeater's possum has been found to be eligible for listing under the following categories:

Criterion 1: A2 (c), A3(c): Critically Endangered

Criterion 2: B2 (a)(b)(iii)(iv)(v); Endangered

Criterion 3: B (a)(b)(iii)(iv)(v); Endangered

Criterion 5: (c); Vulnerable

The highest category for which Leadbeater's possum is eligible to be listed is Critically Endangered.

p.8

…thresholds for population size reduction of very severe 80%, severe 50% or substantial 30% are applicable and these thresholds equate to listing categories of critically endangered, endangered and vulnerable respectively.

Source: TSSC (2015)

Listing under Criteria A2(C) and A3(C) requires (using condensed language, and accepting 6 years as the generation time for Leadbeater's Possum[11]):

- a reduction in population size of ≥80% over the last [A2(C)] or the next [A3(C)] 18 years
- with population assessment being based on a reduction in area of occupancy, extent of occurrence or in habitat quality
- and where the reduction or its causes have not ceased or may not be reversible.

Criteria A2(C) and A3(C) appear to be the most appropriate criteria for assessment in regards to any change in the conservation status of Leadbeater's Possum, and only the calculations under these criteria will be considered here.

The analysis in the Conservation Advice (TSSC 2015) is based on three primary causes:

- decline in habitat quality due to loss of hollow-bearing trees
- decline as a result of fire
- decline as a result of harvesting, primarily clearfelling.

The Conservation Advice concluded that the area of suitable habitat for Leadbeater's Possum reduced by 81-83% over the period 1995-2013, and predicted that the area of suitable habitat would reduce by a further 77-87% over the period 2013-2031. However, there are a number of inappropriate numerical approaches and unrealistic assumptions in the calculations and modelling in the Conservation Advice, and some calculations use unpublished data or data not publically available. These issues are laid out in detail in Appendix A.

In summary:

- Criteria A2 and A3 are both applied across an 18-year period, this being the value accepted for three generations for Leadbeater's Possum. However, the proportional losses from the individual threatening processes are determined or presented over a number of different periods, variously 4 years, 13 years, 16 years, 18 years and 24 years depending on the data

[11] Generation length was taken as 4.5 years in the listing nomination, and three generations as 14 years; in the Conservation Advice, generation length is taken as 6 years and three generations is taken as 18 years.

source, then combined directly into an overall calculated loss without first correcting each to an 18-year period.

- The Conservation Advice combines appropriately data for habitat loss from the three threats, which are individually presented either as absolute areas or proportions of a baseline area, to minimise double-counting or triple-counting of losses, but not always successfully. Predicted future losses of habitat derived as proportions have been correctly combined by multiplication as independent losses in the analysis for Criterion A3. However, in the analysis for Criterion A2(a) v1, losses of habitat each expressed as hectares lost from the total area are summed as though the calculated area losses do not overlap, when in fact the metrics for each area loss will overlap, giving a component of multiple counting - for example, in the analysis for this criterion the area of hollow loss calculated for the total baseline area is subtracted from the area of habitat surviving fire and harvesting, without allowing for the overlap in these areas. A more considered approach, effectively as used in the Conservation Advice in Analysis A2b, would be to assume that losses from fire and harvesting do not overlap (i.e. that there is no harvesting in burnt areas, and no fire losses to areas already harvested) and thus can be summed as area figures, but that the proportional losses of hollow-bearing trees are independent of losses from fire and harvesting and are best incorporated by multiplication.
- The Conservation Advice concluded that the habitat loss for Leadbeater's possum over the period 1995-2013 was either 44-67% (Analysis A2b) or 81-83% (Analysis A2a), then preferred Analysis A2a (a critique of this preference is given below). Recalculation to express these losses over a consistent 18-year period, and combining the various loss types in ways that do not lead to multiple-counting, give estimated habitat losses over the period 1995-2013 of 71% for Analysis A2a and 55-67% for Analysis A2b, or if no preference is shown between these analyses a combined range of habitat loss of 55-71% (see Table A.2).
- For Criterion A2, covering the period up to 2013, the Conservation Advice preferred Analysis A2a (which used as baseline the 11,470 ha of 'suitable habitat' communicated in Lindenmayer et al. (2014a) pers. comm., and the set of loss figures also from Lindenmayer et al. (2014a pers. comm.), over Analysis A2b (which used as baseline the 204,400 ha of 'suitable forest' sourced from VicForests and LPAG data, and figures for loss of hollows from Lindenmayer et al. (2004a) pers. comm. but loss figures from VicForests and the Victorian state government for losses due to fire and harvesting). The Conservation Advice makes this preference on the basis that 'suitable habitat' is more closely aligned with the possum's area of occupancy than is total 'suitable forest'. However, the difference in proportional loss of habitat calculated by the two approaches is not in fact due to the different baselines used in each case – rather, it is due to the different proportional losses due to fire, harvesting and hollows loss applied in the two cases. However, the Conservation Advice does not give a reason why the figures from Lindenmayer et al. (2014a) pers. comm. for the proportion of fire and harvesting loss in 'suitable habitat' are more accurate than the figures from VicForests and LPAG for the proportion of fire and harvesting loss in the broader category of 'suitable forest'.
- This issue is particularly a problem as the 'predicted suitable habitat' of Lindenmayer et al. (2014a) pers. comm. for 1989 (11,470 ha) is a much smaller area than the area modelled by Lumsden et al. (2013) for the possum based on broad surveys, even after the 2009 fires (total 'likely occupancy' of 35,764 ha). The 'predicted suitable habitat' of Lindenmayer et al. (2014a) at 2013 is a smaller area yet, 2,225 ha.
- Calculations in the Conservation Advice for the analysis in Criterion A3, covering the 18 years from 2013 to 2031, require additional assumptions over those for the analysis in Criterion A2. Some of these assumptions are questionable. The assumptions include:

a) not incorporating the most recently published rate of hollows loss that appears to be most appropriate for predictions of future loss of hollows, as used in the work of Burns et al. (2014)
b) assuming fire frequencies much higher than historical. The "35% fire scenario" used in the Conservation Advice is equivalent to a fire of the impact of the 2009 fires once every 18 years. The "50% fire scenario" also used in the Conservation Advice assumes a still greater fire impact. The "12.5% fire scenario" considered but not adopted in the Conservation Advice is most similar to historical fire frequency and impact
c) harvesting at unrealistic levels. One of the scenarios maintained in the Conservation Advice would require harvesting of all available montane ash forest in the Central Highlands over the next 18 years, which would not be permitted under the current code of forest practice system in Victoria or the Central Highlands Forest Management Plan
d) harvesting to occur in reserves. This appears to be an error in the analysis in the Conservation Advice using the area data of Lumsden et al. (2013) for the application of "theoretical harvests" from 2013 to 2031. The Conservation Advice applied various harvesting scenarios to the 15,000 ha of habitat estimated by Lumsden et al. (2013) to be occupied at 2013, even though this is the 'likely occupied' habitat in parks and reserves – but ignored the 'likely occupied' habitat on State forest of 20,521 ha (see Table 4 of Lumsden et al. 2013[12])
e) lack of consideration of prescriptions to mitigate harvesting impacts. A large number of prescriptions are applied during harvesting on State forest, designed to mitigate harvesting impacts on Leadbeater's possum, as established as part of the Central Highlands Regional Forest Agreement, subsequently expanded as a result of the recommendations of the Leadbeater's Possum Advisory Group, and as detailed in the 2014 Action Statement for Leadbeater's Possum. At various points the Conservation Advice makes statements such as (p.13) "These reductions in harvesting activities are expected to reduce the impact of harvesting beyond 2014, however estimates of the level of reduction relative to the baselines of the above analyses are not quantifiable", (p.20) "While some habitat trees may remain in clearfelled areas, it is unlikely that these areas are suitable for long term viability (Lindenmayer et al., 1993a) and therefore areas identified for future clearfell harvesting are likely to represent a level of projected and inferred future Leadbeater's possum habitat decline", and (p.48) "The Committee notes that under future management this is unlikely to be the case, but the result of these theoretical harvests are provided in Table 8 for consideration of the potential loss without the application of future proposed management change", and proceeds as though these prescriptions have no mitigating impact . It is difficult to contemplate how the theoretical harvest loss scenarios used in the Conservation Advice could apply in reality to State forest, given the range of mitigation prescriptions in place.

- The Conservation Advice concluded that the likely habitat loss for Leadbeater's possum over the period 2013-2013 was 77-87% (Analysis A3). Recalculation to express these losses over a consistent 18-year period, and inclusion of realistic assumptions in place of the assumptions critiqued above, gives habitat loss over the period 2013-2013 of 49-50% (see Table A.2).

[12] Reproduced as Table 3 in this briefing note.

These recalculations are summarised in Table A.2. The Conservation Advice concluded that the area of suitable habitat for Leadbeater's Possum reduced by 81-83% over the period 1995-2013, and predicted that the area of suitable habitat would reduce by a further 77-87% over the period 2013-2031. These recalculations conclude that the area of suitable habitat for Leadbeater's Possum reduced by 55-71% over the period 1995-2013, and predicted that the area of suitable habitat would reduce by a further 49-50% over the period 2013-2031[13].

Use of data in the Conservation Advice

A large number of publications from key researchers on Leadbeater's possum are referenced in the Conservation Advice.

However, a substantial portion of the numerical data used in the Conservation Advice to determine whether the reduction in habitat does or does not exceed the 80% threshold required for relisting the species as Critically Endangered, is contained in Lindenmayer et al. (2014a) pers. comm. – a reference that is not publically available or peer reviewed. This personal communication provides all the data used in Analysis A2a, and the data on loss of hollows (the top-ranked threat in terms of proportion of habitat affected) used in Analysis A2b and Analysis A3. Harvest data and projections provided in VicForests (2014) pers. comm. and used in Analysis A2b and Analysis A3 are also not publically available. Lindenmayer et al. (2014b) pers. comm. is also not publically available.

In regard to loss of hollow-bearing trees, the major threat to Leadbeater's Possum, the data provided in Lindenmayer et al. (2014a) pers. comm. and used in the Conservation Advice may have been derived, at least in part, from data published in a number of referenced papers, although the basis of the calculation is not made clear. The range of annual hollow loss rates used is presented in Table A.1. However, the Conservation Advice does not appear to use the most recent data for predicting future hollow numbers over long periods of future time, which is the paper of Burns et al. (2014). This paper presented projections for hollows loss across a range of scenarios for the period 2011 to 2067, presumably as an integration of previous data. The annual rate presented by Burns et al. (2014) for the no-fire, no-harvesting scenario is also shown in Table A.1 and was used in the recalculation of Analysis A3 in this briefing note. The rate of loss of hollow-bearing trees would vary by age cohort (1939 regrowth, other fire cohorts, mature forest and old-growth) and between live and dead trees, with these proportions varying across the conservation and production forest estate, but these differences are not discussed.

The Conservation Advice does not discuss the management arrangements in place for managing Leadbeater's Possum in conservation reserves and State forests in Central Highlands of Victoria. The significant body of work that resulted from the biodiversity assessment in the Comprehensive Regional Assessment (CVRFASC 1997a) leading to the Central Highlands Regional Forest Agreement and resultant Central Highlands Forest Management Plan (DNRE 1998) was not referred to. Alternative possible areas of occupancy at the start of the 18-year period up to 2013, such as the RFA 'critical habitat' of approximately 27,000 ha determined in 1997, were not used in any analysis for Criterion A2 in the Conservation Advice (TSSC 2015).

Management arrangements have been in place since the early 1990s (AHC and DCHR 1994) that have determined how, when and where harvesting can occur in forests inhabited by

[13] Calculated reductions in suitable habitat would be even smaller if expressed over 14 years (the period of time for three generations used in the relisting nomination) rather than over 18 years (the period of time for three generations used in the Listing Advice)

Leadbeater's possum. These management arrangements have significantly controlled and managed impacts and threats of timber harvesting to the conservation of Leadbeater's possum whilst providing resources to support a sustainable timber industry. These management prescriptions have been substantially strengthened following the recommendations of the Leadbeater's Possum Advisory Group, which have been incorporated in the 2014 Leadbeater's Possum Action Statement. However, the Conservation Advice also does not consider these more recently identified management and conservation actions or Lindenmayer's preliminary findings regarding the benefit of alternative silviculture (Box 2). The Conservation Advice has also concentrated on forests available for timber harvesting rather than more generally forests likely to contain Leadbeater's possum or that are potential habitat for Leadbeater's possum.

"The most effective way to prevent further decline and rebuild the population"

The most effective way to prevent further decline in Leadbeater's possum and rebuild the population would be to identify threats, assess their scale and impacts, then manage the most significant of these. The Victorian government's 2014 Leadbeater's Possum Action Statement lists four threats: fire, timber harvesting, decline in habitat quality (predominantly loss of hollow-bearing trees), and population fragmentation. A total of 21 "Actions" are planned or being implemented to address these threats and increase our knowledge base about the possum and its habitat.

The Conservation Advice that underpinned listing of Leadbeater's possum as critically endangered considers quantitatively only three threats to Leadbeater's possum: loss of hollow-bearing trees, fire, and harvesting. Only the direct negative effect of fire on possum populations is considered: however, fire has both negative and positive effects on habitat over time, with a certain amount of fire being essential to allow sites to develop future habitat. Harvesting will not proceed either in critical possum habitat or if colonies are present, so has no immediate effect on possum populations. Harvesting can negatively affect the capacity of a site to develop future suitable habitat for the possum; equally, if undertaken with appropriate silviculture on particular sites, it could significantly benefit the possum (Box 2). These subtleties are ignored in the Conservation Advice, with only direct losses of habitat areas due to loss of hollow-bearing trees, fire, and harvesting being calculated and taken as a measure of the threat.

The management actions stated in the Conservation Advice to be 'required' (pp.32-33) for all subpopulations or the montane population cover protection from fire (particularly high-intensity fires), as well as protection from incompatible land development activities, and provision of linkages between disconnected (fragmented) habitat areas. In addition, the non-specific action of "protecting all current and future Leadbeater's possum habitat" is included, which is capable of multiple interpretations. Timber harvesting, and acceleration of hollow development, are not specifically addressed in these management actions.

Box 4 2015 Conservation Advice "box" regarding Leadbeater's Possum

"The Committee considers the most effective way to prevent further decline and rebuild the population of Leadbeater's possum is to cease timber harvesting within montane ash forests of the Central Highlands"

Source: TSSC (2015), page 33

The statement in the boxed text on p.33 of the Conservation Advice (Box 4) does not therefore provide the logical basis for the management actions that the Conservation Advice states are "required", and is not derived in any explicit way from comparison or ranking of three threats

selected for quantitative assessment in the Conservation Advice. The statement contrasts with the comment of Lindenmayer (2009) about how the use of alternative silviculture could benefit the conservation of the possum (Box 2).

It is possible to compare and rank the three threats of loss of hollows, fire and harvesting through the quantitative treatment of their separate impacts on Leadbeater's possum habitat in the calculations in the Conservation Advice (Table 5). In each of Analysis A2a, A2b v1, A2b v2, A3a, A3b and A3c, loss of hollows or fire have the largest impact on habitat, followed by fire or loss of hollows as the second largest impact. In every scenario addressed in the Conservation Advice, harvesting is calculated as causing the smallest loss of habitat of these three threats – and generally by far the smallest loss of habitat, especially if non-permissible harvesting regimes are excluded.

Table 5 The loss of Leadbeater's possum habitat over 18 years calculated as occurring due to the separate impact of three threats

Analysis type	Natural loss of hollows	Fire effect on habitat	Harvesting effect on habitat
Historical threats: figures from Conservation Advice, Analysis A2[1]			
Analysis A2a	6,613 ha	2,397 ha	1,027 ha
Analysis A2b v1	22% (32,265 ha)	27% (55,300 ha)	1.2% (2,440 ha)
Analysis A2b v2	53.7% (78,756 ha)	27% (55,300 ha)	1.2% (2,440 ha)
Future threats: figures from Conservation Advice, Analysis A3[1]			
Analysis A3a	63%	35% or 50%	6.5%, 10.9% or 28.8%[2]
Analysis A3b	63%	35% or 50%	6.5%, 10.9% or 28.8%[2]
Analysis A3c	63%	35% or 50%	6.5%, 10.9% or 28.8%[2]
Future threats: figures recalculated as in Appendix A			
Analysis A3	38.8%	12.5%	<4.2% or <7.0%[3]

1 Figures are as included in the Conservation Advice, not as amended in Appendix A of this briefing note.
2 The figure of 28.8% would require harvesting of all the available ash forest on State forest over an 18-year period, and is not permissible given current prescriptions, management regulations and legislation.
3 The actual impact of harvesting on habitat would be less than the 4.2% or 7.0% figure calculated due to implementation of silvicultural prescriptions.

The quantitative treatment of threats in the Conservation Advice therefore does not support the statement in the boxed text on p.33 of the Conservation Advice (Box 4). There is no evidence or argument and discussion in the Conservation Advice that ceasing timber harvesting of mountain ash forest as expressed in this boxed text will support further conservation of the species.

Lastly, as noted below, Bayesian analysis presented in LPAG (2014a) showed (Table 11 in that reference) that reservation of all Central Highlands forests in a Great Forest National Park and effectively ceasing all timber harvesting gave no additional benefit to Leadbeater's possum (as measured by the probability of "good" conservation status) over a package of other conservation and management actions that included retention harvesting as an alternative silviculture but had a much smaller impact on the timber industry.

Suggested conservation arrangements for managing Leadbeater's possum

Appropriate conservation actions for Leadbeater's possum need to be considered against the threats to this species (see above).

As a spatially dynamic species, Leadbeater's possum requires the ability to colonise new suitable forest habitat as this becomes available. Little is known about this ability, and how it may be constrained in the current fragmented forest and non-forest landscape. An understanding of population dynamics is needed to underpin appropriate management, and will require: on-going population monitoring across the entire range of the species; research on limitations to dispersal; research on how to successfully reintroduce the species to areas that have become suitable habitat; and an understanding of how to promote the persistence and development of hollows and hollow-bearing trees in areas of forest where these are the limiting factor for the species.

In this context, early spatially explicit population viability analysis undertaken by Lindenmayer and Possingham (1996) associated a higher probability of persistence of Leadbeater's possum with forest blocks containing larger patches of old-growth forest, and highlighted the need for a number of such patches across the range of the species. Bekessy et al. (2009) provided a more recent example of the kind of spatially explicit PVA that allows issues of dispersal dynamics, habitat fragmentation and conservation management (in this case, for the Tasmanian wedge-tailed eagle) to be considered.

Loss of hollow-bearing trees is the major quantitative threat to Leadbeater's possum, and managing the species through the predicted minimum in hollow numbers is a major challenge. Use of nest boxes, artificial hollows, and amended silviculture offer one set of management approaches to this challenge, to complement the mitigation of fire impacts on regrowth forests that are the source of future hollow-bearing trees.

Forest fire is a direct threat to the species. An altered fire regime also has the potential to affect the current and future supply of large trees suitable for forming hollows. Increasing the ability to mitigate forest fire impacts on the forests inhabited by Leadbeater's possum and on the future habitat in the remaining unburnt stands of 1939 regrowth, such as through prescribed burning around these areas, is a key conservation action.

Forestry operations in actual or potential Leadbeater's possum habitat are adopting retention silvicultural systems that retain current and potential future hollow-bearing trees, such as the variable retention harvesting approach used successfully in Tasmania (Baker and Read 2011) for mitigating harvesting impacts upon biodiversity. Salvage harvesting after fire is also likely to deplete the hollow-bearing tree resource and special prescriptions are recommended for applying salvage harvesting in potential habitat for Leadbeater's possum.

The role of reserves, and integrated management across all tenures

Lumsden et al. (2013) notes that the Leadbeater's Possum Reserve System alone is not sufficient to ensure the long-term persistence of the species (based on the PVA showing that the population in that reserve system could drop below 500 adult females in certain circumstances). This point is also made in the Conservation Advice (TSSC 2015, p 29):

> "While the reserve system was established to protect priority areas of Leadbeater's possum habitat, the probability analysis of Lumsden et al. (2013) indicate that the reserves system is insufficient to provide for long-term persistence of Leadbeater's possum."

However, no evidence is adduced that an increase in the area of the reserve system across the Central Highlands would enhance the conservation status of Leadbeater's possum. This is a particular concern given an apparent lack of knowledge and monitoring of how the existing reservation system is performing in terms of Leadbeater's possum conservation and management.

A Bayesian Network model was used in LPAG (2014a) to inform the Advisory Group about the consequences of applying individual actions and packages of actions, to the probability of Leadbeater's possum status being in 'good' condition. The greater the likelihood of Leadbeater's possum being in 'good' condition, the more likely is the possum to persist and potentially recover. The model is a conceptual model of the causal relationships between the most significant factors influencing the status of Leadbeater's possum in the Central Highlands, encompassing all ash forest and snowgum woodland habitat and populations. Factors such as actions, threats, population variables and habitat variables were applied to the model's parameters, with values and relative weightings contributed by experts from DEPI and other organisations. The description of the model indicates that the data used to parameterise the model was patchy, generally qualitative, rarely empirical, and often based on expert opinion: Bayesian modelling can incorporate these forms of data, but the validity of model outputs still relates directly to the accuracy of the input data. The results from this model should hence be viewed as indicative and a guide to help understand and conceptualise the complexity of managing and conserving Leadbeater's possum. Further research and incorporation of empirical data based on monitoring impacts from threats and impacts will enable the model to be refined, and will confirm or challenge the assumptions made in the original model (LPAG 2014a).

LPAG (2014a) indicated a preferred package of management actions that together were predicted to substantially increase the probability of Leadbeater's possum status being in 'good' condition, while having a relatively small negative impact on the timber industry. It is noteworthy that the Bayesian analysis presented in LPAG (2014a) showed (Table 11 in that reference) that reservation of all Central Highlands forests in a Great Forest National Park gave no additional benefit to Leadbeater's possum (as measured by the probability of "good" conservation status) over a package of other conservation and management actions that included retention harvesting as an alternative silviculture but had a much smaller impact on the timber industry.

Reservation of an area of forest does not affect the dynamics of the hollows resource in that forest, and does not affect the likelihood of fire in that forest. Indeed, populations in the reserve system were impacted as heavily or more heavily by the 2009 fires as were populations outside the reserve system: the reserve system itself offers no protection from this major threat.
An approach more likely to be successful with Leadbeater's possum, as with all mobile species, is integrated management across all tenures and forest management areas, including but not limited to the reserve system.

Summary

The actions outlined in the Leadbeater's Possum Action Statement (DEPI 2014a) provide a coherent set of appropriate conservation actions for managing Leadbeater's possum. The guidance material on recovery and impact avoidance, and required management actions, provided in the Conservation Advice (pp.30-33) also provides a good basis for the future

management of Leadbeater's Possum. The Conservation Advice also recommends that the existing Leadbeater's Possum Recovery Plan (Macfarlane et al. 1997) be retained and updated, and this approach should be supported as providing an appropriate mechanism for incorporating conservation actions appropriate to the various threats to the species.

In bringing together the actions from the previous Leadbeater's Possum Recovery Plan and the recent Leadbeater's Possum Action Statement in an updated recovery plan for Leadbeater's possum, the following key conservation actions need to be included:

- Addressing the apparent deficiency of knowledge and information about Leadbeater's possum and its habitat on the conservation reserve estate (national parks and SPZs) and the performance of these reserves for the conservation and management of Leadbeater's possum, and determining the habitat determinants underpinning the recently reported occurrence of Leadbeater's possum in logging regrowth (SEW 2014).
- Producing as a priority a comprehensive, accurate and current spatial layer showing the location of hollow-bearing trees across the range of Leadbeater's Possum, for use in mapping the extent of Zone 1A or 1B Leadbeater's Possum habitat and applying prescriptions associated with hollow-bearing trees.
- Modelling suitable future habitat across both the reserve system and the production forest estate, utilising forest models that include response to recent fires, response to logging, and the rate of hollow-tree decline. This is essential for management planning in regard to Leadbeater's possum, including identifying forests for strategic placement of nest boxes or artificial hollows.
- Facilitation of the recovery of populations and colonisation of new suitable habitat, including by on-going research on animal dispersal, the dynamics of hollow-bearing trees, the use of nest-boxes, and the creation of artificial hollows.
- Facilitating management strategies in all tenures with current occupied Leadbeater's possum habitat to alleviate the loss of critical habitat features (hollow-bearing trees and dense acacia understorey) and to allow such management to prolong the suitability of current occupied habitat.
- Investigating the use and strategic placement of "possum bridges" across roads and easements to see if these are able facilitate movement of Leadbeater's possums and recolonisation of new forest habitat and alleviate threats posed by fragmentation.
- Mitigation of potential future fire impacts on the forests inhabited by Leadbeater's possum, such as through prescribed burning around these areas.
- Management of feral cat populations to increase the likelihood of maintaining populations of Leadbeater's possum in fire refugia, and facilitating the recolonisation of new suitable habitat.

