The Minister approved this conservation advice on 22/4/2015; and transferred this species from the endangered to the critically endangered category, effective from 2/5/2015.

Conservation Advice

Gymnobelideus leadbeateri

Leadbeater's possum

Taxonomy

Conventionally accepted as *Gymnobelideus leadbeateri* McCoy, 1867 (Leadbeater's possum).

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.

Species can be listed as threatened under state and territory legislation. For information on the listing status of this species under relevant state or territory legislation, see http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Reason for conservation assessment by the Threatened Species Scientific Committee

This is a revised listing assessment for Leadbeater's possum. The species was listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in 2000.

This advice follows assessment of new information provided by public nomination to up-list Leadbeater's possum to the **critically endangered** category.

Description

Leadbeater's possum is a small, nocturnal, arboreal possum. It has a prominent dark brown stripe along its back and is pale underneath. Its ears are thin, large and rounded and it grows up to 17 cm in length. Its thick tail grows to 18 cm in length (Cronin, 1991; Strahan, 1998).

Cultural Significance

Leadbeater's possum is the faunal emblem of the state of Victoria.

Distribution

Leadbeater's possum is endemic to Victoria.

Genetic work indicates that Leadbeater's possum consists of two genetically-distinct subpopulations that have historically occupied different habitats (Hansen, 2008). An outlier 'lowland population' is located at Cockatoo Swamp near Yellingbo (Smales, 1994) within 181 ha of lowland floodplain forest where less than 20 hectares provides suitable habitat (D. Harley 2014, pers. comm., cited in DEPI, 2014). The small subpopulation is a surviving remnant of a lowland subpopulation that has historically been, and remains, isolated from others (Hansen, 2008). The Yellingbo population occurs at 110 m elevation (Harley, 2004a).

The core location of the species is an area of approximately 70 x 80 km in the Central Highlands of Victoria at altitudes between 400–1,200 m above sea level (Lindenmayer et al., 1989) where it is patchily distributed (Macfarlane et al., 1997) and occupies alpine forest and subalpine woodland comprising *Eucalyptus regnans* (mountain ash), *Eucalyptus delegatensis* (alpine ash), *Eucalyptus nitens* (shining gum) and *Eucalyptus camphora* (snow gum). Prior to the 2009 fires, the greatest numbers were considered to occur in montane ash forests, and subalpine woodlands including at Lake Mountain, Mt Bullfight, and Mt Baw Baw.

Fossils and historical records indicate that the species was more widely distributed in the past than the present (Lindenmayer et al., 1993c; Bilney et al., 2010). It was once distributed from Mt Willis in north-eastern Victoria to the Yarra Valley near Melbourne, and south to the Westernport region (DEPI, 2014). Leadbeater's possum has always been considered a rare species (Smith, 1984) and the scarcity of specimens, together with the clearing in the late 1800s of areas thought to be its only habitat, led to the belief that the species was extinct (Rawlinson and Brown, 1977; Smith 1984). Specimens were collected after the 1960s in new localities in the Central Highlands (Wilkinson, 1961; Rawlinson and Brown, 1977).

Occupancy modelling following the 2009 fires predicts current strongholds mainly in the south of the Central Highlands, including the Baw Baw Plateau and its southern slopes, the Toorongo Plateau south of the Upper Yalla Catchment and state forest in the vicinity of Powelltown, parts of Toolangi State Forest and southern parts of the Upper Yarra National Park (Lumsden et al., 2013).

Relevant Biology/Ecology

Leadbeater's possums live in small groups of between two to twelve individuals containing one breeding pair, and shelter in tree hollows during the day (Lindenmayer, 1996a). Colonies live in territories that contain multiple den sites (Lindenmayer and Meggs, 1996). Female dispersal is greater than male dispersal (Smith, 1984) and females are subject to higher rates of mortality. Among young adults, males outnumber females by three to one (Lindenmayer, 1996a) and the general adult population is thought to have a sex ratio approaching 3:1 (Smith, 1984).

Breeding is limited by the number of mature females (Lindenmayer, 1996a). Observations of mating behaviour in captivity suggest that Leadbeater's possum is strictly monogamous, that only one adult male per colony is reproductively active (Smith, 1984) and colonies typically contain only a single adult female (Smith, 1984; Harley and Lill, 2007), although other studies have found colonies with two breeding females (Lindenmayer and Meggs, 1996). Breeding females reproduce twice per year and mean litter size is approximately 1.5 (Smith, 1984; Harley and Lill, 2007). Adult longevity is approximately ten years and age at first breeding is typically two years (Lindenmayer and Possingham, 1995b; Lindenmayer et al., 1993b). Generation length ([longevity + age at maturity]/2) for Leadbeater's possum is six years.