These conservation actions for Leadbeater's possum need to be carried out across the various forest types, tenures and uses in the range of the species in an integrated management approach. Population surveys, monitoring, analysis and modelling need to be undertaken across the range of the species, and not just in reserve areas such as those combined into the "Leadbeater's Possum Reserve System", and management actions need to apply equally to the reserve system as to the production estate. Management of populations of Leadbeater's possum over the coming decades and provision of suitable habitat will require co-operation between forest reserve managers and production forest managers, and co-operation between researchers in the variety of interested agencies.

Appendix A: Assumptions and calculations underpinning the listing of Leadbeater's possum as Critically Endangered

Summary

This appendix reviews the assumptions and calculations presented in the Conservation Advice (TSSC 2015) that are the basis for the listing of Leadbeater's possum as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Criteria A2(C) and A3(C) are the criteria used for this relisting in the Conservation Advice, and appear to be the correct criteria for assessing this species. Quantitative estimates were made of the major known threats to this species, namely loss of hollow-bearing trees, fire, and forest harvesting, although predation and forest fragmentation are also threats. However, a significant part of the numerical data used in the calculations was provided to the Threatened Species Scientific Committee as 'personal communications', so cannot be tested directly, only in its application in the Conservation Advice.

The calculations presented under Criterion A2 concluded that Leadbeater's possum experienced an 81-83% loss of habitat over the period 1995-2013, which exceeds the 80% threshold for listing as critically endangered over this historical period. The calculations presented under Criterion A3 concluded that Leadbeater's possum is likely to experience a 77-87% loss of habitat over the period 2013-2031, a figure that was taken as exceeding the 80% threshold for listing as critically endangered over this future period.

However, the calculations presented in the Conservation Advice are confounded by a series of numerical errors and unrealistic assumptions, or use of data that are not publically available. Several of the loss rates are applied over time periods other than the 18 years required as three generations of Leadbeater's possum. Multiple counting of losses occurs. The reason given to prefer the results of the analysis for Criterion A2a over the results of the analysis for Criterion A2b does not relate to difference between the calculations under these criteria. It is not clear why a higher rate of loss of hollows than the recently published figure is used, and unrealistic assumptions are made in regard to future fire areas, and forest harvesting (with harvesting assumed to occur even in reserves, for example). In addition, no consideration is given to any of the prescriptions applied to mitigate the impact of forest harvesting on Leadbeater's possum.

When these errors are corrected and more realistic assumptions made, the total habitat loss over the period 1995 to 2013 under Criterion A2 is estimated to be 55-71%, below the 80% threshold for listing as critically endangered; and the predicted total habitat loss over the period 2013 to 2031 under Criterion A3 is estimated to be 49-50%, again below the 80% threshold for listing as critically endangered[14].

[14] Calculated reductions in suitable habitat would be even smaller if expressed over 14 years (the period of time for three generations used in the relisting nomination) rather than over 18 years (the period of time for three generations used in the Listing Advice)

This appendix first reviews the approach, key assumptions and quantitative basis of the calculations on historical and future Leadbeater's possum habitat presented in the Conservation Advice, then describes the various errors, unrealistic assumptions and use of data not publically available. Revised estimates of loss of historical and future habitat are then presented, calculated using amended numerical inputs, more realistic assumptions, and published data.

Listing criteria

In Conservation Advice issued 22 April 2015, Leadbeater's Possum was listed by the Threatened Species Scientific Committee (TSSC) as Critically Endangered under Criterion A2(C) and Criterion A3(C), but not various other criteria. Criteria A2(C) and A3(C) appear to be the most appropriate criteria for assessment in regards to any change in the conservation status of Leadbeater's Possum, and only the calculations under these criteria will be considered here.

Listing under Criteria A2(C) and A3(C) requires (using condensed language, and accepting 6 years as the generation time for Leadbeater's Possum):

- a reduction in population size of ≥80% over the last 18 years [A2(C)] or the next 18 years [A3(C)]
- with population assessment being based on a reduction in area of occupancy, extent of occurrence and/or quality of habitat
- and where the reduction or its causes have not ceased or may not be reversible.

Criteria A2(C) and A3(C) are shortened to A2 and A3 respectively in the Conservation Advice, as well as this Appendix. Terms such as A2a v1, A2a v2, A2b, A3a, A3b and A3b are used to refer to alternative methods for calculating the reduction in Leadbeater's Possum habitat.

Causes of decline (threats)

Three causes of potential decline in area of occupancy, extent of occurrence and/or quality of habitat for Leadbeater's Possum have been established, and are estimated quantitatively in the Conservation Advice. These are:

- decline in habitat quality due to net loss of hollow-bearing trees ("loss of hollows")
- decline as a result of fire
- decline as a result of forest harvesting.

Other causes of decline that it is less possible to quantitate are predation and forest fragmentation: both of these threats may impact on the successful dispersal of individual Leadbeater's possum to form new colonies and/or recolonise areas of newly suitable habitat (SEW 2014).

Loss of hollows and loss of habitat

The Conservation Advice uses two methods to determine the impact of loss of hollow-bearing trees (hollows), without discussing their relative applicability. At times (e.g. Conservation Advice p.13; TSSC 2015), it is assumed that a certain reduction in hollow number will lead (although perhaps with a time-lag) to a similar reduction in habitat suitability and thus a similar reduction in the area of suitable habitat. At other times (e.g. Conservation Advice p.11, and Appendix 1, p.43; TSSC 2015), data on the proportion of an area where hollows density drops below a given threshold is equated to the proportional reduction in area of suitable habitat. The first approach

may either overestimate or underestimate actual habitat loss, depending on how hollow density and hollow loss processes vary across the suitable habitat, and whether there is a threshold hollow density for habitat to be suitable. The assumptions in the second approach are not stated.

The source of data for the second approach in the Conservation Advice is Lindenmayer et al. (2014a) pers. comm. This is also often the source of data for the first approach.

The rates of loss of hollow-bearing trees used in the calculations in different Criteria can only be compared when these are recalculated as loss per year (Table A.1).

Table A.1 Comparison of hollow loss rates used in the Conservation Advice (TSSC 2015)

Analysis	Reduction in habitat from loss of hollows	Period	Metric	Recalculated as loss per year	Recalculated as loss over 18 years
Past					
Criterion A2a[1]	53.7%	24 years	Area above threshold density	3.17%	43.9%
Criterion A2b[1]	22%	16 years	Hollow density	1.54%	24.4%
	53.7%	24 years	Area above threshold density	3.17%	43.9%
Future					
Criterion A3c[1]	63%	22 years	Hollow density	4.42%	55.7%
Burns et al. (2014)[2]	78.25%	56 years	Hollow density	2.69%	38.8%

1 Data from Lindenmayer et al. (2014a) pers. comm.
2 Burns EL, Lindenmayer DB, Stein J, Blanchard W, McBurney L, Blair D, Banks SC (2014) Ecosystem assessment of mountain ash forest in the Central Highlands of Victoria, south-eastern Australia. Austral Ecology (2014) doi:10.1111/aec.12200

Commencing in 1983, Lindenmayer and co-workers have measured the loss of hollows in dead stags and remaining live old trees in montane ash regrowth forests burnt in the Central Highlands in the 1939 fire. Rates of loss vary over time, with drought, tree size and the extent of other disturbance as important variables; a number of these rates have been published. Hollow loss rates used in the Conservation Advice vary from 1.54% per year to 4.42% per year (Table A.1), with no apparent rationale for these differences.

Burns et al. (2014) published predictions of the loss of hollows in the Central Highlands over the period 2011 to 2067, using the long-term data of Lindenmayer and co-workers. Burns et al. (2014) predicted a drop in hollows from 3.77/ha to 0.82/ha over 56 years in scenarios with no fire or harvesting (as used in the Conservation Advice), equivalent to an average annual loss rate of 2.69% (Table A.1). This appears to be the only available published annual rate appropriate for predicting loss of hollows over relatively long periods of future time. It is used in recalculations for Criterion A3c below.

Fire frequency

Information on historical fire frequency in the Central Highlands is taken from Lumsden et al. (2013), who note that over the last 100 years fires in this region have occurred on average every 10 years. A fire on average every 10 years equates to as 85% probability of at least one fire in the region over an 18-year period (Conservation Advice, p.10; TSSC 2015). However, this "once every 10 years" statistic does not give information about fire size, intensity or impact; widespread, intense fires in the Central Highlands such as in 1939 or 2009 are rarer, having occurred only twice in this region over the last 100 years.

Because fire is probabilistic, the listing sensibly creates scenarios for predicting the likely impact of future fire on Leadbeater's Possum habitat (Conservation Advice, pp.10-11). However, none of the fire scenarios developed could be taken as "conservative", as claimed on p.11 of the Conservation Advice.

The '35% scenario' of the Conservation Advice (35% of habitat burnt in 18 years) is equivalent to a fire on the scale of the 2009 fire once in the 18-year period of interest. This is not consistent with the historical frequency of fires of this intensity, area or impact (twice in the last century, 1939 and 2009), even acknowledging a potential increase in fire risk due to climate change. The '12.5% scenario' (12.5% of habitat burnt in 18 years) can be calculated to be equivalent to 35% of habitat burnt (a 2009-scale fire) every 50.4 years, which is closer to the historical record. The Conservation Advice sensibly discards the non-fire scenario, but selects the 35% and 50% fire scenarios (the latter assuming 50% of habitat burnt in 18 years) to calculate the predicted habitat losses over 18 years (Conservation Advice, Appendix 1; see also Table 2, p.14, TSSC 2015).

Recalculations for Criterion A3 below use the 12.5% scenario for an 18-year period, as this is the closest to the historical evidence. An increased fire frequency due to projected climate change is possible, but the Conservation Advice did not construct any scenario between the '12.5% scenario' and the '35% scenario'.

Harvesting

Unrealistic harvesting levels

The calculations of future habitat losses due to timber harvesting under Criterion A3 in the Conservation Advice apply three scenarios for harvesting over the period 2013-2031. Of these, the third scenario, harvesting all the available ash forest in the Central Highlands (42,260 ha) over 18 years is quite unrealistic as this would not be permitted under codes of forest practice or the Central Highlands Forest Management Plan.

Harvesting modelled to occur in reserves

The proportional losses of habitat due under the harvesting scenarios in Criterion A3 are calculated by dividing the projected harvest areas in each scenario (9,550 ha, 16,050 ha and 42,260 ha) by the total area of unburnt and unharvested montane ash forest as at 2013 (146,600 ha), giving 6.5%, 10.9% and 28.8% proportional losses under the three scenarios. These proportions are then applied (Conservation Advice, Appendix 1, Table 8, p.49; TSSC 2015) to three widely different alternative baseline habitat areas (the 'suitable habitat' of 2,225 ha suggested by Lindenmayer et al. (2014a), the 'likely occupancy' of 15,000 ha taken from Lumsden et al. (2013), and the 'suitable forest' of 146,600 ha calculated from VicForests and LPAG data), to give the areas of each baseline predicted to be lost to harvesting in each scenario. However, under no scenario does this calculation take account of the amount of Leadbeater's Possum habitat that is in reserves within each baseline area. Applying the projected harvesting[15] only to the area of unreserved forest in each baseline, as would occur in practice, would reduce the calculated impact on Leadbeater's Possum habitat by a factor relating to the proportion of Leadbeater's Possum habitat that is in reserves within each baseline area.

[15] Or a higher projected proportion, to account for the 6.5%, 10.9% and 28.8% proportional losses having been calculated on the total area of unburnt and unharvested montane ash forest as at 2013 (146,600 ha), which contains both areas available for harvesting as well as areas not available for harvesting.

The most obvious example of this error is that the 15,000 ha area from Lumsden et al. (2013; reported as 15,243 ha in that reference) used as one of the baselines in Criterion A3 is the area of 'likely occupied' habitat in parks and reserves calculated by those authors, and thus an area completely protected from harvesting. The Conservation Advice appears to have misunderstood the work of Lumsden et al. (2013a), which separately reported the area of likely habitat in parks and reserves (15,243 ha) and the area of likely habitat on State forest (20,521 ha) (see Table 4)[16]. Application of any loss of habitat from this area due to harvesting is thus inappropriate. The recalculation below instead uses as baseline the 35,764 ha total 'occupied habitat' of Lumsden et al. (2013), applies the areas of projected harvesting only to the 20,521 ha 'likely occupied' habitat on State forest, and divides this calculated harvest area by the 35,764 ha total 'occupied habitat' to give the proportion of the baseline impacted by harvesting.

No consideration of prescriptions to mitigate harvesting impacts

A number of prescriptions are applied during harvesting on State forest, designed to mitigate harvesting impacts on Leadbeater's Possum (DEPI 2014). These include a 200 m buffer around identified colonies, a 100 m buffer around old-growth forest, retaining all pre-1900 trees in coupes, not harvesting in coupes with above 10 pre-1900 trees per 3 ha, and implementing retention harvesting instead of clearfelling.

Taken together, these prescriptions are designed to remove impacts of harvesting on existing or potential habitat for Leadbeater's possum. However, scenarios with reduced or zero harvesting impacts are not included in the Conservation Advice. The Conservation Advice (TSSC 2015) on p.13 instead says "These reductions in harvesting activities are expected to reduce the impact of harvesting beyond 2014, however estimates of the level of reduction relative to the baselines of the above analyses are not quantifiable." and proceeds as though these prescriptions have no mitigating impact at all. Similarly, on p.20 the Conservation Advice ignores the current forest management arrangements in the Central Highlands, and uses a 1993 reference to justify the assumption that harvested areas are excluded as habitat indefinitely: "While some habitat trees may remain in clearfelled areas, it is unlikely that these areas are suitable for long term viability (Lindenmayer et al., 1993a) and therefore areas identified for future clearfell harvesting are likely to represent a level of projected and inferred future Leadbeater's possum habitat decline." On the contrary, Lindenmayer (2009, pp.237-8) notes that "the conservation of Leadbeater's Possum is a rare example where altered silvicultural systems (logging methods not based on traditional clearfelling) could significantly benefit the species.".

The use of ratios as measures of proportional decline

Rationale for the use of ratios

The metric for relisting this species is based on a proportional (≥80%) reduction in area of occupancy, occurrence or habitat. Many of the calculations underpinning the Conservation

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[16] Conservation Advice, p.49: "Of the 15,000 ha of habitat estimated by Lumsden et al. (2013) to be occupied at 2013 using occupancy modelling, current strongholds include... Lumsden et al. (2013) note that these areas occur both within the reserve system and outside of these protected areas, however the proportions of these are not described by Lumsden et al. (2013)." This is a mis-interpretation of Lumsden et al. (2013), who calculated the area of likely habitat on State forest as 20,521 ha. The Conservation Advice continues "As some areas occur outside of the protected areas, it is likely that some will be subject to loss due to future harvesting. Of the three harvest loss scenarios of 6.5%, 10.9% and 28.8% are applied to the area estimates of Lumsden et al. (2013), it assumes that this forest is harvested at the same rates as applied generally, with these areas neither avoided nor targeted for harvesting. The Committee notes that under future management this is unlikely to be the case, but the result of these theoretical harvests are provided in Table 8 for consideration of the potential loss without the application of future proposed management change.". The assumed harvests also do not take account of existing land management arrangements.

Advice thus relate to ratios rather than absolute areas. On occasion, and particularly in regard to Criterion A3, the numerical value of the baseline habitat area used is irrelevant, as similar proportional declines are applied to all baseline habitat areas considered.

Problems with the use of ratios

Application of the same proportional loss to different baseline areas assumes that the various baseline areas are equally susceptible to the threatening processes. Thus, for Criterion A3, covering the period from 1995 to 2013, the 'suitable habitat' of 2,225 ha suggested by Lindenmayer et al. (2014a), the 'likely occupancy' of 15,000 ha taken from Lumsden et al. (2013), and the 'suitable forest' of 146,600 ha calculated from VicForests and LPAG data are all assumed to be equally susceptible to hollows loss, and equally susceptible to fire, and equally susceptible to harvesting.

An example of when this is not the case is that the 'likely occupancy' of 15,000 ha taken from Lumsden et al. (2013) (actually, 15,243 ha) refers only to the occupancy of parks and reserves, and so will in fact experience zero loss from harvesting. A more accurate version of this calculation would be (as explained above) to use as a baseline for Criterion A3 the total 'likely occupancy' value of 35,764 ha of Lumsden et al. (2013) as this area covers both reserves and state forests, apply the areas of predicted harvesting only to the non-reserved 20,521 ha part of this area, then divide this calculated harvest area by the 35,764 ha total 'occupied habitat' to give the proportion of the baseline impacted by harvesting. The results of this type of calculation are given below.

For Criterion A2, covering the period up to 2013, the Conservation Advice preferred Analysis A2a (which used as baseline the 11,470 ha of 'suitable habitat' communicated in Lindenmayer et al. (2014a) pers. comm., and one particular set of loss figures) over Analysis A2b (which used as baseline the 204,400 ha of 'suitable forest' sourced from VicForests and LPAG data, and a different set of loss figures). This preference is explained on p.12 of the Conservation Advice as "The Committee considers that predicted suitable habitat is more closely aligned with the possum's area of occupancy. Decline in this area is a more accurate measure of likely decline in Leadbeater's possum." (TSSC 2015). The Conservation Advice is correct that predicted suitable habitat is more closely aligned with the possum's area of occupancy than is the total area of montane ash forest. However, the difference in proportional loss of habitat calculated by the two approaches is not in fact due to the different baselines used in each case – rather, it is due to the different proportional losses due to fire, harvesting and hollows loss applied in the two cases. The calculated proportional loss is greater in Analysis A2a which uses data from Lindenmayer et al. (2014a) pers. comm. for all the three components of habitat loss, and is less in Analysis A2b which uses data from VicForests for fire and harvesting and data from Lindenmayer et al. (2014a) pers. comm. for hollows loss. The Conservation Advice does not give reason why the figures from Lindenmayer et al. (2014a) pers. comm. for the proportion of fire and harvesting loss in 'suitable habitat' are more accurate than the figures from VicForests and LPAG for the proportion of fire and harvesting loss in the broader category of 'suitable forest'.

It is also worth noting that there is evidence that the baseline area of 11,470 ha at 1989 provided in Lindenmayer et al. (2014a) pers. comm. is likely to be a significant underestimate, undermining the preference used (see above) in the Conservation Advice. The surveys of Lumsden et al. (2013) following the 2009 fires detected Leadbeater's possum over a larger area of the Central Highlands than previously known. These authors determined an area of 'likely occupancy' of 35,764 ha at 2013. These results in turn imply a substantially greater area of occupancy before the 2009 fires, either in 1995 at the start of the 18-year period of analysis, or in 1989 as the date to which the baseline data of Lindenmayer et al. (2014a) pers. comm. apply.

Losses calculated from impacts on the smaller area used by Lindenmayer et al. (2014a) pers. comm. are thus less likely to be correct.

Alternative possible areas of occupancy at the start of the 18-year period up to 2013, such as the RFA 'critical habitat' of approximately 27,000 ha determined in 1997 (CVRFASC 1997a; see Table 2 of this briefing note), were not used in any A2 analysis in the Conservation Advice (TSSC 2015).

Recalculation to an 18-year period

Criteria A2 and A3 are both applied across an 18-year period, this being the value accepted for three generations for Leadbeater's Possum. However, the proportional losses from the individual threatening processes are determined or presented over a number of different periods, variously 4 years, 13 years, 16 years, 18 years and 24 years depending on the data source. These proportional losses are then combined directly into an overall calculated loss without first correcting each to an 18-year period.

In the calculations below, the various proportional losses are each separately recalculated to a 18-year period, assuming constant annual rates of loss, and only then combined to give a total loss of habitat for an 18-year period[17].

Combining losses from different sources

In some parts of the analysis, the individual components of habitat loss are derived as absolute areas; in other parts, the individual components of habitat loss are derived directly as proportions of a baseline area. Combining these two approaches into a total figure for habitat loss is not always straightforward. And, although the Conservation Advice notes the need to perform this combination in ways that minimise double-counting or triple-counting of losses, this has not always been achieved.

In Criterion A3, predicted losses of habitat area due to hollows loss, fire and harvesting are all derived as proportions, and are then combined by multiplication as independent losses to give the final proportional loss of habitat (Conservation Advice, Appendix 1, pp.48-49 and Table 8; TSSC 2015).

However, in Criterion A2(a), the version of A2 finally adopted, losses of habitat expressed as hectares lost from the total area are summed, as though the calculated area losses do not overlap – when in fact the metrics for each area loss will overlap. For example, the area of hollow loss calculated for the total baseline area is subtracted from the area of habitat surviving fire and harvesting, without allowing for the overlap in these areas, which is equivalent to applying the full extent of fire only to areas not experiencing loss of hollows (Conservation Advice, Appendix 1, Table 1, p.43; TSSC 2015). This was done in spite of a note under this Table saying "these % estimates attempt to allocate a % loss to each threat independent of each other, and may include some small degree of multiple counting": these losses were not allocated in the Conservation Advice as independent proportions, as required to obviate multiple counting, and in practice the degree of multiple counting was substantial, as calculated below. Multiple

[17] Calculated reductions in suitable habitat would be even smaller if expressed over 14 years (the period of time for three generations used in the relisting nomination) rather than over 18 years (the period of time for three generations used in the Listing Advice)

counting would not occur if the three area losses were expressed as proportions of the baseline area, and combined by multiplication, as occurred in Criterion A3.

A yet more considered approach for Criterion A2a, as used in Analysis A2b of the Conservation Advice (TSSC 2015), would be to assume that losses from fire and harvesting do not overlap (i.e. that all the harvesting occurs in unburnt areas, and there are no fire losses to areas already harvested) and thus can be summed as area figures, but that the proportional losses of hollow-bearing trees occur independent of losses from fire and harvesting and are best incorporated by multiplication. However, this more considered approach has little numerical impact compared to combining all proportional losses by multiplication. These calculations are presented below.

Recalculation of A2, covering past 18 years (1995-2013)

Analysis A2a: 81-83% loss of habitat calculated in the Conservation Advice

This first approach to calculating habitat loss for Leadbeater's Possum over the last 18 years was presented in two alternative versions in the Conservation Advice. Both used data since 1989, that is, used a 24-year period (1989-2013) for the losses. The baseline area used was from Lindenmayer et al. (2014a) pers. comm., in which montane ash forest in Central Highlands totalled 171,200 ha in 1989, with 11,470 ha (6.7%) of this being 'suitable habitat'.

In the first version, Lindenmayer et al. (2014a) pers. comm. estimated suitable habitat at 1989 to be 11,470 ha, and suitable habitat at 2013 to be 2,225 ha, giving a total habitat loss of 80.6% (quoted as 81%: Conservation Advice p.12, Analysis A2a v1; see also p.42; TSSC 2015). Details of the individual calculations for losses due to fire, harvesting and loss of hollow-bearing trees, and how these have been combined are presumably contained in Lindenmayer et al. (2014a) pers. comm., but are not presented in the Conservation Advice. This calculated loss of 81% occurred over 24 years, and can be recalculated as a loss of 71% over an 18-year period.

In the second version, the Conservation Advice presented data for the three separate components of habitat loss, then summed those components before applying them to the area of estimated suitable habitat of 11,470 ha as at 1989 from Lindenmayer et al. (2014a) pers. comm.:

- a reduction in suitable habitat of 6,163 ha due to loss of hollows, from 6.7% of montane ash forest in the Central Highlands (11,470 ha) to 3.1% of montane ash forest in the Central Highlands (5,300 ha), using data from Lindenmayer et al. (2014a) pers. comm. and referring to several papers from these authors. This equates to a 53.7% proportional reduction in habitat area due to loss of hollows
- a reduction in suitable habitat of 2,397 ha due to fire or fire disturbance since 1989 (data provided in Lindenmayer et al. (2014a) pers. comm.). This equates to a 20.9% proportional reduction in habitat area due to loss of hollows
- a reduction in suitable habitat of 1,027 ha due to harvesting (data provided in Lindenmayer et al. (2014a) pers. comm.). This equates to a 9.0% proportional reduction in habitat area due to loss of hollows

These area decreases were summed to give a total habitat loss of 9,587 ha, which equates to 83.6% (quoted as 83%: Conservation Advice p.12; Analysis A2a v2; see also p.42; TSSC 2015) of the estimated suitable habitat of 11,470 ha as at 1989. This calculated loss of 83% occurred over 24 years, and can be recalculated as a loss of 74% over an 18-year period.

However, this loss of 83% was calculated by summing individual area losses as though there would have been no overlap of area lost due to loss of hollows, fire and harvesting, which is incorrect. Performing the calculation by multiplying the losses, assuming them to be independent and overlapping, gives a calculated loss of habitat of 66.7%. Assuming the losses due to fire and harvesting do not overlap (and that they can thus be summed), while assuming the loss of habitat due to hollow loss to be independent (and thus to be combined by multiplication), as is likely to be the case and as is used in Analysis A2b of the Conservation Advice, gives a recalculated reduction in habitat of 67.5%.

Combining these two types of correction (by correcting to 18 years, and by removal of multiple-counting of losses), gives an estimated reduction of habitat of 57% over an 18 year period.

Analysis A2b: 44-67% loss of habitat calculated in the Conservation Advice

This second approach to calculating habitat loss for Leadbeater's possum over the last 18 years used a baseline area of 204,400 ha, being the area of 'suitable forest' (montane ash forest, including snowgum) in the Central Highlands as at 2000 as provided in VicForests pers. comm. (2014). This was taken in the Conservation Advice to be the area of 'suitable forest' as at 1995. This is acceptable, as it is the values of the proportional losses that are important, as well as the time period over which they are calculated and how they are combined, not the exact initial baseline area.

Reductions in habitat were calculated in the Conservation Advice as follows:

- loss by fire of 55,300 ha over the 14-year period 2000-2013, leaving 149,100 ha
- loss to harvesting of 2,440 ha over the period 2009-2013, then leaving 146,660 ha. It is not clear why an estimate of the level of harvesting in 'suitable forest' for the period 2000-2009 was not included, and the total loss calculated as due to harvesting is thus a likely underestimate
- either a 22% loss of hollows in a 16-year period (from 5.1/ha in 1997 to 4.0/ha in 2013, from Lindenmayer et al. (2014a) pers. comm.), taken to equate to a 22% loss of habitat; or a 53.7% loss of habitat with sufficient hollows over 24 years (derived as explained in the comments on A2a, second version, above; data also from Lindenmayer et al. (2014a) pers. comm.) (see Table A.1)

These losses appear to have been combined correctly in Analysis A2b in the Conservation Advice. The two possible values for hollows loss (22% and 53.7%) give rise to the range of total habitat loss calculated in the Conservation Advice (p.12; Analysis A2; see also p.42) of 44-67%.

However, the data used to calculate this habitat loss covered a 14-year period (2000-2013) for fire, a 4-year period for harvesting, and either a 16-year or a 24-year period for hollows loss. Recalculating all these proportional losses separately to 18 years, then combining them, gives an estimated habitat loss of 55-67% over an 18-year period.

Recalculation of A3, covering future 18 years (2013-2031)

Analyses A3a, A3b and A3c used three different baseline areas but applied the same predicted proportional habitat losses to these. These baseline areas were:

- Analysis A3a: baseline of 2,225 ha, being the output from Analysis A2a developed using data of Lindenmayer et al. (2014a) pers. comm.

- Analysis A3b: baseline of 15,000 ha, being the area of 'likely occupancy' in parks and reserves determined by Lumsden et al. (2013)
- Analysis A3c: baseline of 146,660 ha, being the output from Analysis A2b derived in turn from the total suitable forest area in 2000 as provided by VicForests (2014) pers. comm.

Calculations of habitat loss

The three components of habitat loss applied to Analyses A3a, A3b and A3c were derived in the Conservation Advice as follows:

- a reduction in suitable habitat due to loss of hollows of 63% over 22 years, derived from a 63% reduction in hollows density over the period 2013-2035 (Lindenmayer et al. (2014a) pers. comm.)
- a number of fire scenarios involving losses of 0%, 12.5%, 20%, 35% and 50% of habitat over 18 years. The scenario of 0% fire is included on Appendix 1, Table 10, but was not progressed in the Conservation Advice
- three scenarios for reduction in habitat due to harvesting. Harvesting rates from VicForests (2014a) pers. comm. were calculated as giving harvesting impacts of 6.5%, 10.9% and 28.8% of the total area of 'suitable forest' over 18 years.

These proportional losses were combined by multiplication as for independent losses, to give total predicted declines of 70-87% depending on the fire and harvesting scenario adopted (Conservation Advice, Appendix 1, Table 10, p.51; TSSC 2015). The Conservation Advice then argues for the scenarios of 35% or 50% fire being the most likely over the next 18 years, giving predicted declines in habitat of 77-87% over this period.

Recalculation of habitat loss to an 18-year period

The reduction in hollows density used in Analysis A3 was 63% over 22 years. This is equivalent to a loss of 55.7% over an 18-year period. Using this figure gives an estimated total habitat loss over 18 years of 73-84%, rather than 77-87%.

Recalculation using realistic scenarios

A reduction in hollows density of 63% over 22 years, which equates to 55.7% over 18 years, is an average annual loss of 4.42%, greater than any other figure for the rate of loss of hollows used in the Conservation Advice (see Table A.1). The average annual rate of 2.69% loss of hollows used by Burns et al. (2014) for long-term predictions of the loss of hollows in the Central Highlands is thus used here as a more realistic alternative from published data, and gives a loss over an 18-year period of 38.8% (see Table A.1).

A fire scenario of 35% habitat loss is equivalent to a fire on the scale of the 2009 fire once in the 18-year period of interest. This is not consistent with the historical frequency of fires of this intensity, area or impact (twice in the last century, 1939 and 2009), even acknowledging a potential increase in fire risk due to climate change. The fire scenario of 12.5% habitat loss equates to a 2009-scale fire every 50.4 year, closer to the historical record, and is adopted here as a more realistic scenario. An increased fire frequency due to projected climate change is possible, but the Conservation Advice did not construct any scenario between the '12.5% scenario' and the '35% scenario'.

One of the harvesting scenarios (giving a 28.8% loss of the 146,600 ha of montane ash and snowgum forest in the Central Highlands) assumes harvesting over 18 years of all the available ash forest, which is quite unrealistic and would not be permitted under codes of forest practice and the Central Highlands Forest Management Plan. Furthermore, the areas of harvesting

associated with the more realistic harvesting rates of 6.5% (9,550 ha) or 10.9% (16,050 ha) over 18 years should be applied only to the area of forest outside reserves, as Leadbeater's Possum habitat in reserves is not available for harvesting. For example, for the baseline used in Analysis A3b (all of which is reserved forest) the impacts of harvesting would then be 0%. A somewhat better approach is to assume that the projected harvesting of 9,550 ha or 16,050 ha occurs outside the 15,243 ha 'likely occupied' habitat on reserves, and calculate the amount of the 20,521 ha 'likely occupied' habitat on State forest that would be lost by harvesting of 9,550 ha or 16,050 ha across the remaining 131,357 ha of montane ash and snowgum forest in the Central Highlands, in a modified version of Analysis A3c. This approach gives harvesting impacts over 18 years of 4.2% and 7.0% for these two harvesting scenarios, rather than 6.5% and 10.9%. (There is not sufficient information to perform similar calculations for Analysis A3a.)

Moreover, use of these figures for habitat loss due to harvesting assumes that current harvesting prescriptions have no mitigating effect on the impact of harvesting on Leadbeater's Possum habitat on State forest. It is not possible to estimate the extent to which this mitigation of impact occurs (as noted in the Conservation Advice, p.13), but making no allowance is as much an error as assuming complete mitigation of the impacts of harvesting. This issue needs to be dealt with explicitly in interpreting the numerical values of habitat losses calculated.

Combining:

- reduction in suitable habitat due to loss of hollows of 38.8% over 18 years, from Burns et al. (2014)
- fire scenarios involving loss of 12.5% of habitat over 18 years
- a 4.2% or 7.0% reduction in habitat due to harvesting over 18 years

results in an estimate of the predicted overall loss of habitat of 49-50% over an 18-year period.

Conclusions

The calculations presented in the Conservation Advice contain errors of two sorts. Habitat losses over a number of different time periods are combined without first correcting each of these to the 18-year period required by the Criteria. And the different components of habitat loss are at times combined incorrectly, leading to multiple counting of some losses.

When these errors are corrected in Analysis A2, the total habitat loss over the period 1995 to 2013 is reduced from 81-83% in the Conservation Advice, to 55-71% (Table A.2). The final range 55-71% encompasses the outcomes of Analysis A2a v1, A2a v2 and A2b, without expressing preference as to which of these calculations is more likely to be correct. The Conservation Advice prefers Analyses A2a v1 and A2a v2 over Analysis A2b, but the reasons for this may be compromised as discussed earlier in this document (see section above "Problems with the use of ratios").

Correction of errors in Analysis A3 involved both adjusting the hollows loss figures to an 18-year period, and use of more realistic scenarios for each component of habitat loss: a published rate of hollows loss, a fire frequency closer to the historical value, and applying harvesting only to State forest and not also to reserves. When these errors are corrected in Analysis A3, and more realistic assumptions adopted, the total habitat loss predicted over the period 2013 to 2031 is reduced from 77-87% in the Conservation Advice, to 49-50% (Table A.2).

The level of habitat loss predicted for Leadbeater's possum for 2013-2031 would be higher than 49-50% if an increased fire frequency due to climate change was assumed. Alternatively, the

level of habitat loss predicted for 2013-2031 would be lower than 49-50% if prescriptions imposed on harvesting successfully mitigate the impact of harvesting on Leadbeater's possum. However, the reduction in the predicted amount of habitat loss due to silvicultural prescriptions would not be large, as loss of hollow-bearing trees and fire are predicted to cause the majority of habitat loss, rather than forest harvesting.

Table A.2 Summary of habitat loss calculations

Criterion	Analysis	Habitat loss calculated in the Conservation Advice	Correction applied[2]	Corrected habitat loss
Past				
A2	A2a v1	81%	Total loss to 18-year period (insufficient information provided to judge whether individual losses were correctly or incorrectly combined)	71%
	A2a v2	83%	To 18-year period Combining individual losses appropriately Both the above	74% 67.5% 57%
	A2b	44-67%	All individual losses to 18-year period	55-67%
	Range of results	81-83%[1]		55-71%
Future				
A3	A3a-c	77-87%	Loss of hollows to 18-year period Realistic scenarios: published hollows loss rate, the historically likely fire scenario, and applying harvesting only to State forest	73-84% 49-50%
	Range of results	77-87%		49-50%

1 The Conservation Advice prefers Analysis A2a over A2b.

2 Calculated reductions in suitable habitat would be even smaller if expressed over 14 years (the period of time for three generations used in the relisting nomination) rather than over 18 years (the period of time for three generations used in the Listing Advice).

Appendix B: Extracts from Garnett et al. (2003)[18] relating to loss of hollow-bearing trees and the recovery of Leadbeater's possum[19]

...

Status of threat

The 'Loss of hollow bearing trees from Victorian native forests' is listed as a Potentially Threatening Process under the Flora and Fauna Guarantee Act 1988. The 'Continuing net loss of hollow-bearing trees in native forests and woodlands due to firewood harvesting practices' has been nominated and recommended for listing as a Key Threatening Process under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

...

Forest harvesting

Forest management practices that result in a net loss of hollow-bearing trees include timber harvesting, some silvicultural practices and fuel reduction burning. Relative to an undisturbed forest, the number of new hollows formed will be reduced on non-selectively harvested areas (ie clearfall and seedtree systems) because fewer trees grow on and replace old trees as they proceed through various stages of decay and eventual collapse. However, the rate of hollow development may increase as a result of incidental damage to retained trees during harvesting operations. Another consideration is that the survival of retained trees in and beside coupes may be reduced after harvesting through increased exposure and effects of fire used for regeneration. High intensity regeneration burns to promote ash germination can result in premature death of retained trees. However, less intensive regeneration burning in mixed species forests may enhance hollow development. In contrast, in an old forest, the major agents of tree death are fire, fungi and insects, whose effects may interact and increase with old age. These impacts are generally reduced in less intensive, selective harvesting systems such as those applied in mixed species and box ironbark forests where regeneration burning is less likely to take place.

Options available to forest managers to retain hollow densities include varying rotation periods, varying silvicultural systems, retaining areas of high hollow density, retaining existing hollow-bearing trees and trees likely to develop hollows in the future within areas available for harvesting.

Less than a quarter of the total area of State forest across Victoria is available or suitable for timber harvesting. In addition to maintaining a representative reserve system, it is crucial to manage non-reserved areas to ensure that sufficient habitat elements are protected and

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[18] Garnett ST, Loyn RH and Lowe KW (2003) Action Statement No192 Loss of hollow-bearing trees from Victorian native forests and woodlands. Flora and Fauna Guarantee Act 1988. State of Victoria Department of Sustainability and Environment, Melbourne, September.

[19] "..." indicate where text has been omitted in producing the extract

maintained into the future. Key mechanisms for conserving habitat features including hollow-bearing trees within State forest are:

- exclusion or modification of timber harvesting and other disturbances through the application of forest management zones, and/or
- application of prescriptions (rules) governing the way in which these activities are carried out to minimise impacts on habitat values. Forest management zones and prescriptions for the retention of wildlife habitat in State forests are specified in Forest Management Plans and Regional Forest Management Prescriptions, in accordance with the 'Code of Forest Practices for Timber Production' (CFPTP-NRE 1996). Prescriptions vary according to region and forest type.

In relation to hollow-dependent species, the critical factors to consider when developing prescriptions include:

- the habitat requirements of fauna species and their prey, including minimum number, size and type, location of hollow, preferred species and location within the landscape;
- the distribution of hollow-bearing trees taking into account dispersal distances of fauna species;
- the growth stages of the forest to plan for adequate recruitment of hollow-bearing trees over time;
- the forest in the context of the surrounding landscape and existing habitat;
- silvicultural considerations, including adequate regeneration response, and
- operational considerations, including occupational health and safety.

Fire

Severe wildfires can reduce numbers of hollows by killing most of a particular cohort of trees, resulting in a relatively even-aged regrowth with a few old or dead trees. This may create a temporary abundance of hollows as large, fire-killed trees decay, but over the following decades these trees are likely to collapse more quickly than new hollows are formed. This is currently happening in the Central Highlands, where most trees in 65% of the montane ash forests were killed by wildfire in 1939 (Noble 1977; Smith & Woodgate 1985). The subsequent loss of dead hollow-bearing trees in these forests has been estimated at 3.6% per year, as measured over a five year period in the 1980s (Lindenmayer et al. 1990a). Most remaining stags with hollows will collapse in the next 75 years, leaving a period of at least 50 years when there will be a shortage of hollows for Leadbeater's Possum and other arboreal marsupials (Smith and Lindenmayer 1988; Lindenmayer et al. 1990a). The problem exists because trees that germinated after the 1939 fires are not yet old enough to develop hollows.

Fuel reduction burns are fires of low intensity used to remove the fine, more flammable fuel from strategic areas within forests and parks. Variables such as the frequency and intensity of prescribed fire and the forest type may also contribute to the rate of hollow development in trees, and the number and survival of trees with hollows. Ecological burning to achieve biodiversity conservation outcomes may also be a useful tool to alter habitat structure and manage for the loss of hollow-bearing trees.

...

Other management options

Artificial Hollows

There is potential to overcome a scarcity of natural hollows through the provision of artificial hollows and the acceleration of natural hollow development, although the usefulness of artificial hollows, such as next boxes, varies considerably. For instance, the provision of artificial nesting boxes, along with close management of existing natural nesting hollows, is a major component of the recovery program for the endangered Kangaroo Island Glossy Black-Cockatoo (Garnett el al. 2000). Artificial nest boxes were also provided for Red-tailed Black-Cockatoo in south-western Victoria, but with minimal success so far. Turquoise Parrots were reluctant to use nest-boxes but used hollow logs strapped to trees (Quinn & Baker-Gabb 1993). In the Whipstick Forest near Bendigo, Brush-tailed Phascogales *Phascogale tapoatafa* used at least one box in each clump of boxes provided (T. Soderquist pers. comm.). The provision of nest boxes was instrumental in the successful reintroduction of Sugar Gliders to Tower Hill (Suckling & Macfarlane 1983).

Accelerating hollow-development

The rate of natural hollow formation could be artificially accelerated, such as through removal of tree-tops using explosives, inoculation of trees with fungi (Lindenmayer et al. 1991d) or chemicals, artificial establishment of termites, thinning, burning, killing selected trees and direct drilling. A shortage of hollows in regrowth forests resulting from wildfire or past utilisation may be addressed through ecological thinning to promote growth and branch development. It may also be possible to accelerate hollow formation through choice of trees to be used in regeneration or replanting schemes. However, the broad practical application of this process has yet to be demonstrated, and it is likely that, at least initially, it could be applied only in limited specialised circumstances, such as for conserving a highly endangered species. In National Parks and some other reserves, many other factors (e.g. fire, feral bees) may require management to ensure a continuing supply of available hollow trees.

Existing management measures

- ...
- ....
- The Code of Forest Practice for Timber Production 1996 (Code) requires that planning and harvesting operations in native forests specifically address the conservation and protection of flora and fauna values including the protection and provision for recruitment of old trees and strategies for maintaining a mosaic of corridors and zones to enhance conservation values and biodiversity.
- A comprehensive forest management planning framework, which includes Regional Forest Agreements, Forest Management Plans and associated comprehensive adequate and representative reserve systems, and forest management prescriptions, provides for ecologically sustainable management of Victoria's forest resources.
- Forest management prescriptions provide detailed measures for maintenance and protection of State forest habitat values and indicate how they are to be implemented and how they should be varied for particular forest locations.
- In 2001, the State Forest Flora and Fauna Habitat Management Working Group, recommended a series of objectives and principles for a statewide review of prescriptions for the retention of wildlife habitat, including hollow-bearing trees, within the General Management Zone of Victoria's State forests The recommendations of the Working Group

provide for a landscape approach, taking into account harvesting methods, the requirements of key sensitive species and the extent of harvesting within forest landscapes. These principles and objectives will underpin the review of prescriptions for habitat retention across the state.

- ...
- Detailed prescriptions have been developed and implemented for Leadbeater's Possum in montane ash forests (Macfarlane et al. 1995). Under these prescriptions live stands of montane ash forest >120 years old are excluded from logging as well as regrowth ash with >12 hollow-bearing trees/3ha. Veteran old trees are retained on coupes and measures taken to protect them. Trees are also retained to provide hollows in the future, though the optimal pattern and size of retained stands is not yet known and requires further research. Refer to Action Statement
- Research has been conducted on various aspects of hollow-bearing trees for at least 19 wildlife species (Appendix 2).
- Data have already been collected about the incidence of hollows and ground debris from over 3000 State Forest Resource Inventory field plots in State forest throughout Victoria
- Artificial hollows have been erected in numerous forests, often with high occupancy rates (eg Menkhorst 1984a, 1994b; Traill & Lill 1998), including by reintroduced Sugar Gliders (Suckling & Macfarlane 1983) and Brush-tailed Phascogales (T. Soderquist pers. comm.).
- ...

Major Conservation Objectives

Long term objective

To ensure that the conservation status of Victorian fauna is not compromised by a shortage of hollow-bearing trees.

Objectives of this Action Statement

- Significantly reduce the loss of hollow-bearing trees from private land and encourage their retention and replacement.
- Manage parks and State forest to ensure that an appropriate level of hollow-bearing trees is restored and maintained in all forest types.
- Foster an appreciation of the role and importance of hollow-bearing trees in Australian ecosystems.

Intended management actions

The intended management actions listed below are further elaborated in DSE's Actions for Biodiversity Conservation Database. Detailed information about the actions and locations, including priorities, is held in this system and will be provided annually to land managers and other authorities.

Private land and roadsides

1) ...
2) ...

3) Protect hollow-bearing trees and stags on existing roadsides and new alignments, where it is safe to do so. Assess and map stands or isolated trees and incorporate this information early in the planning and execution of road construction and maintenance works.
Responsibility: local government authorities, Vicroads

4) Incorporate information on the location and significance of hollow-bearing trees into Regional Catchment Strategies and Regional Implementation Plans, via Biodiversity Action Plans. Target activity and investment towards the protection of significant areas or stands of hollow-bearing trees.
Responsibility: Catchment Management Authorities

5) ...

6) ...

State forest

14) Continue to identify significant areas or stands of hollow-bearing trees in State forest, using the State Forest Resource Inventory and other relevant information, to inform management decisions.
Responsibility: *DSE Parks and Forests Division, DSE Regions*

15) Continue to implement a range of measures to maintain or enhance the extent and/or density of hollows in State forest where this is known to be limiting the distribution and/or abundance of hollow-dependent species. These measures include:

- Application of management guidelines, including forest management zones and prescriptions, for fauna species as provided in Forest Management Plans (e.g. Lead beaters Possum Special Protection Zones and prescriptions).
- The development and application of revised habitat retention prescriptions for areas within the General Management Zone (GMZ) in accordance with the principles and objectives established by the State Forest Flora and Fauna Habitat Management Working Group.
  Responsibility: *DSE Forests Service, DSE Regions*

Parks and reserves

16) Identify, assess and map significant areas or stands of hollow-bearing trees on parks and reserves, targetting priority species and areas as required.
Responsibility: Parks Victoria

17) Incorporate measures to maintain or enhance the extent and / or density of hollows in park and reserve management plans where this is considered to be limiting the distribution and / or abundance of hollow-dependent species.
Responsibility: Parks Victoria

Research and Monitoring

18) Continue to conduct research, including investigation into the formation of hollows and measures to enhance this process, the use of hollows by hollow-dependent species and the effect of hollow distribution and characteristics on population size and reproductive success in such species.
Responsibility: DSE (Biodiversity and Natural Resources Division)

19) Continue work investigating the use of forest inventory mapping of hollow-bearing trees for developing predictive models of hollow incidence to facilitate appropriate forest management. Initial work has been undertaken (Fox et al. 2001).

20) Develop cost effective methods for monitoring the effectiveness of habitat retention measures on a landscape scale.
Responsibility: DSE (Parks and Forests Service, Biodiversity and Natural Resources)

21) Use the native vegetation permit tracking system to monitor the loss of hollow-bearing trees on private land.
Responsibility: DSE (Regions)

Appendix C: ACTION 7 prescriptions[20]: Logging coupe planning and harvesting (Macfarlane et al. 1997)

Various techniques can be used to maintain and develop Leadbeater's Possum habitat and work towards simultaneous Leadbeater's Possum conservation and timber production.

7.1 **Assessment:** Assessment of proposed logging coupes and roading to validate zoning classification will continue to be undertaken using resource information held on GIS and elsewhere in NRE, aerial photographs, helicopter reconnaissance and ground inspection.

7.2 **Buffer Strips**: Consideration will be given to retaining buffer strips of unlogged forest to avoid creating large areas of continuously logged forest (e.g. > 40 ha coupe conglomerates). These will be most applicable where streamside or other reserves do not form coupe boundaries. These buffer strips will be allowed to grow to ecological maturity (at least 250 years old) and thereby provide hollow trees for Leadbeater's Possum and other hollow-dependent wildlife. The width of buffers should ensure that the health of trees within them is maintained, and allow for continual replacement of hollow trees in the future. The desired width will vary with aspect, position on slope or ridge, and climatic factors. Where possible logging operations should be staggered so that a retained buffer strip is not simultaneously exposed on both sides.

7.3 **Coupe Shape**: The practice of logging variably sized and shaped coupes, interspersed with areas of undisturbed forest, ensures a scattering of different age classes and hence habitat niches throughout the forest. The desired shape of logging coupes to aid Leadbeater's Possum conservation may vary depending on the physical characteristics of vegetation both within and adjacent to the coupe. Coupe shape may change to accommodate the protection of Zone 1A and Zone 1B areas.

7.4 **Protection of Hollow Trees**: Protective measures to aid the continued survival of nest trees on logging coupes will be used, including the use of fire retardants and the bulldozing of fire breaks around such trees. Special attention will be given to the protection of currently living nest trees regardless of zoning classification. Even if these trees die after subsequent fire or exposure they will still provide potential nesting sites for Leadbeater's Possum during the following rotation. Hollow-bearing trees will not be felled for seed collection purposes. Consideration will be given to the protection of groups of >10 retained trees from regeneration burning to minimise windthrow effects.

7.5 **Salvage Logging**: Special plans for salvage logging, required under the Code of Forest Practices for Timber Production (1996), should consider both the number and spatial distribution of hollow-bearing trees and zoned accordingly, especially in areas of Zone 1B. Zone 1A forest will not be salvage logged.

Prescriptions developed for normal logging operations will be adhered to in all areas where salvage logging is undertaken.

7.6 **Adoption and refinement of alternative silvicultural systems** NRE will continue to undertake operational trials of retained overwood silvicultural systems with a view to their

[20] Extracted from Macfarlane *et al.* (1997, p. 27-28)

adoption as an alternative to the current system of clearfelling in selected areas of ash forest within the Central Highlands. Such areas will be selected considering existing and potential habitat within each Leadbeater's Possum Management Unit (LMU).

Appendix D: Extract of Victorian Central Highlands Forest Management Plan (DNRE 1998) guidance relevant managing Leadbeater's possum[21]

Retention of hollow-bearing trees guideline

MANAGEMENT GUIDELINE

Tree retention on timber harvesting coupes

Trees should be retained on timber harvesting coupes to assist in the provision of hollows for hollow dependent wildlife on State forest. The following should be taken into account when the number of existing and potential hollow-bearing trees to be retained on a timber harvesting coupe is determined:

- the species and likely density of hollow-dependent wildlife inhabiting the area
- the existing mix of eucalypt species, their size and the availability of hollows
- the short- and medium-term rarity of hollow-bearing trees within and surrounding the coupe
- the proximity of areas unavailable for timber production (for example streamside reserves, other areas of SPZ or GMZ-other)
- the likelihood of windthrow of retained trees.