Leadbeater's possum habitat is usually defined as montane ash forest dominated by mountain ash, alpine ash and shining gum with a dense understorey of *Acacia* and an abundance of large hollow-bearing trees. The species also inhabits sub-alpine woodland dominated by snow gum containing a dense midstory of mountain tea tree (*Leptospermum grandiflorum*) along drainage lines (Jelinek et al., 1995) or forest dominated by mountain swamp gum (*Eucalyptus camphora*) with a dense midstory of *Melaleuca* and *Leptospermum* species (Smales, 1994).

Colonies live in territories of 1–3 ha that contain multiple den sites and are actively defended from neighbouring colonies (Lindenmayer and Meggs, 1996). Leadbeater's possum is typically sedentary and territorial, with resident animals travelling between den trees and feeding areas, or between alternative den trees (Lindenmayer and Meggs, 1996; Smith, 1984) with the distance between a set of nest sites used by a colony possibly exceeding 100 m (Lindenmayer and Meggs, 1996). The species appears to have long-term site fidelity (Lindenmayer et al., 2013a).

Leadbeater's possum may be a central place forager. Nest trees are spaced close to the centre of a relative exclusive home range (Smith, 1984), and linear strips of habitat (e.g., 80 m) may be insufficient for their social and dietary requirements (Lindenmayer et al., 1993d).

Leadbeater's possums feed on carbohydrate-rich plant and insect secretions (e.g. sap, manna, honeydew) and invertebrates (Smith, 1980; 1984). In montane ash forest, the species has been recorded incising acacias and feeding on the gum that exudes into the wound (Smith, 1980). Smith (1980) also highlights the dietary importance of an undescribed species of tree cricket. Paperbarks and tea trees may also be incised in lowland swamp forest.

Tree hollows are a critical resource for Leadbeater's possum and the species' abundance is positively correlated with hollow availability (Lindenmayer et al., 1991b). The majority of trees occupied by Leadbeater's possum are dead hollow-bearing trees. Living hollow-bearing trees are also used and become the next cohort of dead hollow-bearing trees in the future (Lindenmayer et al., 2013a). Leadbeater's possum rarely descends to the ground and is highly reliant upon dense, continuous vegetation with interconnecting lateral branches and/or high stem density (Lindenmayer, 1996a).

The key attributes of Leadbeater's possum across all forest types (LPAG, 2013) are:

- Hollow-bearing trees (for nest sites and refuge) with large internal dimensions in the order of 30 cm in diameter are a critical habitat feature for Leadbeater's possums (LPAG, 2013), particularly and almost exclusively large old trees (Lindenmayer et al., 2013a; Lindenmayer et al., pers. comm., 2014a).
- Density of hollow-bearing trees is recognised as a critical habitat feature (e.g., DEPI, 2014). There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's possum (e.g., Lindenmayer et al., 1991b; Lindenmayer et al., 2013b; Lindenmayer et al., pers. comm., 2014a), with nest hollow availability the limiting factor to population size. Density of less than one hollow-bearing tree per hectare is considered to represent ecosystem collapse for the Mountain Ash Forest ecosystem (Burns et al., 2014).
- predominance of smooth-barked eucalypts (with loose bark hanging in strips providing shelter for insect prey and material for nests) or gum-barked eucalypts (related to foraging behaviour) (Lindenmayer, 1996a; Harley, 2004a;b;c). Forest types of Leadbeater's possum are most commonly ash forest typically dominated by mountain ash, alpine ash and shining gum but it is also known to occur in subalpine woodlands and lowland swamp forest dominated by snow gum or mountain swamp gum (Smith and Hartley, 2008)
- a structurally dense interlocking canopy or secondary tree layer of continuous interconnecting structure (to facilitate movement) (Lindenmayer, 1996a; Harley, 2004a;b;c), and
- a wattle understory (providing food) (Smith and Lindenmayer, 1988; Menkhorst and Lumsden, 1995; DSE, 2013).

Habitat considered most likely to be currently occupied by Leadbeater's possums is characterised by lush, unburnt vegetation in gullies, located in areas that have relatively low summer temperatures and high summer rainfall (Lumsden et al., 2013). An optimum habitat is an uneven-aged ash forest with a dense understory of wattle trees and a supply of hollow-bearing trees of between 4.2 – 10 per 3 ha (Smith and Lindenmayer, 1988). Leadbeater's possums appear to have critical minimum habitat size of around 12 ha (Lindenmayer et al., pers. comm., 2014b).