On timber harvesting coupes in the Central Highlands:

- all ash eucalypts originating before 1900 should be retained
- at least 40 trees per 10 hectares should be retained for the length of the rotation in ash eucalypt forest originating since 1900, and in all mixed-species forests
- retained trees should be a mixture of:
  - hollow-bearing trees (where present)
  - other trees most likely to develop hollows in short term

Distribution of retained trees:

- In mixed-species forest retained trees should remain scattered across the timber harvesting coupe
- Potential hollow-bearing ash eucalypts should be retained in clumps to increase their protection from exposure, windthrow and fire
- Within 150m of retained vegetation there is no requirement to retain potential hollow-bearing trees (although at least 40 trees per 10 hectares should be retained across the coupe)
- Trees should be retained where they can be most easily protected from damage during harvesting and site preparation treatment.

Extracted from page 16 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

[21] "…" indicate where text has been omitted in producing the extract

Leadbeater's possum guidance and action

Leadbeater's Possum

... The habitat of the species in mountain forests is primarily determined by:

- nest-tree abundance and distribution
- food availability, particularly wattle in the understorey
- vegetation structure which allows the possum to move freely through the forest in search of food.

...

Habitat Classification and Management

The Flora and Fauna Guarantee Action Statement which has been prepared for the species (CNR 1995b) defines the three zones of Leadbeater's Possum habitat.

1. Zone 1A habitat contains living older trees and is expected to be important for the long-term conservation of the species. Zone 1A habitat is protected in either conservation reserves or the SPZ. Appendix L indicates the extent of existing Leadbeater's Possum Zone 1A habitat and ash-eucalypt forest across its known range.

2. Zone 1B habitat currently contains good habitat, but most of the existing hollow-bearing trees are dead and are likely to collapse in the near future. Zone 1B habitat in the GMZ is excluded from timber harvesting until either of the Zone 1B habitat attributes (the presence of dead mature or senescing trees, or wattle understorey) no longer exist.

3. Zone 2 habitat consists of the remaining ash-eucalypt forests.

Table 3.2 defines Zone 1A, Zone 1B and Zone 2 habitat. To promote the development of Zone 1A habitat and mixed-aged forest, NRE will continue research into, and operational trials of, the Retained Overwood silvicultural system in regrowth stands adjacent to stands of veteran trees.

Table 3.2 Leadbeater's Possum habitat Zones

Zone	Density of hollow-bearing trees[1]	Hollow-bearing tree1 type	Wattle density[2]	Management
1A	>12 per 3 ha in patches greater than 3 ha	Living trees containing hollows	n/a	Special Protection Zone
1B	> 12 per 3 ha in patches greater than 10 ha	Dead or living trees containing hollows	> 5 m2/ha	General Management Zone but excluded from timber harvesting while Zone 1B attributes remain.
2	Regrowth ash forest of varying ages; or areas with features of Zone 1A or Zone 1B but <3 ha or 10 ha respectively	n/a	n/a	General Management Zone

Notes: 1. Hollow-bearing trees are Mountain Ash, Alpine Ash or Shining Gum, either living or dead.
2. Density is expressed as basal area - the sum of the cross-sectional area of the boles of the trees.

System of Retained Habitat for Leadbeater's Possum

In accordance with the Action Statement, NRE aims to conserve Leadbeater's Possum over its known range.

The known range of the possum has been divided into 21 Leadbeater's Possum Management Units (LMUs). The LMU boundaries are based on the extent and spatial distribution of ash-eucalypt type forest (see Map 4). LMUs contain between 4 000 ha and 15 000 ha of ash-type forest with an average of 7940 ha (see Appendix L). They are composed of one or more adjacent forest management blocks, containing contiguous patches of ash-eucalypt forest. The target for the conservation of Leadbeater's Possum is to maintain viable populations of the species in all LMUs. The LMU boundaries may be revised following completion of mapping of the ash-eucalypt forest across the Central Highlands being undertaken by the Statewide Forest Resource Inventory (see Section 6.1).

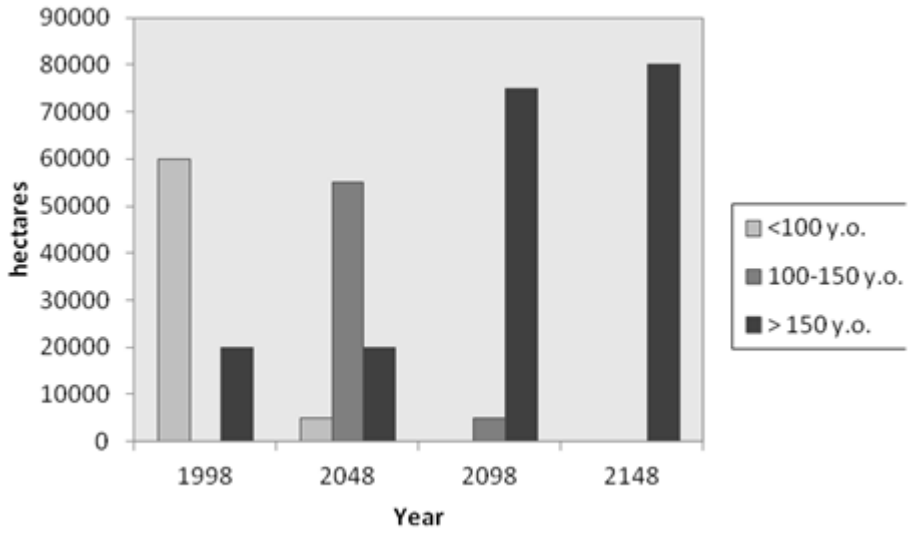
Habitat for Leadbeater's Possum is provided by retaining patches of ash-eucalypt forest in each LMU. The area and configuration of the patches was determined after taking into account:

- the target to retain at least 600 ha of ash-eucalypt forest in each LMU in either conservation reserves or the SPZ;
- the aim to retain patches of between 50 and 100 ha in area;
- the aim to link the retained patches, where feasible, through the linear reserve system;
- the area and spatial distribution of high-quality and low-quality habitat within each LMU;
- the area and spatial distribution of retained ash-eucalypt forest in adjacent LMUs;
- the total area of Zone 1A habitat retained in each LMU (see Appendix L);
- the total area of ash-eucalypt forest retained across the Central Highlands.

This plan retains patches of ash-eucalypt forest totalling at least 600 ha in 15 of the 21 LMUs. Many of the retained patches include existing Zone 1A habitat. Ash-eucalypt forest in the six remaining LMUs is primarily 1939 regrowth. This forest will not start to develop Zone 1A habitat characteristics for another 50 to 100 years. By the year 2100, at least 45% of the total area of ash-eucalypt forest in the Central Highlands will be over 150 years old (see Figure 3.1). This future relative abundance of suitable habitat provides a significant opportunity to adapt the system of retained habitat for Leadbeater's Possum to future management requirements.

NRE will assess the adequacy of the system of retained habitat for Leadbeater's Possum when the results of a computer-based habitat model become available. This model ranks the forest according to its suitability for Leadbeater's Possum habitat, using age class, density of live and dead hollow-bearing trees and slope data, for each patch of forest. Map 5 shows an example of the results of the modelling.

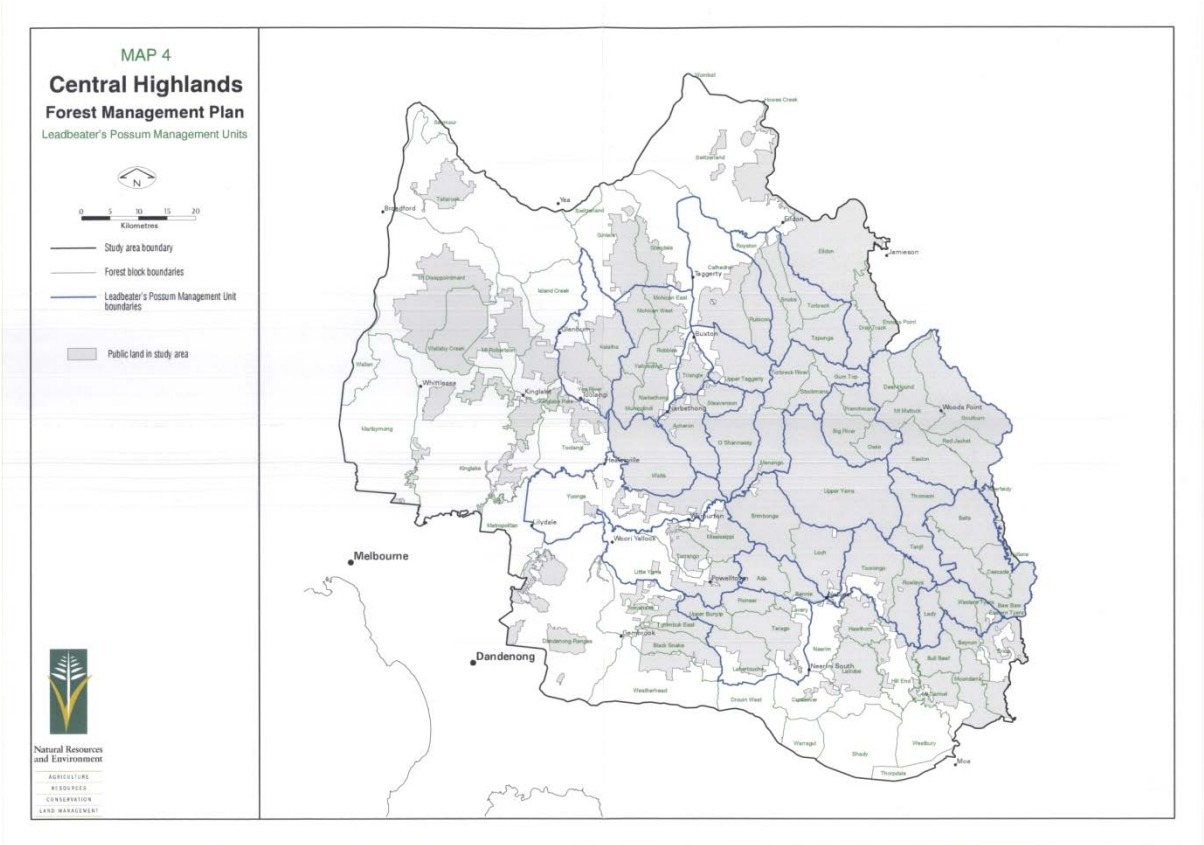
Figure 3.1 Area by age-class distribution of ash-eucalypt forest in conservation reserves or the SPZ in the Central Highlands

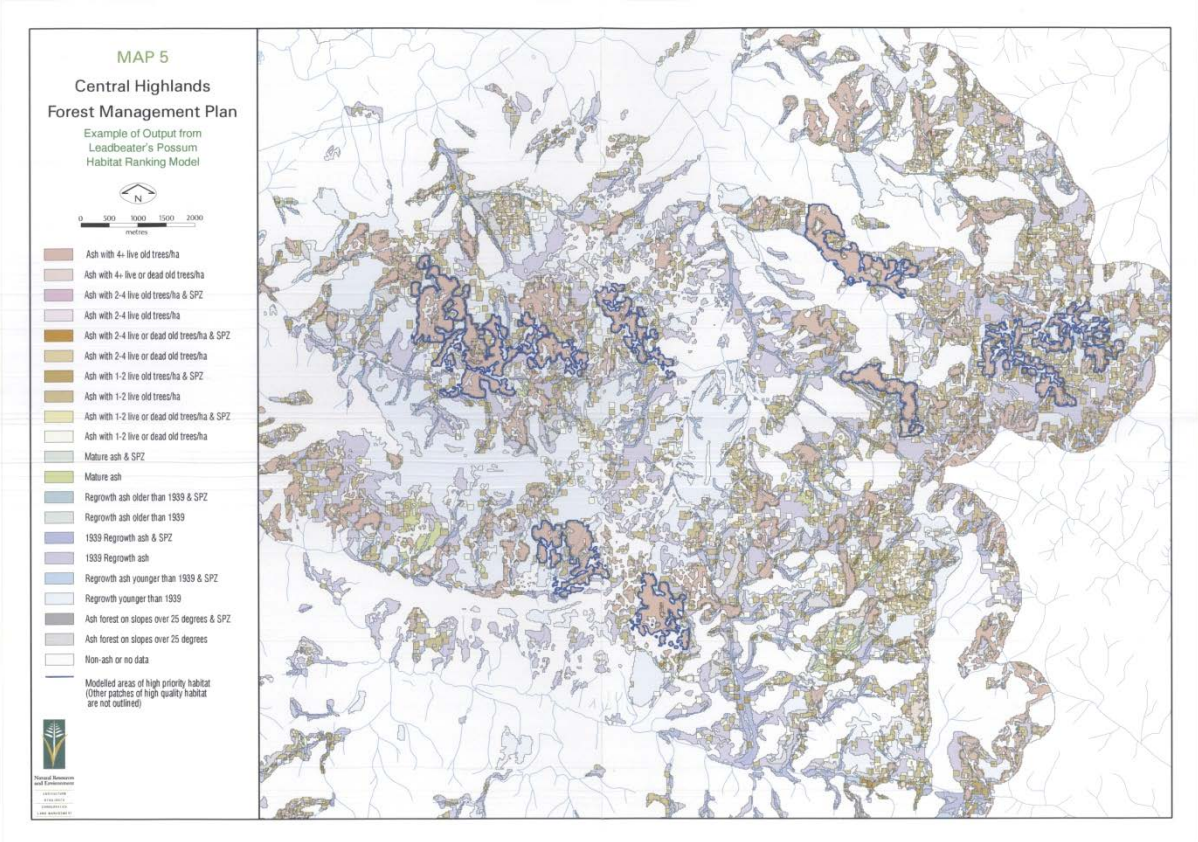


Notes:
1. The total area of ash-eucalypt forest in the Central Highlands is 181 000 ha. Of this, approximately 85 000 ha or 47% is in conservation reserves or the SPZ (includes 4500 ha of ash-eucalypt forest which is considered unstocked from a commercial point of view).
2. Assumes no wildfires
3. Assumes that existing 'mature' forest is over 150 years old
4. Assumes that unstocked ash-eucalypt forest in conservation reserves and the SPZ will not be restocked
5. Excludes ash-eucalypt forest in GMZ - Other and in Other Public Land (see Section 2.1)

Extracted from page 21 to 23 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

Map 1 Maps 4 and 5 of Forest Management Plan showing Leadbeater's possum management unit and example of habitat ranking index




MAP 5
Central Highlands
Forest Management Plan
Example of Output from
Leadbeater's Possum
Habitat Ranking Model
N
0 500 1000 1500 2000
metres
Ash with 4+ live old trees/ha
Ash with 4+ live or dead old trees/ha
Ash with 2-4 live old trees/ha & SPZ
Ash with 2-4 live old trees/ha
Ash with 2-4 live or dead old trees/ha & SPZ
Ash with 2-4 live or dead old trees/ha
Ash with 1-2 live old trees/ha & SPZ
Ash with 1-2 live old trees/ha
Ash with 1-2 live or dead old trees/ha & SPZ
Ash with 1-2 live or dead old trees/ha
Mature ash & SPZ
Mature ash
Regrowth ash older than 1939 & SPZ
Regrowth ash older than 1939
1939 Regrowth ash & SPZ
1939 Regrowth ash
Regrowth ash younger than 1939 & SPZ
Regrowth younger than 1939
Ash forest on slopes over 25 degrees & SPZ
Ash forest on slopes over 25 degrees
Non-ash or no data
Modelled areas of high priority habitat
(Other patches of high quality habitat
are not outlined)

MANAGEMENT PRESCRIPTION

Leadbeater's Possum

- Include Leadbeater's Possum Zone 1A habitat (living mature and senescing trees - see Table 3.2) in the SPZ.
- Exclude Zone 1B habitat from harvesting until either of the Zone 1B habitat attributes (the presence of dead mature or senescent trees, or wattle understorey) no longer exist.
- On completion of the modelling of the suitability of forest for Leadbeater's Possum habitat, review the adequacy of the retained habitat system established in this plan.

Extracted from page 23 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

Forest production guidance and action

Forest Production

Aims

To provide a long-term non-declining supply of hardwood sawlogs to the timber industry.

...

To use silvicultural treatments and prescriptions that are environmentally and economically sound.

...

Code of Forest Practices for Timber Production (Code)

The purpose of the Code is to ensure that commercial timber growing and timber harvesting operations are carried out on both public land and private land in such a way that:

a) promotes an internationally competitive forest industry;

b) is compatible with the conservation of the wide range of environmental values associated with the forest; and

c) promotes the ecologically sustainable management of native forests proposed for continuous timber production.

...

Resource Inventory and Yield Modelling

Forecasts of the sustainable yield of sawlogs require data on forest type, age structure, standing volume and growth. A number of inventories have been undertaken across the State forests of the Central Highlands in the past, using a variety of standards. The Statewide Forest Resource Inventory (SFRI) is assessing the forests of the Central Highlands for information including tree species, height, age and standing timber volume. This project commenced in the Central Highlands in 1996. Data for this area is expected to become available in 1999.

...

The SFRI program will collect additional yield information in both the ash-eucalypt and mixed-species forests.

RFA implications for sustainable yield

...

Achieving a Non-declining Yield of Sawlogs

One aim of State forest management is to maintain a non-declining yield of sawlogs. The strategies which will be implemented so that the aim will be achieved include:

1) Creating a more balanced age class distribution. A balanced age class distribution provides for efficient long-term log allocation and an increased capacity to supply veteran trees for habitat purposes. The present forest has a high proportion of ash-eucalypt regrowth from the 1939 wildfires and, in the Dandenong FMA, the 1983 wildfires. The major legacy of these fires and the related salvage harvesting are large areas of relatively young uniform-aged ash-eucalypt forest. Most of the harvesting since the mid-1980s has been concentrated in 1939 regrowth stands.

   Harvesting of the 1939 regrowth ash-eucalypt forests earlier and then later than the nominal rotation age of 80 years will have the effect of creating a more balanced age class distribution in the net productive area, particularly for the ash-eucalypt forests.

22) Increasing the volume of timber harvested from mixed-species forests to about 20% in the future as significant areas of regrowth approach rotation age. Generally less than 10% of the sawlog allocation is currently produced from the less productive mixed-species forests. Appendix S provides a definition of the mixed-species forest types.

23) Unstocked ash sites will be regenerated through the reforestation program (see Section 6.2).

Achieving a non-declining yield of sawlogs will also rely on:

- Strict adherence to the FMA timber harvesting prescriptions and the zoning scheme outlined in this plan. Any reduction of available harvestable area will have implications for wood supply levels in the medium term.
- Undertaking Timber Stand Improvement operations in degraded mixed-species stands to improve their productivity (see Section 6.2);
- Limiting harvesting to the sustainable yield;
- Maintenance and construction of an adequate network of timber extraction roads;
- Availability of markets for a range of timber products;
- Economically viable and environmentally sensitive timber harvesting and regeneration systems.

Salvage

Events such as wildfire, wind storms, disease or a plague of pest species can lead to substantial areas containing stands of dead or damaged trees. To make some economic use of these trees, timber salvage operations may be implemented. These may require modified timber harvesting prescriptions. Salvage harvesting may occur within State forest subject to the following Management Guideline. ...

ACTIONS

...

Complete the Statewide Forest Resource Inventory of the forest resource, including the development of forest growth and yield models, to provide data for the next review of sustainable yield rates prior to 2001.

...

Extracted from page 44 to 49 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

MANAGEMENT GUIDELINE

Salvage

All areas of SMZ and GMZ are available for salvage harvesting following the preparation of a salvage harvesting plan which will be subject to the Code and which will consider:

- flora, wildlife, cultural and water production values
- access to the area
- the volume of timber to be recovered
- the environmental, economic and social consequences of a salvage operation
- rehabilitation of the area following the salvage harvest

Areas of SPZ not available for salvage harvesting are those which contain:

Code exclusions;

- Leadbeater's Possum Zone 1A habitat;
- Buffers for threatened species which dwell in stream or riparian areas;
- Aboriginal or Historic places.

Areas of SPZ may be available for salvage harvesting and subsequent re-zoning when:

- the impact of the destructive event has led to the SPZ no longer containing the value for which it was identified;
- the value for which the area of SPZ was identified may be better represented by reserving another area of forest in SPZ;
- the value that an SPZ buffer was protecting no longer exists and will not be replaced or when the vegetation contained in the buffer may pose a safety problem.

Proposed amendments to the zoning scheme should ensure that there is no net deterioration in the level of protection of values in the SPZ, nor any long-term net deterioration in timber production capacity. Refer also to the Management Guideline for reviewing management guidelines, management prescriptions and the zoning scheme in Chapter 9.

Sustainable yield forecasts may require review following a major salvage operation.

Extracted from page 48 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

Silviculture and overwood silvicultural systems guidance and action

6..2 SILVICULTURE

Silviculture involves treating forest stands to achieve management aims which include timber and water production and flora and fauna conservation. Silvicultural treatments include harvesting, regeneration and tending operations, such as thinning. The combination of these treatments form a silvicultural system through which the structure, composition and growth of a stand can be manipulated.

The success of a silvicultural system must be measured by ecological, economic and social criteria. Harvesting and regeneration systems used in the Central Highlands will:

- ensure adequate regeneration of the original species mix;
- obtain the desired growth;
- maximise sawlog yield;
- minimise impact on flora, fauna, cultural or water catchment values;
- incorporate social and economic considerations;
- protect regeneration from excessive damage by factors such as browsing, disease and fire.

...

Wildlife habitat will be maintained on timber harvesting coupes according to the 'Tree retention on timber harvesting coupes' Management Guideline (see Section 3.1).

...

Retained Overwood

This silvicultural system for ash-eucalypt forests was proposed as a result of wildlife research and requires further operational development and evaluation. The aim of this system is to enhance and increase the area of high quality habitat for arboreal wildlife and to promote a multi-aged forest. It involves the retention of a proportion of existing and potential hollow-bearing trees during harvesting and regeneration operations. Large old trees with good wildlife habitat characteristics are preferred for retention. Where these are not present in suitable densities, regrowth trees can be retained. The exposure of these trees may accelerate the development of hollows.

Smith and Lindenmayer (1988) consider that the availability of potential nest trees ceases to be a limiting factor for hollow dependent possums and gliders in ash-eucalypt forests once about 12 potential nest trees per three hectares are present. Burgess et al (1994) considers the long-term retention of about 10% of the basal area (with a minimum of 10 trees per hectare) throughout the rotation to be sufficient to enhance the development of a multi-aged forest. Burgess maintains that in most cases tree retention should be restricted to about 10% of the basal area because of safety considerations and because of the potential for these trees to inhibit the subsequent development of the regrowth.

Where the retained trees are fire-sensitive species, seedbed preparation is currently achieved by mechanical means. Nevertheless research is being undertaken to identify a suitable method

that includes burning, as this will induce better regeneration of acacias, which are an important food source for many arboreal wildlife species in ash-eucalypt forests. Operational trials of the Retained Overwood system will be held in ash-eucalypt forest in areas adjacent to stands of veteran trees.

...

ACTIONS

...

Implement and evaluate operational trials of the Retained Overwood silvicultural system in 1939 ash-eucalypt regrowth forest adjacent to stands of veteran trees.

- As required, undertake new research projects and review existing projects which examine operational aspects of relevant silvicultural systems.

Extracted from page 50 to 54 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

Plan implementation guidance and action

Chapter 9

PLAN IMPLEMENTATION

...

Reviewing the Plan

...

This Forest Management Plan applies until 2008 or until other circumstances warrant a major review.

Monitoring

NRE's aim is to manage the forests of the Central Highlands so that the forests' natural and cultural values are maintained and the use of the forests' resources provide long-term community benefit. Integral to achieving this aim is the development of criteria and indicators against which the effects of forest management and utilisation activities on the forest's natural, cultural and economic values, can be determined (see also Section 3.3).

NRE has a number of processes established to monitor forest management and utilisation activities, including:

- Regular audits of timber harvesting operations in State forest are undertaken to provide information on implementation of the Code of Forest Practices for Timber Production;
- Water quality in a number of State forest streams is regularly monitored through the Victorian Water Quality Monitoring Network. Data from this can be used to detect trends in water quality and yield in forest catchments;
- All timber harvesting and other management operations are recorded each year;
- Forest sawlog growth and standing sawlog volume and residual log volume is monitored through measurement of the Permanent and Continuous Forest Inventory plots;
- Timber volumes harvested are recorded and compared with forest growth and yield estimates and forecasts of sawlog sustainable yield;
- Visitor numbers are recorded at a number of recreation sites;
- The Statewide Forest Resource Inventory (SFRI) project is establishing consistent descriptions for forests throughout Victoria and will provide a baseline for future monitoring of changes in the
- condition of the forests;
- The Pest Management Information System provides a means of recording pest infestations and
- reporting on the effectiveness of control programs;
- The Wildlife Atlas and Flora Information System provide means of collecting and reporting on flora and fauna data from a wide range of sources;
- Geographic Information Systems assist in data recording and storage, and enable the analysis of data sets to examine the effects of proposed forest operations on forest management zones and to determine the area subject to harvesting.

In addition, many of the current research programs aim to increase our understanding of the impact of natural and human-induced processes operating throughout the forest. The results of this research and the research needs identified in this plan will improve the effectiveness of NRE's monitoring programs. Research needs identified in this plan include determining:

- the habitat requirements and population dynamics of large forest owls;
- the extent of the critical habitat zone of the Spotted Tree Frog;
- the seasonal use of breeding and non-breeding habitat and the response to disturbance in Montane Wet Forest by the Baw Baw Frog;
- the impact of timber harvesting on water yields;
- effective methods for pest species control;
- the extent of windthrow in buffers containing Mountain Ash;
- the extent of damage to rainforest and associated buffers as a result of timber harvesting operations;
- the association between forest management history and Myrtle Wilt status which includes determining the effectiveness of current management prescriptions;
- the reasons for the outbreak of psyllids and appropriate methods of control;
- the response of flora and fauna communities to the long-term effect of artificial regulation of fire intensity, frequency and seasonality.

ACTIONS

Each year the Regional Forest Managers in the Gippsland and North East Regions will:

- Certify to the Regional Managers - Gippsland and North East Regions that the Wood Utilisation Plan prepared by the Senior Foresters - Central, Dandenong and Central Gippsland FMAs conforms to this plan
- Provide prescriptions for the preparation of coupe plans for harvesting in the Special Management and General Management Zones
- Consider new information and, if necessary, make recommendations on possible refinements or amendments to management strategies or the zoning scheme
- Make available for public inspection and comment an up-to-date zoning map, a list of any proposed zone amendments and proposals for harvesting in the SMZ
- Prepare an annual report on the implementation of this plan. This report may include information on significant outcomes such as:
  - * implementation of biodiversity management guidelines, new records of threatened species, and any observed responses to management initiatives
  - * key timber production data such as area and volume harvested by product type and areas subject to stand improvement operations critical to the maintenance of sustainable yield
  - * water quality and yield prescriptions
  - * implementation of pest plant and animal control guidelines
  - * major road maintenance or construction works
  - * compliance with the Code of Forest Practices for Timber Production and the Timber Harvesting Regulations

- * significant research outcomes.

Develop and progressively implement criteria, indicators and monitoring programs for forest biodiversity, water quality and other environmental values.

Links with the Central Highlands Regional Forest Agreement

In March 1998, the Prime Minister of Australia and the Premier of Victoria signed the Central Highlands Regional Forest Agreement (RFA). The RFA established the framework for the future management of forests in the Central Highlands. Importantly, it satisfied the environmental protection and industry development requirements of both Governments, ensuring a durable basis for future planning and investment.

The RFA formally accredits the Central Highlands Forest Management Plan as part of Victoria's Ecologically Sustainable Forest Management system. The RFA also makes reference to several other issues associated with the plan. These are summarised below.

CAR Reserve System

In the Central Highlands, the comprehensive, adequate and representative (CAR) reserve system on public land primarily comprises areas established for conservation purposes (e.g. National and State Parks) and areas set aside for conservation within the SPZ in State forest. In signing the RFA, the Commonwealth and Victorian Governments have agreed that the CAR reserve system satisfies the National Reserve Criteria.

...

Integrated Forest Planning System

Victoria has developed a system of linked computer-based tools collectively called the Integrated Forest Planning System (IFPS). The IFPS provides a means of modelling the growth, development and harvesting of forest stands as well as a range of other forest values. Its major application to date has been in forecasting sustainable sawlog yields in the Otway and Midlands Forest Management Areas and in parts of the Central Highlands planning area. Application of the IFPS for the whole Central Highlands was prevented by a lack of suitable spatially-referenced forest stand information. This information will be provided by the Statewide Forest Resource Inventory (SFRI) (see chapter 6). The RFA commits Victoria to implementing IFPS in time for the next review of sawlog sustainable yield in Central Highlands which is due in2001.

...

Monitoring and Reporting

The RFA commits the Victorian and Commonwealth Governments to joint development of an appropriate set of indicators to monitor and review the sustainability of forest management practices. The Governments have agreed that any indicators established will be consistent with the criteria established under the Montreal Process, and will take into account the framework of regional indicators developed by the Montreal Process Implementation Group. These processes further advance the monitoring and reporting commitments in this plan.

Extracted from page 74 to 79 of the Victorian Central Highlands Forest Management Plan (DNRE 1998)

Appendix E: Extract of Leadbeater's Possum *Gymnobelideus leadbeateri* knowledge base used to develop the Central Highlands Regional Forest Agreement (CVRFASC 1997a)

Box 2 Profile of an endangered species: Leadbeater's Possum

A small possum endemic to the Central Highlands of Victoria, Leadbeater's Possum is classified as Endangered (CNR 1995a, ANZECC 1991). It is currently found mainly in mountain forests dominated by Mountain Ash, Alpine Ash and Shining Gum and has recently been recorded in Snow Gum woodland at Lake Mountain (Jelinek et. al. 1995). A small population also exists in Yellingbo State Nature Reserve, in lowland swamp forest. The habitat requirements of the species are primarily determined by:

- nest-tree abundance and distribution
- food availability, particularly wattle in the understorey
- vegetation structure which allows the possum to move freely through the forest in search of food.

The 1939 fires burnt approximately 84% of the Central Highlands ash-eucalypt forests. Young regeneration resulting from these fires, or uneven-aged ash-eucalypt forest, that contains wattles and an ample supply of hollow-bearing trees is ideally suited for the species. The fire-killed remnants of mature forest and resultant regrowth from the 1939 fires has provided abundant feeding and nesting habitat during the past 30 years. However, as the fire-killed nest trees decay and fall, the extent of this type of habitat is diminishing. Loss of further potential nest trees in Leadbeater's Possum habitat due to timber harvesting would further reduce the ability of the species to survive.

Available information indicates that preferred nest trees are collapsing naturally at an average annual rate of more than 3.6% which will mean that, in the next 50 - 100 years, their availability for Leadbeater's Possum will be significantly diminished.

Furthermore, even if timber harvesting were excluded, the regrowth ash forests will not be capable of providing suitable nest sites for a further 150 years - assuming that ash trees must be about 200 years old before they can provide suitable nest sites. It therefore follows that the existing older-aged forest must continue to provide habitat for at least another 150 years, unless alternative silvicultural systems can be applied at an operation level (LCC 1994).

Of the 23,900 ha of older-aged forest in the Central Highlands, almost 10,000 is within the Yarra Ranges National Park, with the remaining 14,000 ha in State forest. The objective of the Leadbeater's Possum Action Statement (CNR 1995B) is to conserve the species over its known range. To achieve this, timber harvesting is excluded from all Zone 1A possum habitat (see table below) that is, ash forest containing a certain density of mature and senescing trees. As a result, the 14,000 ha of older-aged forest in State forest referred to above has been included in the Special Protection Zone (SPZ) in the proposed Central Highlands Forest Management Plan. Zone 1B habitat, as defined in the table below is also protected from timber harvesting at least until it no longer provides suitable Leadbeater's Possum habitat.

Leadbeater's Possum habitat Zones				
Zone	Density of hollow-bearing trees[1]	Hollow-bearing tree1 type	Wattle density[2]	Management
1A	> 12 per 3 ha in patches > than 3 ha	Living trees containing hollows	n/a	Conservation Reserves Special Protection Zone
1B	> 12 per 3 ha in patches greater than 10 ha	Dead or living trees containing hollows	> 5 m2/ha	Conservation Reserves General Management Zone but excluded from timber harvesting while Zone 1B attributes remain.
2	n/a	n/a	n/a	Conservation Reserves General Management Zone

Notes:
1.Hollow-bearing trees are Mountain Ash, Alpine Ash or Shining Gum, either living or dead.
2.Density is expressed as basal area - the sum of the cross-sectional area of the boles of the trees.
Source NRE (1996)

Analysis of the forest containing suitable habitat is based on 21 Leadbeater's Possum Management Units (LMUs) which have been delineated across the Central Highlands based on the extent and spatial distribution of ash-eucalypt type forest. Each LMU generally contains between 6000 ha and 10 000 ha of ash-type forest and is composed of one or more adjacent forest management blocks, containing contiguous patches of ash-eucalypt forest. The target for the conservation of Leadbeater's Possum will be to maintain viable populations of the species in all LMUs. The LMU boundaries may be revised following completion of mapping of the ash-eucalypt forest across the Central Highlands being undertaken under the Statewide Forest Resource Inventory.

The Proposed Forest Management Plan protects all Zone 1A habitat (important for the long-term conservation of the species) according to the principles set down in the Leadbeater's Possum Action Statement (Macfarlane et al. 1995). In addition, timber harvesting will continue to be excluded from Zone 1B habitat in State forest until either of the Zone 1B habitat attributes (the presence of dead mature or senescing trees, or wattle understorey) no longer exist.

The Plan also achieves the target of retaining patches of ash-eucalypt forest totalling 600 ha per LMU in 15 of the LMUs. Ash eucalypt forest in the six remaining LMUs is primarily 1939 regrowth. This forest will not start to develop Zone 1A habitat characteristics for another 50 to 100 years. By the year 2100, at least 44% of the total area of ash-eucalypt forest in the Central Highlands will be over 150 years old (see Table below). This future relative abundance provides significant opportunity to adapt the Leadbeater's Possum reserve system to future management requirements. (NRE 1996).

Area by age-class distribution of ash-eucalypt forest included in conservation reserves or the SPZ in the Central Highlands from 1996 to 2146

	1996	2046	2096	2146
Ash-eucalypt forest less than 100 years old	61,400 ha	4,900 ha		
Ash-eucalypt forest 100 to 150 years old		56,500 ha	5,100 ha	500 ha
Ash-eucalypt forest more than 150 years old	23,900 ha	23,900 ha	80,200 ha	84,800 ha

Notes:

1. Areas are expressed to the nearest 100 ha.
2. The total area of ash-eucalypt forest in the Central Highlands is 181 000 ha. Of this, 89 500 ha or 49% is in conservation reserves or the SPZ (includes 4200 ha of ash-eucalypt forest which is considered unstocked from a commercial point of view).
3. Assumes no wildfires
4. Assumes that existing 'mature' forest is over 150 years old
5. Assumes that unstocked ash-eucalypt forest in conservation reserves and the SPZ will not be restocked
6. Excludes ash-eucalypt forest in GMZ - Other and in Other Public Land

To analyse areas of forest which would form the most appropriate future system of retained habitat for Leadbeater's possum a computer model is being used. In the model, the forest is ranked according to its suitability for Leadbeater's Possum habitat, using age class, density of live and dead hollow-bearing trees and slope data, for each patch of forest. The model will produce a series of options of suitable habitat. Within each LMU, patches (generally greater than 50 ha) of ash-eucalypt forest will be retained (with a target of at least 600 ha in each LMU). On completion of the modelling and subsequent field authentication, the zoning system established in the Proposed Forest Management Plan will be reviewed in the light of the options provided by the model. Where possible, the patches will be linked through the linear reserve system. In State forest, the patches will form part of the SPZ (NRE 1996).

NRE is also continuing research into, and operational trial of, the retained overwood silvicultural system in regrowth stands adjacent to stands of veteran trees with the aim of promoting mixed-aged forest that could benefit Leadbeater's Possum.

Other detailed prescriptions relating to the management of habitat for Leadbeater's Possum in timber production forests in the Central Highlands are outlined in the Action Statement (Macfarlane et al. 1995), and the proposed Forest Management Plan. A Recovery Plan is currently in the final stages of preparation.

Source: pages 100-101; CVRFASC (1997a) Refer to the bibliography of the report for embedded references

Leadbeater's Possum

Gymnobelideus leadbeateri

RARITY

a) Geographic Range

- Classification of range size: Medium
- Range size within region: (ha): 170 000 - 235 000
- Proportion of region occupied (%): 14 - 20
- Source: Macfarlane and Seebeck (1991)

b) Abundance

- Classification of abundance: Medium - this is dependent on the quality of the habitat
- Population Estimate: 7500 ± 2300, estimated for the population in 1980
- Density: 1.6-2.9 possums/ha
- Home Range (ha): 1.3-1.9
- Source: Smith (1984a), Smith et al. in Smith and Lindenmayer (1992)

c) Habitat Specificity

- Classification of habitat specificity: Narrow - mainly confined to wet and damp forests
- Vegetation types used in the region: Montane Damp Forest, Montane Wet Forest, Wet Forest, Riparian Forest, Subalpine Woodland
- Source: Smales (1994), Jelinek et al. (1995), Macfarlane et al. (1995)

DYNAMICS

Population Trend in Last Decade

- Increasing, stable or declined: Probably declined, due a decline in nest tree availability and the progression of current favorable habitat to a structurally less-suitable successional stage
- Source: Smith et al. in Macfarlane et al. (1995), Smith and Lindenmayer (1988), Lindenmayer (1990)

Population trend since discovery by Europeans

- Increasing, stable or declined: Declined
- Source: Lumsden et al. (1991)

SPATIAL DYNAMICS

a) Population variability

- Classification of population variability: Low
- Source: Smith (1984a)

b) Dispersal

- Classification of powers of dispersal: High, juvenile females disperse further
- Average distances dispersed: Unknown, juvenile females typically beyond natal home range
- Maximum distance dispersed: Unknown
- Source: Smith (1984a)

LIFE HISTORY PARAMETERS

a) Reproductive output

- Classification of reproductive output: Low
- Age of sexual maturity (yrs): 1.5
- Mean clutch/litter/brood size: 1.4
- Mean no of clutches/litters/broods per year: 2
- Time of year young born/hatch: April-June, October-December (majority of births)
- Source: Smith (1984a)

b) Longevity

Classification of lifespan: Short-lived

- Average lifespan (yrs): Unknown, high mortality in juvenile females
- Maximum lifespan (yrs): 4 females, >7 males
- Source: Smith (1984a)

c) Morphology

Adult body size

- Weight (g): 100-135(122) Spring, 110-166(133) Autumn
- Length (mm): 150-170(160)
- Source: Smith in Strahan (1995)

d) Social organisation

- Colonial or non-colonial: Colonial
- Territoriality: Females territorial, transient females unsuccessful breeding
- Source: Smith (1984a)

e) Other

- Nomadic, migratory, sedentary: Sedentary
- Mode of feeding: Insectivore (arthropods), Exudivore
- Source: Smith (1984b)

THREATS

1. **Fire (planned): Ranking (2)** Macfarlane and Seebeck (1991), Lindenmayer (1990), Milledge

et al. (1991)

2. **Fire (unplanned): Ranking (3)** Lindenmayer and Possingham (1994), Macfarlane et al. (1995)

3. **Logging: Ranking (3)** Andrew et al. (1984), Fleming et al. (1979), Smith and Lindenmayer (1988), Macfarlane and Seebeck (1991), Lumsden et al. (1991), LCC (1991), Smith and Lindenmayer (1992), Lindenmayer (1995)

4. **Introduced Species: Ranking (1)**

5. Pest Control: Ranking (0)

6. Grazing: Ranking (0)

7. Disease: Ranking (0)

8. Illegal Harvesting: Ranking (0)

9. Non-forestry Clearing: Ranking (0)

10. Mining/Quarrying: Ranking (0)

11. **Roading: Ranking (1)** Macfarlane and Seebeck (1991)

12 Recreation: Ranking (0)

13. Vandalism/Disturbance by Humans: Ranking (0)

14. **Other: Enhanced Greenhouse Effect Ranking (2))** Lindenmayer (1990) Bennett et al. (1991), Macfarlane and Seebeck (1991)

Current management:

Leadbeater's Possum is listed under the Victorian Flora and Fauna Guarantee Act 1988 and the Commonwealth Endangered Species Protection Act 1992. An Action Statement (Macfarlane et al. 1995), a Draft Management Strategy (Macfarlane and Seebeck 1991) and Management Guidelines which are applicable only to timber production forests, are currently being implemented. Management actions include: the establishment of a zoning system with specific prescriptions relating to the assessment of habitat, size and shape of coupes, buffer establishment and the protection of all hollow-bearing trees regardless of zoning classification. All known colonies are to be protected and other management activities including roading and reforestation are to be addressed. Intended management actions outlined in the Action Statement include: establishment of 21 Leadbeater's Possum Management Units, resource assessment surveys to determine the extent and distribution of current optimum and potentially optimum habitat, a revision of the current zoning system to reflect habitat changes over time, logging coupe assessment, retention of buffer strips, protection of hollow trees, salvage logging plans, operational trials of retained overwood silvicultural systems, reserve establishment, continuation of research to assist and improve long-term conservation, captive management planning, social and economic planning and continuation of community education (Macfarlane et al. 1995).

Comments: The distribution of Leadbeater's Possum is centered on the montane ash forests (*Eucalyptus regnans*, *E. delegatensis* and *E. nitens*) of the Central Highlands (Macfarlane et al.

1995). There is a single colony in a lowland swamp forest (*E. camphora* and *E. ovata*) within Yellingbo State Nature Reserve (Smales 1994) and a few records from Lake Mountain within snow gum woodland (*E. pauciflora*) (Jelinek 1995).

The habitat of Leadbeater's Possum includes large old trees for breeding and shelter, a vegetation structure that facilitates movement, and available food (Macfarlane et al. 1995). In ash forests Leadbeater's Possum forages for arboreal arthropods beneath the decorticating bark of the eucalypts and the sap of Acacia species (Acacia dealbata, A. melanoxylon and A. frigescens). A dense layer of Acacias also provides a suitable structure for movement (Smith 1984a). The montane ash forests of the Central Highlands are a valued timber resource and loss of hollow trees as a consequence of logging is a major threat to Leadbeater's Possum (Smith and Lindenmayer 1992, Lindenmayer 1995). Harvesting prescriptions stipulate that all live hollow trees are to be left standing and protected on logging coupes. However, these trees are often killed during the hot regeneration burns used for seed bed preparation in these forests, and are highly vulnerable to windthrow and collapse. The longevity of these habitat trees post logging requires research (Lindenmayer et al. 1990, Rhind 1996)

Although wildfire has been important in the development of suitable habitat for Leadbeater's Possum, widespread, severe wildfire was predicted to have a major negative impact on the persistence of the species. This impact is particularly evident in areas with little old-growth forest (Lindenmayer and Possingham 1994) and is a major threat to the species (Macfarlane et al. 1995). A contraction in the range of Leadbeater's Possum as well as E. regnans and E. delegatensis was predicted by models of the likely influence of the Enhanced Greenhouse Effect (Lindenmayer 1990), and is a moderate threat to the species.

Source: pages 245-246; CVRFASC (1997a)

Appendix F: Extract of Actions from Action Statement No 62 (DEPI 2014a) [22] Leadbeater's Possum Gymnobelideus leadbeateri Flora and Fauna Guarantee Act 1988

Intended management actions

Primary responsibility for implementing the following actions is indicated below. DEPI is responsible for overall co-ordination of the implementation of this Action Statement. The following actions are marked to show if they are a policy commitment (*), regulatory commitment (#) or included in the business planning of the responsible agents (^). Policy commitments are not enforceable obligations. The actions marked as regulatory commitments are measures specified for the purposes of clause 2.2.2 of the Code of Practice for Timber Production 2007. All special protection zones reserved for Leadbeater's Possum values added after July 2014 as described in the government response to the Leadbeater's Possum Advisory Group recommendations and implemented through this Action Statement and subsequently through the Management Standards and Procedures for timber harvesting operations in Victoria's State forests 2014 will be in addition to the current level of biodiversity protection (at 30 June 2014). This will be revised in accordance with actions 1a and 21.

Objective I	**To secure populations or habitat from potentially incompatible land use or catastrophic loss**
Explanation	A key objective for the Leadbeater's Possum Action Statement is to secure populations and habitat from potentially incompatible land use or catastrophic loss. The key areas of focus are protect Leadbeater's Possum colonies and habitat, protect and enhance old growth forest, protect habitat from incompatible development activities, transition into retention harvesting and manage fire around known colonies and high quality habitat. This objective also includes research actions that are directly linked to on ground management.
Action 1	Protect Leadbeater's Possum colonies
Action 1a #	**Establish a Special Protection Zone (SPZ) to exclude timber harvesting operations from within a 200 metre radius centred on the verified detection site for each colony (Advisory Group recommendation 1) #**
Explanation	Bushfires in February 2009 and ongoing habitat decline have led to a reduced population of Leadbeater's Possum. The remaining wild population is therefore critical to the species' recovery. Ensuring the remaining colonies are protected will maximise capacity for the species

[22] DEPI (2014a). Action Statement No 62. Leadbeater's Possum *Gymnobelideus leadbeateri* Flora and Fauna Guarantee Act 1988. The State of Victoria Department of Environment and Primary Industries. http://www.depi.vic.gov.au/__data/assets/pdf_file/0009/272574/LBP-ActionStatement_pdf.pdf

	to recover. All future harvesting activities, including thinning and the construction of new roads, are to be excluded from the timber harvesting exclusion zones around colonies. DEPI will create SPZs around all verified records from the 15 years prior to February 2014 (based on records within the Victorian Biodiversity Atlas), and all new records once the record is verified. Verification will occur to a standard developed by DEPI. All records and special protection zones will be mapped, consolidated and published as datasets in DEPI's Corporate Spatial Data Library. This information will be made accessible to stakeholders to inform forest management planning, timber planning, compliance, enforcement and auditing, and fire planning and suppression. The effectiveness of this action in supporting the recovery of the Leadbeater's Possum is to be reviewed after two years of surveying (commencing July 2014) or once 200 new colonies are located whose exclusion zones impact the General Management Zone or Special Management Zone, whichever comes first. Responsible agent: DEPI
Action 1b *	**Delay harvesting for two years (until June 2016) in areas where the ARI 2013 occupancy model (Lumsden et. al. 2013) predicts a greater than 0.65 probability of being occupied by Leadbeater's Possum to allow surveys to be undertaken (Advisory Group recommendation 2) ***
Explanation	To reduce the risk of harvesting in areas with a high probability of occurrence of Leadbeater's Possum, timber harvesting to be delayed for two years to enable surveys to be undertaken in these areas. The area of predicted high probability of occurrence is to be based on the ARI occupancy model for Leadbeater's Possum (Lumsden et. al.. 2013). Responsible agent: VicForests
Action 1c *	**Undertake targeted Leadbeater's Possum surveys focusing on predicted high occupancy areas, as identified by the ARI 2013 occupancy model (Lumsden et. al.. 2013) and aligned with VicForests' harvest plan, to identify and map colonies and clusters of colonies within the known range (Advisory Group recommendation 1) ***
Explanation	As it is likely that the locations of only a relatively small proportion of all colonies are known, it is important to undertake further surveys to locate additional colonies to be protected. Surveys are to be designed to maximise increasing records while also contributing to improving habitat models and understanding habitat requirements. Responsible agent: DEPI
Action 1d *	**Actively seek out Leadbeater's Possum records from groups and institutions that are known to have undertaken survey work (Advisory Group recommendation 1) ***
Explanation	It is important that all records of Leadbeater's Possum are consolidated, so records will be actively sought. To facilitate the assessment of records from external organisations, survey standards will be developed to outline the criteria required to verify a Leadbeater's Possum record. Where a report of a Leadbeater's Possum from the community cannot be confirmed, surveys will be undertaken to verify the report. Verification will occur to a standard developed by DEPI. All records will be published in the DEPI Victorian Biodiversity Atlas in a timely manner. Responsible agent: DEPI

Action 2	Protect Leadbeater's Possum habitat
Action 2a ^	**Retain the Leadbeater's Possum Reserve ^**
Explanation	There is an extensive parks and reserves system within the range of Leadbeater's Possum including a specific Leadbeater's Possum Reserve containing examples of high quality habitat. This reserve will be retained, potentially with some amendments to be made through the Central Highlands forest management zoning review. Where possible these reserves will be linked by wildlife corridors, streamside reserves, buffer strips and areas of State forest not suitable or available for timber harvesting. Responsible agent: DEPI, Parks Victoria
Action 2b # ^	**Identify and protect Zone 1A and Zone 1B habitat (Advisory Group recommendation 6) # ^**
Explanation	To complement the reserve, the best examples of Leadbeater's Possum habitat outside the reserve system are also protected as follows: Zone 1A # Establish an SPZ over areas of Zone 1A habitat where there are more than 10 live mature or senescent hollow-bearing ash trees per 3 ha in patches greater than 3 ha. In Zone 1A habitat hollow-bearing trees are defined as live mature or senescent trees of Mountain Ash, Alpine Ash or Shining Gum containing hollows. During salvage harvesting after fire Zone 1A habitat is assessed as if all the trees were live. Include this area as special protection zone in the zoning scheme. Zone 1B # Exclude timber harvesting operations from areas of Zone 1B habitat where there are more than 12 hollow-bearing trees per 3 ha in patches greater than 10 ha and wattle density exceeds 5 m2/ha. In Zone 1B habitat hollow-bearing trees are dead mature or senescent living trees of Mountain Ash, Alpine Ash or Shining Gum containing hollows. This prescription applies until either of the Zone 1B attributes (the presence of dead mature or senescent living trees containing hollows, or wattle understorey) no longer exist. Responsible agent: DEPI, VicForests
Definitions #	'hollow bearing trees' - In Zone 1A means live mature or senescent trees of Mountain Ash, Alpine Ash or Shining Gum containing hollows - In Zone 1B means dead mature or senescent living trees of Mountain Ash, Alpine Ash or Shining Gum containing hollows. 'Leadbeater's Possum Management Unit' (LMU) means aggregations of one or more forest management blocks containing contiguous patches of ash-eucalypt forest within the known range of Leadbeater's Possum. These spatial units are used to distribute retained habitat areas across the known range of Leadbeater's Possum. 'mature' is a growth stage of trees. Mature Ash species have the following characteristics, in order of assessment priority. Note that no single characteristic defines maturity on its own, although the first characteristic (apical dominance) holds the most significant assessment weight: 1. Lack of clear apical dominance within the upper crown 2. Presence of permanent shaping branches with diameters at least one third of the bole diameter at their junction with the bole (clear of collar) 3. Shaping branches are not related either to the presence of a long term natural gap in the canopy, or to an open grown tree position. In the case of a natural gap, such branches often occur only on one side of the tree, and the 'assessment weight' given to this characteristic may

	need to be downgraded (i.e. the need for other indicators increases as part of the overall assessment) 4. The shaping branches contribute significantly to lateral crown shape and may be competing with other shaping branches for tree height position, creating a rounded crown appearance (related to (1) above) 5. Apical dominance will also cease at the shaping branch level (having reached maximum length), and can induce secondary (epicormic) branch development along shaping branches 6. Some branch death (dieback) and breakage is typical, but not a dominant feature. This loss of leaf area (photosynthetic capacity) can also induce secondary (epicormic) growth to replace lost photosynthetic capacity, and 7. Diameters of early mature trees may occur between 90 to 200 cm dbhob (i.e. diameter at breast height over bark), with typical heights of 50 to 100 m. Diameters of full mature trees may be expected between 150 to 300 cm, with typical heights of 60 to 100 m. This overlap of ranges between trees in different stages indicates why diameter and height are not good indicators of growth stage. 'senescent' is a growth stage of trees. Senescing eucalypts are characterised by dead branches and declining crown leaf area, with the trunk of the tree likely to contain burls and bumps. The top of the tree is invariably broken off with the resulting crown being composed of more than 95 % secondary, branches of epicormic origin. 'dead trees' are obviously (physiologically) dead. They are self-supporting (rooted into the ground) and would remain standing should any supporting material be removed. Dead trees must be more than 6 m in height and greater than 1.50 m in diameter at breast height. Dead trees must be Mountain Ash, Alpine Ash or Shining Gum. However, as it is not always possible to determine the species of a tree once it is dead, all dead eucalypt trees where species cannot be determined are assumed to be Mountain Ash, Alpine Ash or Shining Gum.
Zone 2 ^	The following paragraphs on Zone 2 and protection of trees containing hollows should be considered as guidance (non-mandatory) in the General Management Zone. ^ Zone 2 Consists of the remaining ash forest-eucalypt forest: regrowth ash forest of varying ages; and areas with features of Zone 1A or Zone 1B but <3 ha or 10 ha respectively. Protection of trees containing hollows Protective measures to aid the continuing survival of nest-trees on logging coupes should be used, including the use of fire retardants and the provision of fire breaks around such trees. Special attention should be given to the protection of currently living nest-trees, regardless of zoning classification. Even if these trees die after subsequent fire or exposure they will still provide potential nesting sites for Leadbeater's Possum during the following rotation. Hollow-bearing trees should not be felled for seed collection. Responsible agent: DEPI, VicForests
Action 2c *	Undertake an inventory to improve the understanding of the extent of Zone 1A habitat, building upon previous assessments. (Advisory Group recommendation 6) *
Explanation	There is currently no spatial layer that maps the extent and distribution of Zone 1A habitat across the range of Leadbeater's Possum, due to the difficulty in remotely mapping mature or senescent hollow-bearing trees. A range of approaches need to be explored to determine which is most effective. The ability to predict where Zone 1A habitat occurs across the landscape in advance of timber harvesting planning would enable areas to be excluded during the planning phase, rather than when coupes are being marked out. Responsibility: DEPI, VicForests
Action 2d ^	Provide training for field staff in identification and protection of habitat. ^

Explanation	Appropriate staff are to be provided with training in the recognition and interpretation of Zone 1 habitat and the application of protection measures. Responsibility: VicForests
Action 3	Protect and enhance old growth ash forest
Action 3a #	Exclude timber harvesting operations from within 100 metres of modelled old growth ash forests (currently depicted in the DEPI spatial layer: MOG2009.shp) within the Leadbeater's Possum range. (Advisory Group recommendation 5) #
Explanation	Old growth ash forests contain the highest densities of hollow-bearing trees (Lindenmayer et. al.. 2000). Hollow-bearing trees are an essential habitat component for Leadbeater's Possums. However, past and current disturbances and management practices, such as fire and timber harvesting, have resulted in old growth Mountain Ash forest now comprising less than 3 % of the Mountain Ash forest estate in the Central Highlands (Lindenmayer et. al.. 2012). These areas are sparsely distributed as small and highly fragmented patches spread across the landscape. All existing patches of modelled old growth ash forest (currently based on DEPI Modelled Old Growth spatial layer, mog2009.shp) are currently protected from timber harvesting, however, applying a 100 m buffer around these patches should provide additional protection where adjacent to timber harvesting coupes. These areas are to be mapped, consolidated and published as datasets in DEPI's Corporate Spatial Data Library and replicated in VicForests' information systems. The information will be accessible to all stakeholders. Responsibility: DEPI, VicForests
Action 3b #	Protect from timber harvesting operations at least 30 % of the ash forest in each LMU within the range of Leadbeater's Possum to develop into old growth ash forests (Advisory Group recommendation 7) #
Explanation	The extent of old-growth forest changes over time – stands become 'old-growth' as they reach their oldest growth stage, or as the effects of past disturbance become negligible. Currently less than 3 % of the ash forests in the Central Highlands is considered to be old growth forest, whereas prior to European settlement it is estimated that 30-60 % of the Mountain Ash forests of the Central Highlands were multi-aged or old growth (Lindenmayer et. al.. 2011). The reserve system within the Central Highlands allows for a significant proportion of the current forest to become old growth in the future if not disturbed by bushfire. Leadbeater's Possum Management Units (LMU) will be used as the basis for setting targets for future old growth to ensure a spread across the range of the species. Currently, two of the 21 LMUs have less than 30 % of their ash forests reserved. To reach the target of at least 30 % of the ash area protected within each LMU, an additional 274 hectares of ash forest would be required to be protected within these LMUs (66 hectares in LMU 1 and 208 hectares in LMU 15). DEPI will consider the following factors in the selection of retained areas: - are they the least likely to burn during bushfires; - are they the oldest age class, that will develop into old growth the quickest; - whether they consolidate other patches that may develop in old growth. Responsibility: DEPI, VicForests
Action 3c *	Improve understanding of habitat survival to identify landscape features and habitats that are resilient to natural disturbance processes such as bushfires. (Advisory Group recommendation 7) *
Explanation	Models are needed to predict the extent and spatial configuration of suitable habitat for

	Leadbeater's Possum under various scenarios of landscape-scale disturbance, principally fire and timber harvesting. The models should be based on historic disturbance patterns and likely future patterns, including those influenced by climate change. Responsibility: DEPI, Universities
Action 4 ^	Protect habitat from incompatible development activities. ^
Explanation	The permitted clearing of native vegetation regulations, including the policy of avoiding, minimising and offsetting vegetation loss, is to continue to be applied to development proposals and other activities that may affect Leadbeater's Possum. Activities include road and track construction or maintenance in or adjacent to habitat, and recreational development in parks. Canopy connectivity is to be maintained across tracks and ski trails at Lake Mountain and on the Baw Baw plateau. The Lake Mountain and Mt Baw Baw Alpine Resort Management Boards will be provided with information to guide their site maintenance and development activities to avoid impacts on Leadbeater's Possum's habitat. Land managers/operational teams for the Baw Baw plateau are to be provided with information to guide their site maintenance/development activities so that they do not impact on Leadbeater's Possum conservation. Responsibility: DEPI, Parks Victoria
Action 5	Transition to retention harvesting
Action 5a *	From July 2014, undertake retention harvesting in at least 50 % of the area of ash harvested within the Leadbeater's Possum range. (Advisory Group recommendation 3) *
Explanation	Retention harvesting aims to reduce the time for Leadbeater's Possum habitat to develop in clearfelled areas (normally ≥ 200 years) by allowing trees to mature and develop hollows along with the younger regrowth to provide foraging substrate. This design allows some hollow-bearing trees to be preserved within an 80-year harvest rotation. VicForests will provide a specific retention harvesting definition relevant to the Central Highlands Ash Forests, as part of implementation they will reconcile their harvest areas and report to DEPI annually. Responsibility: VicForests
Action 5b *	Investigate alternatives to high intensity regeneration burns linked to post-burn retention harvest criteria. (Advisory Group recommendation 4) *
Explanation	High intensity burning has been identified as a threat to retained habitat within and adjacent to areas harvested. However, high intensity burning is the most effective, safe and cost effective method of regenerating ash harvesting coupes. The move to retention harvesting may require alternative methods of regeneration. Investigations into how the risks to retained habitat may be managed while maintaining effective regeneration post-harvest are required. This investigation may include consideration of the objectives of post-logging regeneration which currently focuses heavily on eucalypt species regeneration. Alternative methods may produce reduced eucalypt regeneration but provide an improved ecological outcome. This may require amendments to the regulatory requirements after completion of the research. Responsibility: DEPI, VicForests
Action 6	Fire management of known colonies and high quality habitat

Action 6a *	Identify known colonies and high quality habitat as critical assets on the Natural Values database (part of DEPI's fire system) to inform fire operations and risk landscapes planning. (Advisory Group recommendation 8) *
Explanation	All recorded Leadbeater's Possum colonies and their associated timber exclusion zones and high-quality habitat, whether formally reserved or not, need to be mapped, consolidated and published as datasets in DEPI's Corporate Spatial Data Library. This information will be made accessible to DEPI's fire operations and planning divisions to assist with fire operations planning, suppression and management. High quality habitat will be identified using a range of approaches, including, but not limited to occupancy and species habitat models; areas of Zone 1 habitat; the Leadbeater's Possum reserve system; areas known to contain comparatively large numbers or high densities of colonies; areas that were unburnt in the 2009 bushfires but are surrounded by burnt forest that may be acting as fire refuges; areas that were old growth ash forest prior to the 2009 bushfires; and long-term monitoring sites. Responsibility: DEPI, Parks Victoria
Action 6b *	Investigate and implement, where possible and appropriate, active fire management activities to protect identified colonies and high-quality habitat from bushfire, taking into consideration other threatened species requirements. (Advisory Group recommendation 8) *
Explanation	Intensive, widespread bushfires are the biggest threat to the ongoing persistence of Leadbeater's Possum. The aim of this action is to increase the protection of Leadbeater's Possum colonies and habitat through intensified fire planning and management, including suppression activities and fuel management in adjacent drier forest types, taking into consideration other threatened species' requirements. Areas of high quality habitat as identified in the previous action will be excluded from planned burns. Responsibility: DEPI, Parks Victoria
Action 6c *	Develop approved fire recovery protocols that can be enacted without delay following fire or other disturbance events that affect known colonies. (Advisory Group recommendation 8) *
Explanation	Developing fire recovery protocols prior to the next large fire should assist in decision-making and timely emergency management responses. Fire recovery protocols will assist incident management teams in how to protect or extract important or at risk colonies during an emergency event. Such extractions may remove animals from harm's way. The protocols would include planning, resources, logistics, deployment of field teams and recipient site considerations and address issues such as under what conditions are animals to be brought into captivity, or provided with supplementary feeding or nesting sites. Responsibility: DEPI, Parks Victoria, Zoos Victoria
Action 6d ^	Investigate the impact of strategic fuel breaks/habitat fragmentation on Leadbeater's Possum^
Explanation	A research program to evaluate the impacts of strategic fuelbreaks on Leadbeater's Possum and the effectiveness of mitigation measures should be continued. Responsibility: DEPI, Universities
Action 6e ^	Finalise the fire management plan for the area of the current Yellingbo Nature Conservation Reserve (Recommendation 1A - Government response to VEAC Yellingbo Investigation Final Report) ^

Explanation	The fire management plan is to be finalised as soon as possible. In addition, DEPI is developing a Strategic Bushfire Management Plan for the East Central Bushfire Risk Landscape in collaboration with public and private land managers, community and interested stakeholders. The strategic planning process has identified Yellingbo Conservation Reserve as an important environmental asset in this landscape. Responsibility: DEPI, Parks Victoria

Objective II	To maintain or increase the extent of habitat
Explanation	A key objective of the Leadbeater's Possum Action Statement is to maintain and increase the extent of habitat. This is in addition to the actions under Objective I. The key areas of focus here are in providing artificial nest boxes to support existing populations, investigating how to accelerate hollow development improving habitat and increasing the extent of habitat at Yellingbo Nature Conservation Reserve. The following objective also includes research actions that are directly linked to on ground management.
Action 7 *	Provide artificial nest boxes in a targeted manner at key locations to support existing populations. (Advisory Group recommendation 9) *
Explanation	In many areas, den sites are a limiting resource for Leadbeater's Possum populations. While the maintenance of hollow-bearing trees should always be considered the highest priority when considering den site availability, in certain circumstances, the decline in den sites can be ameliorated to some extent through the targeted provision of artificial nest boxes. The situations in which nest boxes have proved most successful are where the vegetation structure allows boxes to be placed at the height that animals typically move through the vegetation. These include sites characterised by tea-tree in the midstory such as at Yellingbo where all the remaining colonies use nest boxes, and in Snow Gum woodlands such as at Lake Mountain and Mt Bullright, where nest boxes have been used extensively. Existing nest boxes at Yellingbo, in sub-alpine woodland and selected montane ash forest sites are to be maintained and monitored. In addition, new boxes are to be installed to investigate the extent of other populations occurring in sub-alpine woodland and ash forest, including the Baw Baw plateau and Mt Matlock. The projects in the Central Highlands are to be delivered through the Project Possum program, which is a partnership between Parks Victoria, Zoos Victoria and the Friends of the Leadbeater's Possum. Volunteers are to be involved in the monitoring of the boxes. Project Possum sites are predominantly in national parks, catchment areas and other reserve areas. The success of the program will be evaluated after five years. Responsibility: DEPI, Parks Victoria, Zoos Victoria
Action 8 *	Investigate approaches to accelerate hollow development (Advisory Group recommendation 10) *
Explanation	It is predicted that there will be a severe shortage of hollow-bearing trees suitable as nesting sites for Leadbeater's Possum over the next 50-70 years. This is due in part to the loss of dead stags from within 1939 regrowth forests before the live trees in this age class commence producing hollows. While the highest priority is to protect existing hollow-bearing trees, this may not be enough to ensure sufficient hollows are available through the bottleneck period and so approaches for accelerating the development of hollows are to be explored. If successful techniques can be developed there is potential to transform areas that are currently unsuitable as habitat for Leadbeater's Possum. However, it is currently unknown which techniques may be the most successful and cost-effective for creating the type of hollows needed by Leadbeater's Possum. There are two broad approaches that could be taken. One is to use silvicultural or other forest management processes, such as ecological thinning practices that promote hollow

	development in younger forest through enabling trees to grow larger more quickly, or modified harvesting practices that promote damage to retained trees. Alternatively, accelerated hollow development could be undertaken through mechanical or other processes, such as drilling or cutting a hollow into a tree, manipulating/pruning tree branches, or introducing fungus to accelerate hollow development. Both approaches will be investigated. Responsibility: DEPI, Universities, VicForests
Action 9 ^	Undertake habitat management/restoration at Yellingbo ^
Explanation	Habitat management/restoration is urgently needed to address the lack of eucalypt regeneration in the floodplain at Yellingbo. Challenges to achieving this include the current lack of understanding of lowland swamp forest ecology, seasonal floodplain inundation, weed invasion and browsing by native and introduced herbivores. Habitat restoration is necessary to increase the amount of structurally dense forest, providing additional foraging habitat and connectivity. Until an appropriate disturbance mechanism is developed that can be applied over large areas, active possum territories should be revegetated with canopy and middle-storey species such as Mountain Swamp Gum, paperbark and tea-tree. The long-term target is to provide approximately 80 hectares of suitable foraging habitat for Leadbeater's Possum in the reserve. Effective habitat management at Yellingbo requires the following: 1. Hydrological restoration in the floodplains of the Cockatoo and Macclesfield Creeks (currently being investigated by Melbourne Water), 2. Development and application of a disturbance regime in the floodplain to promote the regeneration of dense stands of Mountain Swamp Gum, 3. Application of a disturbance regime to promote regeneration of canopy and midstorey species on the terraces immediately adjacent to the floodplain. Until appropriate disturbance mechanisms are developed to promote regeneration over large areas, revegetation should be undertaken in priority sites at Yellingbo, e.g. active possum territories. Responsibility: Melbourne Water, Parks Victoria, Zoos Victoria
Action 10 *	Establish the Yellingbo Conservation Area and coordinating committee (VEAC recommendation R5) *
Explanation	Yellingbo Nature Conservation Area be designated to include a 2940 hectare area and be managed in an integrated way to achieve the long-term security of biodiversity and other natural values, including the survival of the lowland Leadbeater's Possum. Responsibility: DEPI, Parks Victoria (for Secretariat of the Committee)
Action 11 *	Management of the Coranderrk Nature Conservation Reserve (VEAC recommendation A2) *
Explanation	The Coranderrk Nature Conservation Reserve, located north of the Yellingbo Conservation Area, has the potential to play an important part of the broader public land network for lowland Leadbeater's Possum in the future. This site could be used as an extension for the captive insurance program at Healesville Sanctuary, with a view to establish a free ranging insurance population and harvest the offspring to establish or supplement other wild lowland Leadbeater's Possum populations. The VEAC Yellingbo Investigation has recommended that this reserve be used in accordance with the general recommendations for nature conservation reserves, except that (a) public access and recreation including bushwalking, nature observation, heritage appreciation and picnicking may continue to be limited at the discretion of the land manager and (b) this area is managed in an integrated way to achieve the long-term security of biodiversity and other natural values and directions set by the Yellingbo Conservation Area Coordinating Committee.

	Responsibility: Zoos Victoria
Action 12 *	Management of the Haining Education area (VEAC recommendation E1) *
Explanation	The Haining Education area could be restored to provide important habitat for the lowland Leadbeater's Possum. The VEAC Yellingbo Investigation recommended that this area be used in accordance with the general recommendations for community use areas and the current use of the area be changed to provide for other forms of land management and educational opportunities with a greater emphasis on sustainability, including improved protection of riparian areas and restoration of habitat for the lowland Leadbeater's Possum. The Haining Education area could be an important location for future translocations of lowland Leadbeater's Possum. Responsibility: Parks Victoria, Zoos Victoria

Objective III	To increase knowledge of biology, ecology or management requirements
Explanation	A key objective of the Leadbeater's Possum Action Statement is to increase the knowledge of biology, ecology and management requirements of the Leadbeater's Possum. The key areas of focus are to examine the feasibility of translocations Leadbeater's Possums, investigate key ecological requirements, undertake population monitoring and investigate critical habitat characteristics. In addition to the research actions listed above linked directly to on-ground management, the following research actions will be undertaken to improve knowledge of the ecology of the species to inform management.
Action 13	Examine the feasibility of translocating Leadbeater's Possums from wild to wild. (Advisory Group Recommendation 11)
Action 13a *	Examine the feasibility in Central Highlands*
Explanation	There are likely to be areas that will be suitable in the future, but are currently unoccupied, Leadbeater's Possum habitat within the Central Highlands, especially in areas that were burnt severely in the 2009 bushfires. Where hollow-bearing trees are available and once the vegetation has recovered sufficiently to provide foraging habitat, this could potentially be ideal habitat but may take some time to be recolonised if there are not surviving colonies close enough for animals to naturally disperse into the area. Due to the distances required for dispersal and the low dispersal rates, it may take many years or decades for the species to naturally recolonise these areas. This is where translocation could be effective. However, there are many unknowns regarding the efficacy of translocation in this situation. This action will involves investigating the desirability and feasibility of translocating Leadbeater's Possums to establish new colonies in suitable but unoccupied habitat. Subsequent translocation, and monitoring the success of any re-establishments, could then be undertaken subject to the results of the feasibility study. Responsibility: DEPI, Parks Victoria, Zoos Victoria
Action 13b ^	Examine the feasibility in Lowlands^

Explanation	The desirability and the feasibility of undertaking translocation of lowland Leadbeater's Possum from wild to wild and from captivity to the wild is also to be investigated for Yellingbo Nature Conservation Reserve and surrounding areas. Protocols will be developed to guide decision making regarding translocation of colonies into unoccupied habitat. Potential localities to conduct assisted colonisation trials will be identified. Trial translocation guidelines for Leadbeater's Possum will be developed in alignment with DEPI's Procedure statement for translocation of threatened native fauna in Victoria Responsibility: DEPI, Parks Victoria, Zoos Victoria
Action 14	Investigate dispersal and recolonisation capabilities of Leadbeater's Possum. ^
Explanation	While extensive dispersal data have been collected at Yellingbo, currently there is limited knowledge of Leadbeater's Possum dispersal characteristics in montane ash forest. The latter needs to be investigated to improve our 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 fire. Molecular techniques will be used to estimate rates of dispersal/gene-flow in local areas. Responsibility: DEPI, Universities
Action 15 ^	Undertake population monitoring at key locations and collect demographic information. ^
Explanation	Monitoring of population dynamics is important for implementing effective site-specific and general management strategies, especially detecting response to conservation measures and disturbance. The long-term, broad-scale population and habitat monitoring being conducted by ANU is to continue across the Central Highlands. It is investigating the habitat requirements and population viability of Leadbeater's Possum, populations of large old trees, forest dynamics, fire dynamics, and impacts of timber harvesting and restoration ecology. Detailed long-term population monitoring is to continue at Yellingbo via the annual nest box monitoring program. Key areas investigated should include long-term site occupancy, colony sizes, reproductive rates, dispersal and recruitment. Continue to expand the captive 'insurance' and breeding program for lowland Leadbeater's Possum founded from Yellingbo animals in order to establish more lowland populations. Nest boxes are to be monitored in sub-alpine woodland at Lake Mountain and Mt Bullfight to examine the recolonisation rate by Leadbeater's Possums at sites that were severely burnt in 2009. Responsibility: DEPI, Parks Victoria, Universities, Zoos Victoria
Action 16 ^	Investigate stag-fall rates in Leadbeater's Possum habitat. ^
Explanation	Monitoring stag-fall rates should continue on all long-term monitoring sites, and is a particularly high priority since the 2009 wildfire. Comparisons of pre/post-fire stag-fall trends should be be undertaken. Responsibility: DEPI, Universities
Action 17 ^	Determine habitat critical to survival of populations in sub-alpine woodland ^
Explanation	Leadbeater's Possum populations inhabit sub-alpine woodland dominated by Snow Gum at several localities. This action involves identifying and mapping suitable habitat at these locations. It should include an assessment of den characteristics and availability and other

	important habitat attributes. Responsibility: DEPI, Parks Victoria, Zoos Victoria
Action 18 ^	Determine structure of Leadbeater's Possum populations. ^
Explanation	Priorities for further genetic sampling in montane ash forest throughout Leadbeater's Possum's range are to be identified. Genetic differentiation among Leadbeater's Possum populations in montane ash forest to be assessed to enhance understanding of the extent of population and habitat fragmentation. Responsibility: DEPI, Universities, Zoos Victoria
Action 19 ^	Investigate den tree characteristics in lowland swamp forest. ^
Explanation	Data collected on den trees used by Leadbeater's Possum at Yellingbo should be analysed and used for conservation management of the species. Responsibility: Parks Victoria, Zoos Victoria

Objective IV	To maintain or increase community awareness and support
Explanation	To create a significant increase in community awareness of Leadbeater's Possum, which should lead to an increase in community participation in community organised activities.
Action 20 *	Community engagement. (Advisory Group recommendation 12) *
Explanation	Implement ongoing community engagement, including with environment and industry groups. Involve community stakeholders in monitoring activities. Continue to implement and enhance education programs to improve understanding of Leadbeater's Possums and their management. Responsibility: DEPI, Parks Victoria

Objective V	To review and evaluate the ecological effectiveness of actions for the recovery of the Leadbeater's Possum
Explanation	Assess the extent to which these actions have supported the recovery of Leadbeater's Possum and assess if further interventions are required.
Action 21	Evaluate the effectiveness of actions to support the recovery of Leadbeater's Possum.*
Explanation	On-going monitoring and review will feed into an adaptive management process to continue to improve the management of Leadbeater's Possum. It will also help ensure that the community has timely information on progress achieved in implementation, which will assist in meeting their expectations for increased transparency and maintain support for recovery actions. There

	will be a full review of the Action Statement in 2017 to assess the extent to which these actions have supported the recovery of Leadbeater's Possum and to assess if further interventions are required, including quantitative measures of successful population recovery. For example after further investigation into the current distribution and habitat relationships, and the assessment of the availability of Zone 1A, review the adequacy of this retained habitat system for identifying areas of good quality habitat. Responsibility: DEPI, Parks Victoria, Zoos Victoria, VicForests, Recovery Team

Appendix G: Extract of Victorian Government (2014) key achievements in the first six months of supporting the recovery of Leadbeater's possum

1	Protect Leadbeater's Possum colonies	• Exclusion of timber harvesting within 200 metres of Leadbeater's Possum colonies incorporated into regulation • 33 surveys at 13 sites and cameras installed at 10 sites to trial improved detection techniques • New survey standards drafted to improve new record submission and verification • New equipment and training planned to support community involvement in submission of new records • Targeted landscape scale surveys to commence in November 2014 • All known Leadbeater's Possum colonies and their timber harvesting exclusion zones incorporated into VicForests' data systems to inform operational planning.
2	Delay harvesting in high probability occupancy areas	• Timber harvesting delayed in over 600 hectares of forest within the range of Leadbeater's Possum.
3	Transition to retention harvesting	• Regrowth Retention Harvesting commenced in July 2014, with the new Regrowth Retention Harvesting Instruction applied to the Rusty coupe near Toolangi • Field staff trained and tested for competency in the application of the Regrowth Retention Harvesting Instruction.
4	Revised regeneration practices	• Trialling and monitoring new practices for forest regeneration where timber has been harvested.
5	Buffer old growth	• Exclusion of timber harvesting from within 100 metres of modelled old growth ash forest in the Leadbeater's Possum range incorporated into regulation.
6	Amend definition Zone 1A habitat	• Amendment to the definition of Zone 1A Leadbeater's Possum habitat incorporated into regulation to protect Leadbeater's Possum colonies and current and future habitat.
7	Protect future old growth	• Target to protect 30 per cent of ash forest in each Leadbeater's Management Unit for future habitat incorporated into regulation.
8	Fire management	• The East Central Strategic Bushfire Management Plan identifies known Leadbeater's Possum colonies, high quality habitat and timber assets for protection. A risk based approach to fire management is part of this plan, providing further safeguards • The Fire Operational Plans in DEPI fire districts are now informed by the East Central Strategic Bushfire Management Plan • New fire recovery protocols in development, with opportunity for community input.
9	Install nest boxes	• 37 nest boxes installed at Dowey Spur near Powelltown and 61 at Mt Baw Baw.
10	Accelerate hollow development	• Creation of tree hollows will be accelerated mechanically, as demonstrated by arborists at a field day • An Australian Research Council Linkage Grant awarded for research on silvicultural approaches to accelerate hollow development.

11	Translocation	• Feasibility assessment to commence in 2015-16.
12	Community engagement	• Working with the community and targeted stakeholders in the delivery of agreed actions • A web portal, in development, will allow the community to easily access Leadbeater's Possum information with an interactive map for viewing spatial information.
13	Monitoring and review	• Released the first public progress report.

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Australian Government
Department of Agriculture and Water Resources
ABARES

ABARES Briefing Note

Australian Bureau of Agricultural
and Resource Economics and Sciences

15 December 2015

LEADBEATER'S POSSUM: COMMENTS ON DRAFT RECOVERY PLAN

This briefing note presents comments on a draft of the Leadbeater's Possum Recovery Plan as available to ABARES in December 2015.

Comments on draft Leadbeater's Possum Recovery Plan (December 2015)

1) Expressing the long-term Recovery Objective in terms of the probability of persistence (or probability of extinction) of Leadbeater's possum is supported, as it is more realistic in the long term than alternative metrics based on population size or habitat extent (both of which vary naturally over time for this species), or level of listing (which is derived from changes over time in population size or habitat extent).

   However, care needs to be given to the exact phrasing of the objective. 'Maximising' the probability of persistence is not useful as it implies that conservation measures need to continue until 100% probability of persistence is attained, which is not practical for any species and ignores the value of future adaptive management. Instead, a goal probability value is needed. As an example of the required structure, instead of 'minimising' the probability of extinction, Lumsden et al. (2013)[1] investigated conditions under which there was a 5% probability of the LBP population falling below 500 adult females in a 200-year time period. The long-term Recovery Objective could thus be phrased in terms of attaining a 75% or 90% or 95% probability of persistence of Leadbeater's possum over a 200-year period (whatever number is the accepted value for such analyses), allowing for future adaptive management.

2) Loss of hollows by decadal decay and collapse of old trees needs to be separated out as a different threat to threats from severe fire and fire regime change.

[1] Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadik TA, Smith SJ, Acevedo S, Cheers G, Jemison ML and Nicol MD (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

3) The text on timber harvesting in Section 4.2.2 of the Draft Recovery Plan focuses unduly on historical clearfelling as though this is a current threat. Greater emphasis needs to be given in this section and elsewhere to retention regrowth harvesting, as currently being applied.

4) It is commendable that the Recovery Plan takes an all-tenures (tenure-blind), whole-of-landscape approach, especially in regards to future PVA modelling.

5) Each performance criterion in the Recovery Plan needs a time period over which it is to be measured.

6) Actions under Objective 6 need to describe more explicitly (i) monitoring the performance of the reserve system for conservation of Leadbeater's possum, and (ii) monitoring the efficacy of management outside the reserve system, such as prescriptions for timber harvesting, actions to reduce fire risk, and creation of additional nesting habitat. It is generally accepted that monitoring, reporting and accountability were weaknesses of the previous Recovery Plan.

7) The Draft Recovery Plan at times assumes that the reserve system alone will be able to carry the complete task of providing habitat for Leadbeater's possum. This is not correct, especially as Leadbeater's possum occurs across multiple tenures in the broader forest landscape and has highly dynamic habitat requirements.

   A conservation approach combining reservation with management by prescription outside reserves provides the formal underpinning to forest management in RFA regions, and is both optimal and practical. The reserve system in RFA regions is designed according to JANIS criteria[2] and needs to be 'adequate'. Adequacy means that the reserve system provides the desired level of species protection when considered alongside management of surrounding land, which in the case of Leadbeater's possum is State forest.

   Implicit in the maintenance of biodiversity is the requirement to sustain ecological processes and functions and provide for the maintenance of natural patterns of speciation and extinction. This requires that the adequacy of a reserve system be considered in a landscape context (e.g., Saunders and Hobbs 1991)[3]. The extent of inclusion of whole catchments, the degree of sympathetic management of adjacent lands, and the options for provision of corridors to provide linkages are important in the development of integrated nature conservation strategies. Factors operating within the surrounding landscape that are particularly relevant to determining the adequacy of the reserve system are threatening processes (e.g., land clearing and disease), and the conservation strategies adopted in forests outside those areas reserved specifically for conservation[2].

   The PVA reported by the Arthur Rylah Institute for Environmental Research[1] showed that the Leadbeater's Possum Reserve System was not sufficient by itself to support long-term conservation of the species. However, this PVA did not consider Leadbeater's possum habitat or colonies on adjacent state forest or other tenure, which after the 2009 fires is the majority of the habitat or population, and did not include the contribution made by habitat protection

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[2] Commonwealth of Australia (1997) Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia. Report by the Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee, Commonwealth of Australia, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/rfa/publications/nat_nac.pdf

[3] Saunders D, Hobbs R, Margules C (1991) Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32

measures in state forests. Rather than solely concluding that a larger reserve area was needed, the Lumsden et al. (2013) report therefore concluded that:

> additional management actions (e.g. protection of known colonies in state forest, protection of additional areas of suitable habitat, habitat enhancement, alternative silvicultural practices) need to be considered to reduce the extinction risk of Leadbeater's Possum throughout its range.

There is text in the Draft Recovery Plan that could be ambiguous without an explanation of the above meaning of the term "adequate", such as on p.43, Action 2.3:

> Expand the permanent reserve system to incorporate sufficient areas of current and prospective suitable habitat to ensure that it is adequate for the long-term conservation of Leadbeater's possum.

There is also text in the Draft Recovery Plan that implies the reserve system alone should provide the complete conservation needs of Leadbeater's possum, such as on p.44, Performance criteria, 5:

> Sufficient areas of current and prospective suitable habitat are incorporated in an expanded reserve system to ensure that the system to maximise [sic] the likelihood of persistence of Leadbeater's possum, over at least a 100-year period.

Taken in isolation, this approach would lead to a reserve system of much greater extent than that needed to provide adequate protection for Leadbeater's possum, and such text needs to be rephrased to take account of conservation actions outside the reserve system.

While other text, e.g. Action 2.6, relates to conservation actions to be taken outside the reserve system, the complementary nature of these two approaches (reservation, and protection off-reserve) needs to be taken into account in articulating actions and performance criteria.

8) The Recovery Plan could usefully separate out emergency actions from actions with long-term benefit. Emergency actions could include:

a) Creating early hollows in the 1939 regrowth forest (such as through nest boxes, artificial hollows, and altered silviculture).
b) Translocation of Leadbeater's possum to areas of recently burnt old-growth forest that the species might otherwise not be able to colonise, when this becomes habitat.
c) Active fire management around the ash forest.

All of these actions are in the Draft Recovery Plan, but could usefully be brought together in one place.

Australian Government
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Australian Bureau of Agricultural
and Resource Economics and Sciences

08 February 2016

LEADBEATER'S POSSUM: COMMENTS ON DRAFT RECOVERY PLAN

This briefing note presents comments on a draft of the Leadbeater's Possum Recovery Plan as available to ABARES in February 2016.

Comments on draft Leadbeater's Possum Recovery Plan (February 2016)

1) Key points that still need to be considered in this draft cover:

   a) separating out the threat from loss of hollow-bearing trees due to decay and collapse from threats due to fire and to fire regime change
   b) explicitly requiring monitoring of the performance of the reserve system for conservation of Leadbeater's possum
   c) combining reservation and management by prescription outside reserves in actions to protect Leadbeater's possum.

2) The Draft Recovery Plan lacks a logical framework of identifying and ranking threats, analysing the efficacy of actions against these threats, and giving priority to the most effective and efficient actions against the most significant threats.

   Page 15 of the Draft Recovery Plan includes the paragraph (**emphasis** added by ABARES):

   > This Recovery Plan recognises that there has been very substantial investment over several decades in research and management actions, and some notable conservation policy initiatives, with these efforts contributing significantly to enhanced knowledge of the species and to the maintenance of some subpopulations. Notwithstanding such effort, the current and projected trends for the species and its habitat are catastrophic. **Existing management and protective mechanisms are demonstrably insufficient to stop the decline and support the recovery of the species.** A concerted long term vision, commitment and management effort, with adequate resourcing and policy settings, is necessary to protect this species into the future

   Existing management and protective mechanisms are focussed on reservation, and prescriptions on timber harvesting. ABARES agrees that a continued focus on these mechanisms, through additional reservation and more stringent prescriptions, will not assist Leadbeater's possum – yet, in spite of the above text, these existing mechanisms

remain as the key initial actions of this Recovery Plan. The new approaches mentioned in this Recovery Plan need substantially more emphasis in the plan to deliver on the logic of the above paragraph: these new approaches include fire risk reduction around Leadbeater's possum habitat; habitat augmentation through nest-boxes, artificial hollows and understorey manipulation; and research on translocation of colonies.

3) Additional text covering socio-economic issues, sequencing of actions, costs of actions, and other biodiversity benefits has been added to the Draft Recovery Plan. However:

   a) very little detail is given on socio-economic issues, including no calculations on impact on the forest industry and communities. It cannot be said that the Recovery Plan has demonstrated that it "minimises any significant adverse social and economic impacts, consistently with the principles of ecologically sustainable development", as required under the EPBC Act, Section 270(3).
   b) the sequencing of the actions in the important Objective 2 is ill-considered, with actions marked 'Urgent' proposed to precede the outcomes of research or reviews to determine whether those actions are even appropriate. A suggested renaming, reprioritisation and resequencing of actions is given in Appendix A.
   c) no description of Indigenous consultation has been included.

4) There are a number of key errors and omissions in the draft Recovery Plan:

   a) Adequacy of the reserve system: the concept of whether the reserve system is 'Adequate' for conservation of Leadbeater's possum is explicitly misrepresented. Existing reserves are concluded to be inadequate alone, yet reservation is argued to have primacy as a conservation instrument. However, the CAR reserve system that provides the scientific framework to the National Reserve System ensures that formal and informal reserves function in a complementary manner to off-reserve management – all need to be considered together as components of the CAR reserve system. Accepting the arguments in this Recovery Plan would constitute a substantial change in policy given that prescriptions are an important component of the CAR reserve system.
   b) Performance of the reserve system: the major threats to Leadbeater's possum are not addressed by reservation, the performance of the existing reserve system for Leadbeater's possum has not been monitored or measured, and some key conservation actions (fuel reduction, creation of artificial hollows) may be contentious if implemented in the reserve system – yet the reserve system is asserted to have primacy as a conservation instrument.
   c) Threat of loss of hollow-bearing trees: loss of hollow-bearing trees by decay or collapse was quantitatively the greatest or second greatest threat to Leadbeater's possum in each of the six scenarios analysed in the 2015 Conservation Advice from the Threatened Species Scientific Committee, as well as in figures recalculated by ABARES and presented in a previous briefing note. Loss of hollows underpins the predicted minimum in Leadbeater's possum population size over the next several decades. However, loss of hollows is not treated as a separate threat in this Recovery Plan, and urgent actions to mitigate loss of hollows are not clearly identified in the action section of the Recovery Plan. Provision of natural or artificial nesting hollows is a key requirement in minimising the risk of extinction of Leadbeater's possum and allowing for its long-term recovery.
   d) Prescriptions on timber harvesting: timber harvesting is always described as a significant threatening activity, with the mitigating effects of silvicultural prescriptions

and novel silvicultural techniques being discounted. However, regrowth retention harvesting, for example, is designed to allow harvested regrowth stands to retain the capacity to develop hollow-bearing trees over time, addressing a threat to Leadbeater's possum.

e) Sequencing of actions: a number of key actions concerning habitat protection, colony protection and expansion of the reserve system are marked 'Urgent' and needing to be implemented in the first year of the plan. However, the nature of these actions and whether they are even appropriate depends on the outcomes of landscape habitat modelling, population viability analysis and land-use planning that should be required to occur first. The actions concerning habitat protection, colony protection and expansion of the reserve system need relabelling as 'Essential'

f) Logic underpinning some actions: some of the actions and performance measures are not derived from the habitat or threat sections of the Recovery Plan.

5) The plan contains large amounts of material that does not connect to proposed actions, and is thus not relevant to the plan. Some of this material (such as on climate change and forest carbon) deals with contentious areas but presents only one of the several perspectives argued in the literature.

   Many of the objectives in the draft Recovery Plan and some of the underpinning actions are not clearly written, are not sufficiently detailed or specific for implementation, and are capable of ambiguous interpretation.

Role of the reserve system

The 'Comprehensive, Adequate and Representative' (CAR) reserve system for Australia was endorsed by all Australian governments as signatories to the National Strategy for Conservation of Australia's Biological Diversity (2010)[1]. The CAR reserve system provides the scientific framework for the National Reserve System[2], and is designed to have the following attributes:

1) Comprehensive: the inclusion in the National Reserve System of examples of regional-scale ecosystems in each bioregion

2) Adequate: the inclusion of sufficient levels of each ecosystem within the protected area network to provide ecological viability and to maintain the integrity of populations, species and communities

3) Representative: the inclusion of areas at a finer scale, to encompass the variability of habitat within ecosystems

Components of the CAR Reserve System on public land[3] are:

1) dedicated reserves within the meaning of the IUCN categories I-IV

[1] https://www.environment.gov.au/biodiversity/conservation/strategy

[2] https://www.environment.gov.au/land/nrs/science/scientific-framework

[3] JANIS (1997) Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia. A Report by the Joint ANZECC / MCFFA National Forest Policy Statement Implementation Sub-committee (JANIS), Commonwealth of Australia, Canberra. http://www.agriculture.gov.au/SiteCollectionDocuments/rfa/publications/nat_nac.pdf

2) informal reserves, and

3) values protected by prescription.

The formal and informal components of the reserve system thus function in a complementary manner to management of non-reserve land. It is the combination of reservation and off-reserve management that provide for recovery of threatened species, with this combination being especially important for species such as Leadbeater's possum which have habitat that is dynamic in space and time across a wider landscape.

However, the Draft Recovery Plan explicitly requires the formal reserve system to take primacy in providing habitat for Leadbeater's possum, to the extent that population viability analysis should show the population of Leadbeater's possum in the formal reserve system alone is secure (that is, has minimal probability of extinction). This is a rewriting of the goals for the CAR reserve system. Moreover, it is an inappropriate approach for Leadbeater's possum, a species that occurs across multiple tenures in the broader forest landscape, has highly dynamic habitat requirements, and faces major threats of fire and of loss of hollows that occur on both reserved and non-reserved land. Overriding the accepted approach of the CAR reserve system is likely to have major negative socio-economic implications yet not provide any conservation benefit for Leadbeater's possum.

The Leadbeater's Possum Action Statement (DSE 1995)[4] recommended the establishment of a Leadbeater's Possum reserve system as a key strategy for the long-term conservation of the species, in addition to prescriptions in timber production areas and the adoption of alternative silvicultural systems. Lumsden et al (2013)[5] calculated that the Leadbeater's Possum Reserve as established was not sufficient by itself to support long-term conservation of the species. However, this Population Viability Analysis did not consider Leadbeater's possum habitat or colonies on state forest or other tenure (which after the 2009 fires is the majority of the habitat or population), and did not include the contribution made by habitat protection measures and new silvicultural systems in state forests. Lumsden et al (2013) therefore concluded that:

> additional management actions (e.g. protection of known colonies in state forest, protection of additional areas of suitable habitat, habitat enhancement, alternative silvicultural practices) need to be considered to reduce the extinction risk of Leadbeater's Possum throughout its range.

Lumsden et al (2013) did not conclude solely that a larger reserve area was needed. However, the Recovery Plan has moved forward with only that part of this conclusion, namely protection of additional habitat through reservation, and has ignored the other components of this conclusion, yet references the work of Lumsden et al (2013) in support of this approach.

Moreover, as noted in a previous ABARES briefing note:

> [There is no] evidence that an increase in the reserve system across the Central Highlands would enhance the conservation status of Leadbeater's possum. Bayesian analysis presented in the Technical Report of the Leadbeater's Possum Action Group

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[4] DSE: Department of Sustainability and Environment (1995). Leadbeater's Possum *Gymnobelideus leadbeateri* . Flora and Fauna Guarantee Action Statement No. 62. Department of Sustainability and Environment, Melbourne

[5] Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadik TA, Smith SJ, Acevedo S, Cheers G, Jemison ML and Nicol MD (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

> indicated that reservation of all Central Highlands forests gave no additional benefit over a package of other conservation and management actions.

Finally, the performance of the existing CAR reserve system for Leadbeater's possum has not been monitored. The projected population minimum over the next 50 years has been long predicted, and results from a well-known cause (loss of hollow-bearing trees killed in the 1939 fires) that reservation does not address. The other major threat (wildfire) occurs independent of tenure, on reserves as well as elsewhere. And key, urgent management actions involve interventions such as installation of nest-boxes, creation of artificial hollows, and fuel reduction that are likely to be significantly more contentious on conservation reserves than off-reserve.

It is therefore not the case that additional reservation will necessarily provide benefit to Leadbeater's possum.

Appendix A: Resequencing and reprioritisation of actions

Resequencing and reprioritisation is proposed for Actions 2.1-2.9 and Action 5.2. Re-numbering of the actions in Objective 2 as 2.1-2.9 could logically follow. Note suggested edits *in italics* to names of Actions.

Action 2.1 depends in part on the outcome of Actions 2.4-2.5, 5.2 and 6.1.
Actions 2.2-2.3 depend completely on the outcome of Actions 2.4-2.5, 5.2 and 6.1.

Actions and priority from Draft Recovery Plan		**Proposed resequencing and reprioritisation**	
Action	**Priority**	**Action**	**Priority**
Objective 2: A whole of landscape management regime is in place ensuring that all currently suitable and prospective habitat across the species' known range is maintained, enhanced and effectively managed to maximise its suitability for Leadbeater's possum			
2.1 Review, and refine current timber harvesting regulatory prescriptions	Essential	2.4 Refine and update *habitat,* distributional *and viability* models	Urgent
2.2 Enhance existing protection for important habitat features	Urgent	2.5 Undertake land-use planning that provides sufficient habitat now and into the future	Urgent
2.3 Enhance protection for areas in which colonies are not known but may occur	Urgent	2.9 Assess the risks and cost-effectiveness of fire management options	Urgent
2.4 Refine and update distributional models	Urgent	2.7 Assess the practicality and cost-effectiveness of habitat augmentation*, and implement where beneficial*	Urgent
2.5 Undertake land-use planning that provides sufficient habitat now and into the future	Urgent	2.1 Review, and refine where required, current timber harvesting regulatory prescriptions	Essential
2.6 Expand permanent reserve system	Urgent	2.2 *Maintain or* enhance existing protection for important habitat features	Essential
2.7 Assess the practicality and cost-effectiveness of habitat augmentation	Urgent	2.3 *Maintain or* enhance protection for areas in which colonies are not known but may occur	Essential
2.8 Enhanced habitat for lowland swamp forest habitat	Essential	2.6 *Maintain or* expand permanent reserve system	Essential
2.9 Assess the risks and cost-effectiveness of fire management options	Urgent	2.8 Enhanced habitat for lowland swamp forest habitat	Essential
Objective 5: Targeted research addresses key knowledge gaps such that management options are better informed and management actions more effective.			
5.2 Undertake key research on demography and ecology, especially dispersal and population size	Highly beneficial	5.2 Undertake key research on demography and ecology, especially dispersal and population size	Urgent

Australian Government
Department of Agriculture and Water Resources
ABARES

ABARES Briefing Note

Australian Bureau of Agricultural
and Resource Economics and Sciences

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TIMBER HARVESTING AND FIRE RISKS AND SEVERITY IN AUSTRALIA'S NATIVE FORESTS

This briefing note presents a summary of data on whether timber harvesting affects the likelihood or severity of wildfire in native forests.

Key points

1) Recent large fires in the Central Highlands of Victoria, especially in 2009, have led to a debate about whether timber harvesting increases the likelihood or severity of forest fire, compared to management without timber harvesting as in the reserve system.

2) ABARES analysis indicates that:

   a) Many variables affect fire behaviour and fire impacts. Each wildfire occurs in different weather conditions across a different area with different forest types, topography, fire history and management history.
   b) A few reports and commentaries argue, or lend themselves to the view, that timber harvesting increases fire risk or severity, while others use similar data to argue the contrary view.
   c) Given the small proportion of all forests that is available for timber production and the scattered nature of logging sites, the claim that timber harvesting increases fire severity or risk at a landscape level seems implausible.
   d) There may be a larger impact of harvesting on fire severity in areas containing commercial mountain ash stands. However, even in the case of the most recent (2009) large fire in Victoria that was quoted in reports suggesting timber harvesting increases fire severity, CSIRO analysis showed that mountain ash forests comprised only 4% of the total area burnt on the first day of that fire.
   e) There is no unequivocal or generally accepted evidence for the asserted connection between timber harvesting and increased fire risk. It is not plausible to claim that the proposition that timber harvesting increases fire risk has been demonstrated beyond reasonable doubt, but there is also limited research that supports the opposite case.

Introduction

Various recent reports and commentaries claim that timber harvesting increases fire severity or risk in Australia's native forests. Other reports and papers have since claimed that no such relationship exists. Nearly all the work relates to mountain ash forests in Victoria's Central Highlands.

Given the small proportion of forests that is available for timber production and the scattered nature of logging sites, the claim that logging increases fire risk at a landscape level seems implausible. However, perhaps because so many variables affect individual fire behaviour and fire effects, there is as yet no general synthesis. Further, similar analyses of other forest types in other regions could lead to different conclusions. It is not plausible to claim that a case either way has been demonstrated beyond reasonable doubt, even for mountain ash forests.

This report provides a preliminary assessment of research on whether timber harvesting in Australia's native forests makes them more or less prone to fire, that is, whether timber harvesting increases or decreases fire severity or risk. The report is based on studies, observations and analyses undertaken by researchers and experts. This is a contested issue. The scientific aspects are made all the more complex by the widely varying natural fire regimes[1], fire behaviour and fire impacts in different forest types across Australia.

Background to issue

The series of recent large fires in the central highlands of Victoria sparked a debate about whether timber harvesting increases the probability of ignition and severity of fire, at least in some forest types. This proposition was first put forward by Lindenmayer et al. (2009), and contrasts with the long-argued view that the presence of a timber industry in native forests supports fire suppression by providing roads, machinery and people to help with fire-fighting, as well as by reducing fuel loads.

The counterargument to the proposition that timber harvesting increases fire risk and/or impact was first assembled by Attiwill et al. (2014a), who summarised research showing that, while timber harvesting is known to affect site microclimate, stand structure and species composition, these effects are generally temporary, can resemble site dynamics following wildfire, and can (in young regenerating forest) lead to reduced rather than increased fire risk. The duration and intensity of those effects also vary depending on the forest type and silvicultural system used (such as selection systems or clearfelling), as well as the nature of the post-harvest regeneration burn, if any. For example, Mueck and Peacock (1992) found that species richness in forest communities in East Gippsland was relatively low in the first years after harvesting, but equal to that in old-age forest after about 20 years.

At a broader scale, timber harvesting changes the spatial pattern of stands of various ages across the forest landscape, and also involves road construction, which potentially increases the likelihood of fire by providing access to ignition points while decreasing potential fire impacts by increasing access for fire suppression. It is therefore plausible that a timber harvesting event affects fire regimes at a site level, and that a timber harvesting regime across a landscape affects fire regimes at a landscape level. However, since fire is inevitable in most Australian forests, the real question is whether there is any real difference at a landscape level between the likelihood,

[1] 'Fire regime' refers to the frequency, intensity and seasonality of fire over time in a particular location or ecosystem.

severity or effects of fire in forests managed for timber production and the likelihood, severity or effects of fire in forests where timber production is not permitted.

Review of recent research

Several published reviews and research reports, mainly of work undertaken since the "Black Saturday" Kilmore East–Murrindindi wildfires in Victoria, February 2009, provide insights that help assess whether timber harvesting affects the likelihood or severity of fire. These are summarised and assessed below.

Work done before the 2009 fire

Lindenmayer et al. (2009) reviewed published literature and concluded that 'industrial logging' (by which was meant harvesting sawlogs and pulpwood at a certain scale) is likely to make some kinds of forests more prone to an increased probability of ignition and increased fire severity[2] and/or frequency. However, all but one of the sources for that conclusion related to boreal forests (coniferous forests of the far northern hemisphere) or to tropical rainforests (which are not managed for timber production in Australia). Cruz et al. (2012) point out the notable differences in the mechanisms driving propagation of high-intensity fires in eucalypt forests and in conifer forests. The key differences arise from stand structure characteristics and the propensity of wildfire in eucalypt forests to spread by initiating spot fires ahead of the fire front. The relevance of the international studies reviewed by Lindenmayer et al. (2009) to Australian forests managed for timber production is therefore questionable.

The one source cited by Lindenmayer *et al*. (2009) that related to Australia or to eucalypt forests is Mueck and Peacock (1992). That work reported that logging in some moist forests in East Gippsland, Victoria, had shifted the species composition towards one more characteristic of drier forests that Lindenmayer et al. (2009) described as tending to be more fire-prone (although 'fire-prone' was also not defined). Attiwill et al. (2014a) cite Williams (1995), who had reviewed the data on the East Gippsland sites studied by Mueck and Peacock (1992) as well as other data, and who found that the differences in species composition observed by Mueck and Peacock were actually attributable to differences in elevation and rainfall between the sites studied. On this basis, and recognising that no other source relating to eucalypt forests was used by Lindenmayer et al. (2009), Attiwill et al. (2014a, b) considered the conclusion of Lindenmayer et al. (2009) that logging increases fire risk to be invalid.

Studies of the 2009 fire – younger and older logging regrowth

A fire started on 07 February 2009 at Kilmore East in central Victoria in severe weather conditions and burned rapidly in a south-easterly direction for about 6 hours, before a cold front with gale force winds changed the direction of fire spread to the north-west. The fire merged with other fires and burned a total of more than 400,000 hectares over three weeks (Cruz et al. 2012).

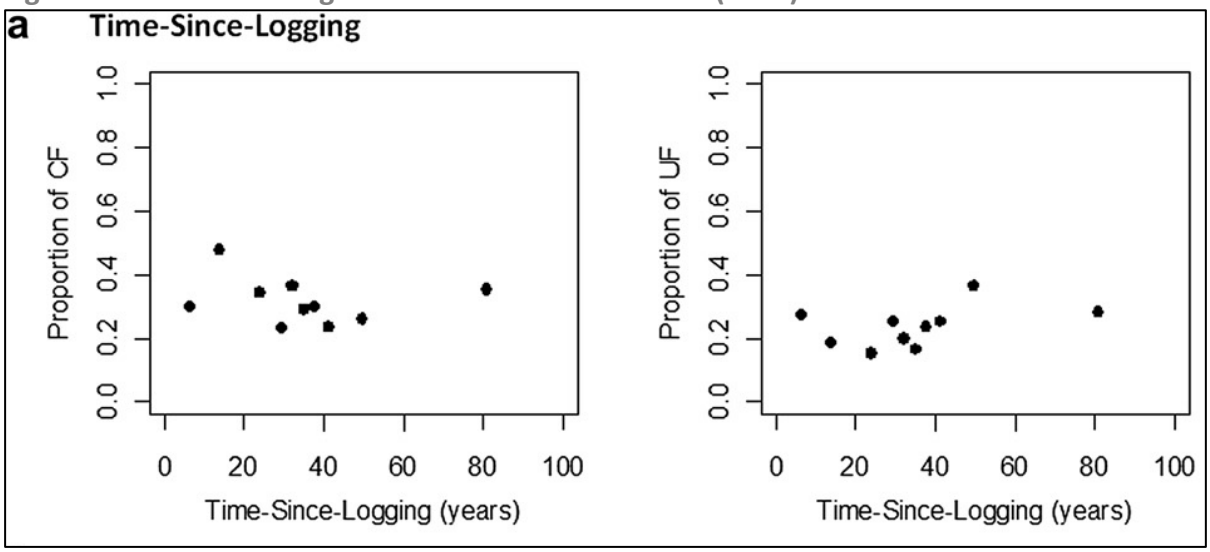
Cruz et al. (2012) studied the fuel types across the area burnt in the first day of that fire, and found that dry sclerophyll eucalypt forest comprised about 54% of the area burnt within the fire perimeter as at 24:00 on 07 February. Other significant vegetation types burnt were

[2] Fire 'severity' was not defined in Lindenmayer *et al.* 2009, but as used by Taylor *et al.* (2014a) is defined as 'the extent of loss or consumption of the vegetation and other biomass as a result of fire'. Other writers have used a broader definition, including effects on soil erosion, vegetation regeneration, restoration of community structure, faunal recolonisation, and other responses (Keeley 2009). Fire *intensity* usually refers to the energy output per unit length of the fire front.

grasslands/open woodland and mixed dry-wet sclerophyll eucalypt forest, covering 20.5% and 16.5%, respectively, of the area burned; only 4% of the area burned in that period was wet sclerophyll (that is, mountain ash-dominated) eucalypt forest. Cruz et al. (2012) also found that the wet sclerophyll forests burned predominantly at a fire intensity lower than that experienced by other vegetation types: the proportions of crown fire and severe scorch in wet sclerophyll forest were amongst the smallest of the various vegetation types.

Price and Bradstock (2012) studied the Kilmore East–Murrindindi section of the Kilmore East fire, seeking to answer several questions about the efficacy of previous fuel treatment in mitigating property loss during wildfires. One of those questions was: '*Did recent logging reduce fire intensity to potentially suppressible levels?*'. They concluded that weather had the most pronounced effect on the likelihood of crown fire and that the '*effects of logging age* (that is, time since logging) … *were weak*'; their Figure 4 shows this weak relationship between the proportion of areas burnt by crown and understorey forest fire and time since logging (Figure 1).

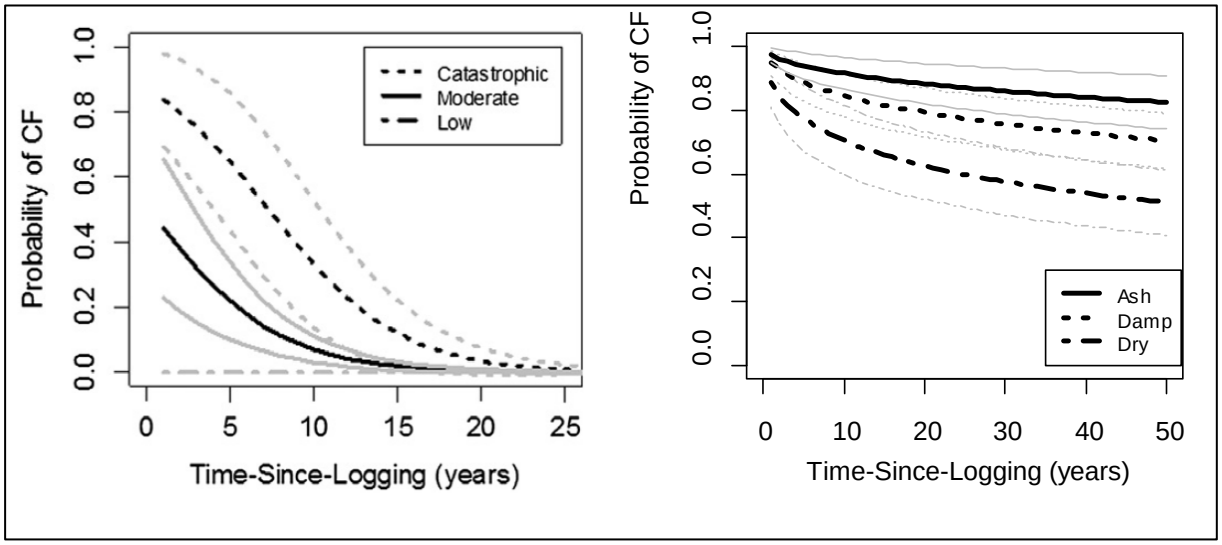
Figure 1: extract from Figure 4 of Price and Bradstock (2012)



The occurrence of crown fire (CF; left) and understorey fire (UF; right), as a proportion of area burnt in the February 2009 Kilmore East–Murrindindi fire, is plotted against time since logging.

However, while finding that these raw data indicated that time since logging had at most a weak effect on the proportion of crown fire, Price and Bradstock (2012) and Bradstock and Price (2014) used these data to model a strong dependence of crown fire probability on time since logging (Figure 2). Price and Bradstock (2012) describe the results of predictive modelling as: '*Time since-logging decreased the likelihood of crown fires, such that long unlogged areas could reduce crown fire likelihood by about 0.3–0.4*'.

Figure 2: extract from Figure 6 of Price and Bradstock (2012), and Figure 1 of Supplementary Material of Bradstock and Price (2014).



In each case, the modelled probability of crown fire (CF) in the February 2009 Kilmore East–Murrindindi fire is plotted against time since logging. Left-hand graph is for all forests combined, under a range of fire conditions from low to catastrophic; right-hand graph is for different forest types under moderate fire conditions. Pale grey lines in each case are confidence limits for predictions.

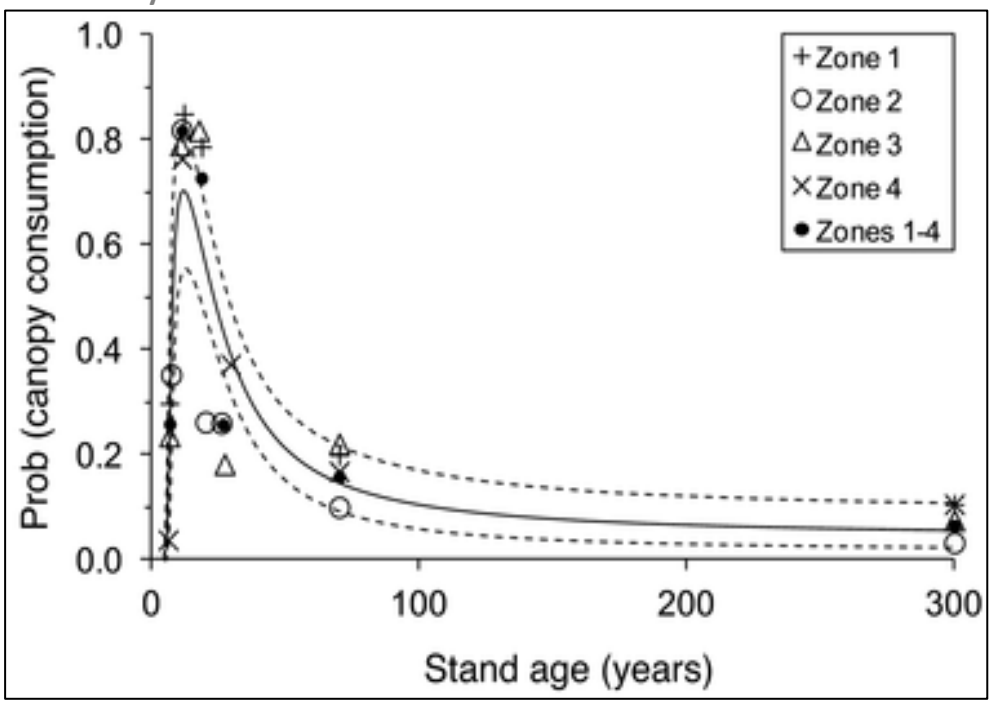
Responding to the apparent contradiction between the raw data (Figure 1) and the results predicted by modelling (Figure 2), Attiwill *et al*. (2014b) suggested that '*Reasons why the Price & Bradstock model does not accurately predict behavior of these fires include their choice of Fire Danger Index classes, and their assessment of fire severity as crown damage which is a function not only of fire intensity but also of stand structure, particularly height and density*'.

Taylor *et al*. (2014a) studied mountain ash forests burned during the same 2009 fire. They concluded that crown fire was strongly correlated with the age of the stands, again using modelled probability outputs (Figure 3). Crown fire was rarely, if ever, predicted to occur in stands younger than 7 years. The probability of crown fire increased rapidly with age up to approximately 15 years, so that stands 7 to 36 years old mostly sustained "canopy consumption and scorching". The probability of crown fire then decreased with age, such that it was predicted to occur at low probability in the oldest stands (see next section).

The conclusion of Taylor *et al*. (2014a) for stands younger than 7 years is consistent with the data of Attiwill *et al*. (2014a) for forests burned in the same 2009 fire, and this phenomenon is well known: there is little surface fuel in these young stands, and they contain a dense ground-vegetation layer that restricts surface drying and reduces wind. Attiwill *et al*. (2014a) found similar early-age effects in forests burned by wildfires in south-west Western Australia.

Regenerating forests one to three decades or so after logging tend to be densely stocked, suppressed trees are dying and providing dry fuel, there is commonly a dense shrub layer, and the trees are shorter than in mature stands. In such stands, a lower fire height (and thus fire intensity) is required to scorch or burn tree crowns and produce the symptoms of 'high-severity' fire. These characteristics would be present whether the forest was regenerating after logging or after wildfire.

Figure 3: Figure 7 of Taylor *et al.* (2014a) showing modelled probability of canopy consumption versus stand age, based on data from the Kilmore East-Murrindindi Fires, 07 February 2009.



Zones are areas that the fire burned at various periods before (Zone 1) and after (Zones 2-4) the wind change.

Thus, of the mid-aged forests 10-69 years old that were burnt in the Kilmore East–Murrindindi fire, 58% of experienced a crown burn or severe scorch, compared to 46% of the burnt older forests and 35% of the burnt young forests (Table 1). However, such sites are only a small proportion of the total forest and fire areas, with only 2.0% of the area burnt in the Kilmore East–Murrindindi fire being mountain ash in State forest that had been logged or regenerated by wildfire since 1940 (Table 2).

Table 1: Burnt areas by stand age in the Kilmore East–Murrindindi fire, February 2009.

Year of stand origin	Stand age (years)	Area burnt in 2009 (hectares)	Proportion of burnt area that was crown burn or severe crown scorch
Older forests			
Pre–1900	>109	74	45%
1900–1939	70–109	10,841	46%
Subtotal older forests	>70	10,915	46%
Mid-aged forests			
1940–1979	40–69	1,094	56%
1980–1999	10–29	3,994	58%
Subtotal mid-aged forests	10–69	5,088	58%
Young regrowth forests			
2000–2009	0–9	2,170	35%
Subtotal young regrowth forests	0–9	2,170	35%
Total forests	0–>109	18,173	48%

Adapted from Figure 4 of Attiwill *et al.* (2014a), which sourced data from the Department of Sustainability and Environment, Victoria. The areas burnt predominantly reflect the proportion of different forest age-classes present in the landscape immediately before the 2009 fire, plus the particular forest area subject to that particular fire.

Table 2: Burnt areas in the Kilmore East–Murrindindi fire February 2009

	Area (hectares)	Proportion of burnt area
Total area burnt	185,000	100%
…of which mountain ash in State forest	18,173	9.8%
…of which area logged or regenerated by wildfire since 1940	7,258	3.9%
…of which:		
crown burnt or severe scorch	3,750	2.0%
moderate, light or no scorch	3,508	1.9%

Adapted from Figure 4 of Attiwill *et al*. (2014a), which is based on data sourced from the Department of Sustainability and Environment, Victoria. 'Mountain ash in State forest' refers only to areas in the general management zone of State forests, and does not include mountain ash forest in national parks, water supply catchments, or reserves on State forest.

Taylor et al. (2014b) also argue that the fact that the proportion of logging regrowth across the fire area is small does not disprove the argument that logging has increased the severity of fire. This they argue is because logging is concentrated in mountain ash forests. While that is superficially plausible, that concentration would also mean that the patches of young logging regrowth, up to around seven years age, are also concentrated in those localities, and that is the age group in which the several studies mentioned suggest fire severity is likely to be lowest. So the older regrowth, where fire severity might tend to be higher, is intermingled with younger regrowth, where fire severity apparently tends to be lower. Which effect outweighs the other and whether on balance at a landscape scale there is any significant effect has not yet been determined.

Are old forests less susceptible to fire?

Taylor et al. (2014a) found that high-severity fire was 'infrequent' in mountain ash stands older than 40 years, although the authors might have meant 'less likely than in younger stands' rather than 'infrequent'; the historical record shows that that fires are common in older forests in this region (Table 3), mountain ash forests are fire-dependent (Ashton and Chinner 1999), and substantial areas of stands older than 40 years burned in the February 2009 fire (Table 1).

Taylor et al. (2014a) and Lindenmayer et al. (2009) opine that mountain ash forests develop features that make them less likely to burn as they mature. These features include tree ferns providing shade that keeps the moisture content of fine fuels higher and development of 'moss mats' that hold a lot of water. Those suggestions are plausible but do not appear to have substantially reduced the area of older forests suffering crown burn or severe scorch in the Kilmore East–Murrindindi fire: this forest type is fire-dependent and, sooner or later, and especially under extreme weather conditions, fires will occur and be propagated in older forests. In contrast with the suggestion that fire is less likely (or infrequent), the data show that show that 46% of the burnt stands of all forest types greater than 70 years old suffered crown burn or severe scorch in the Kilmore East–Murrindindi fire ((Table 1).

The landscape view

Historical records tell us that large fires are common in Victoria. Table 3 shows records of large fires in Victoria since the middle of the 19th century. It is difficult to tell how precise the earlier area records are, with unburnt areas expected within the large areas reported burnt. Wetter and topographically protected locations might not have burned in any of these fires; equally, the large extent of the various fires indicates that some locations will have burned in two or more of

these events. It is apparent that fire is the norm, rather than the exception, at a landscape scale in Victoria.

Table 3: Large fires in Victoria since mid-19th century

Location/s recorded	Year	Fire area (hectares)
Victoria	1851	7,600,000
Central Highlands	1898	260,000
Central-south Gippsland	1926	394,000
Central Highlands and elsewhere	1932	2,040,000
Central Highlands	1939	1,380,000
North-east	1943–44	1,100,000
Central Victoria, Otway Ranges	1983	87,000
Eastern Highlands	2003	1,100,000
Central Highlands	2009	185,000

Sources: Attiwill (1994); Lutze *et al.* (1999); BRS (2010).

Ashton and Chinner (1999) commented that a long period (by which they seem to mean several decades, if not a century or more) without fire in mountain ash forest is unlikely. Further, on the basis of 50 years of monitoring, they concluded that regeneration in mature mountain ash forests will almost certainly fail without fire. That conclusion is supported by Attiwill (1994), who found that mountain ash forests in their natural state are either even-aged or include at the most two to three age-classes, the result of regeneration following stand-replacing fires intermingled with the result of regeneration following fires of lesser intensity.

Another indication of whether wildfire is less likely in older forests is provided by a study in East Gippsland, Victoria, in a forest stand with dominant eucalypt species silvertop ash, messmate and mountain grey gum (Woodgate et al. 1994). This is a forest type in which, unlike mountain ash, the fire regime is not of stand-replacing fires. The stand was classified as 'damp forest' and tree ages were estimated at up to around 300 years when the study was undertaken in 1992. A 300-year fire history derived from growth ring measurements showed that 12 wildfires had passed through the stand at an average interval of 22 years, ranging from 10 to 40 years between fires. The sequence of fires over time showed no trend to a lower fire incidence with age at this site.

Taylor et al. (2014a) and Lindenmayer et al. (2009) might be correct that severe fires are relatively less likely in older mountain ash forests, perhaps because these forests develop features that make them less likely to burn. However the stand structure and history of extensive fires that have burnt mountain ash forests in the Central Highlands of Victoria suggests that such forests do and will burn and are typically regenerated by fire. The key question is therefore what fire regime and fire type promotes forest regeneration, an optimal age-class structure, and a healthy and resilient landscape – and what is the impact on these parameters of the presence of a harvesting regime across part of that landscape?

Does forest tenure matter?

Attiwill et al. (2014a) also compared the severity of fires in 2002/03 and 2006/07 in parks and reserves, where timber harvesting had never occurred or not occurred for many years, to fire severity in state forests where timber harvesting is regular and on-going. Fires in these two season occurred in the Alpine, North-East and Gippsland regions of Victoria, and covered a wide range of forest types. Many factors will have contributed to any differences between fire severity in these fires, and the comparison is not immediately amenable to statistical analysis. However,

it appears that fire severity is not consistently greater or lesser in parks, reserves and water supply catchments, where timber harvesting has not been permitted for many years, than in State forest where timber harvesting is permitted (Figure 4).

Figure 4: Figure 5 of Attiwill *et al*. (2014a) showing fire severity by land tenure for Victorian fires in 2002/03 and 2006.07.

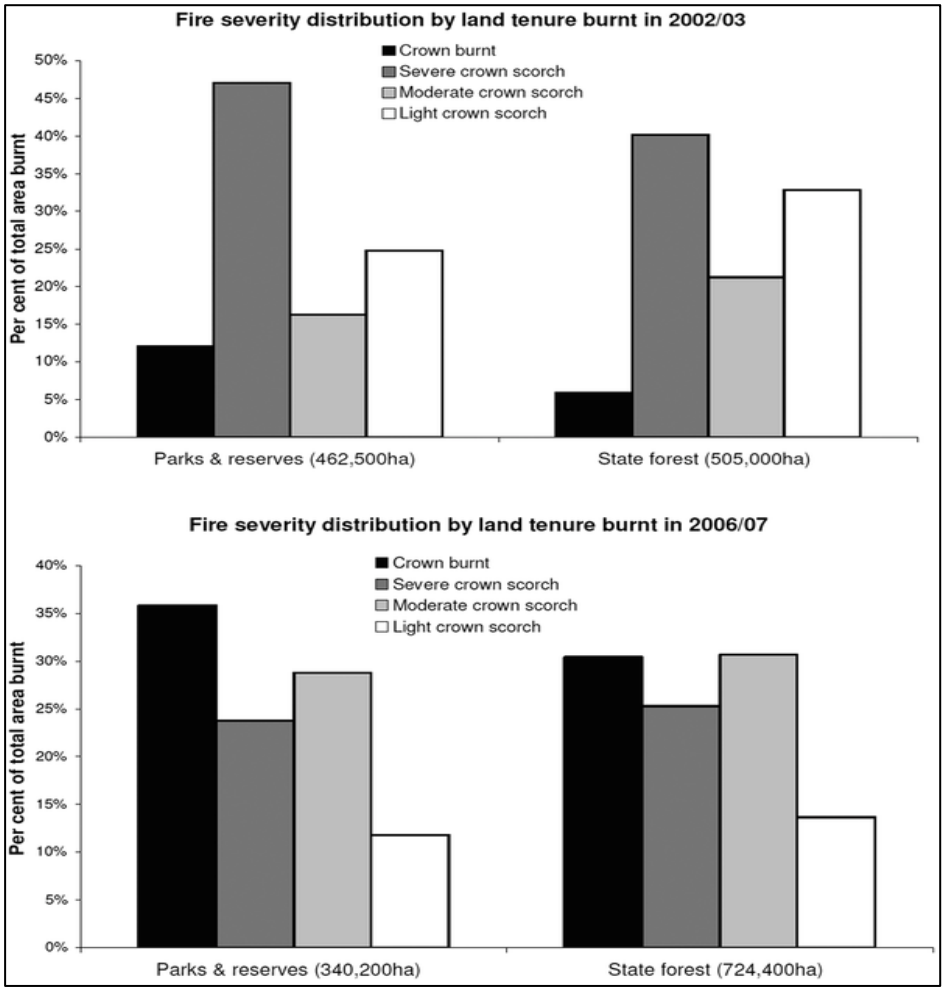


Figure from Attiwill et al. (2014a), which is based on data sourced from the Department of Sustainability and Environment, Victoria.

Conclusion

Many variables affect fire behaviour and fire impacts. Each wildfire occurs in different weather conditions across a different area with different forest types, topography, fire history and management history. In the case of the most recent (2009) large fire in Victoria, mountain ash forests comprised only 4% of the total area burnt on the first day of the fire.

Given the small proportion of all forests that is available for timber production and the scattered nature of logging sites, the claim that timber harvesting increases fire severity or risk at a landscape level seems implausible. There is no unequivocal or generally accepted evidence for the asserted connection between timber harvesting and increased fire risk.

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