Leadbeater's possums do not occur on burned sites, including those subject to low and moderate severity fire, clearfell logged, or regenerated montane ash forest where hollow-bearing trees are largely absent (Lindenmayer et al., pers. comm., 2014a) until required conditions have returned.

Habitat of the lowland population is different to that throughout the possum's core range of montane ash forest (Harley et al., 2005). The lowland population occupies lowland swamp forest of varied densities of mountain swamp gum with *Melaleuca* spp or *Leptospermum* spp in the middle-story. Densities of Leadbeater's possum are highest in young (e.g., 20–40 years old) stands of forest supporting high stem density. Like the montane population, the lowland population habitat has a predominance of smooth-barked eucalypts (that provide exudates from the trunks), hollow-bearing trees (that provide den sites) and highly-connected in the middle-story or canopy (Harley et al., 2005). Given the genetic distinction of this population, its gene pool may include genes involved in adaptation to a lowland swamp environment, adding to the conservation importance of this population.

Threats

The primary threats to Leadbeater's possum are habitat loss and ongoing deterioration of habitat quality including loss of vegetation type and structure. These threats result in a loss in the species' ability to shelter, breed, disperse, and feed. This situation has resulted in immediate population decline as well as ongoing decline in reproduction rates. Loss of habitat quality has resulted in complete abandonment of habitat in some instances, or reduction in population size and reproduction rate (e.g., at Yellingbo during the past nine years).

The loss of habitat and loss in habitat quality have occurred and continue to occur through a number of causes:

<u>Loss through fire</u>
Fire results in:

- direct mortality of Leadbeater's possums
- loss of habitat (extent and fragmentation). Leadbeater's possum is absent from sites burnt in the 2009 fires regardless of fire severity (Lindenmayer et al., 2013a, b) with 36 per cent of the potential ash forest habitat burnt in 2009 (Lumsden et al., 2013) (or 35 per cent (LPAG, 2013), and
- loss of habitat quality.

Fire is the primary form of natural disturbance in mountain ash forest. Prior to European settlement the fire regime was less frequent than at present, and occurred in late summer (Lindenmayer et al., 2013b). Many major fires have occurred in the Central Highlands over the past 400 years, the largest and most extensive known are the 1939 'Black Friday' fires which burnt over 1.5 million hectares state-wide, including much of the area of Leadbeater's possum habitat (Lindenmayer and Ough, 2006; DSE, 2008).

Lumsden et al. (2013) and LPAG (2013) note that over the last century, bushfires have occurred in the Central Highlands on average every ten years, and that the frequency and intensity of wildfires are likely to increase under climate change scenarios, which predict increased rates of extreme climatic events (Lumsden et al., 2013). The last decade has seen a significant and measurable increase in the number, intensity and area burnt by bushfires and projections suggest that this will continue to escalate (DSE, 2008).

Of the 195,000 ha of ash forest and snow gum woodlands considered to be potential habitat of Leadbeater's possum at 2009, 68,000 ha (35 per cent) was burnt in 2009 (LPAG, 2013) and 45 per cent of the best Leadbeater's possum habitat within montane ash forest (Lumsden et al., 2013). Of the three sub-alpine sites where Leadbeater's possum have been monitored – Lake Mountain, Mt Bullfight and Mt Baw Baw; Lake Mountain and Mt Bullfight were burnt in 2009. The Lake Mountain site was thought to contain up to 300 individual Leadbeater's possums prior to the 2009 fires, with only four individuals recorded since (Harley and Antrobus, unpublished data cited in Harley and Lindenmayer pers. comm., 2013). Surveys at Mt Bullfight indicate that the population supports fewer than 50 individuals following the 2009 fires (Harley and Lindenmayer pers. comm., 2013)

Low intensity fire can stimulate some regeneration but may not kill all over-story trees, resulting in multi-aged stands. In severe, high intensity wildfires, almost all the over-story trees may be killed, but seeds are released that germinate as a uniform regenerating cohort. Fire in an old growth forest will produce a pulse of large dead trees and fire scarred living old trees that can provide nesting habitat for cavity-dependent species such as Leadbeater's possum (Lindenmayer et al., 2013b).

Wattle in the understory provides food for Leadbeater's possums. Wattles age and decline over more than 50 years after fire. Bushfire usually kills wattle, but promotes regeneration of this foraging habitat, which forms suitable substrate within 20 years of fire (LPAG, 2013).

While fire may promote the capacity for older trees to form hollows from fire scarring, young trees do not stand long after they are burned and are not able to form cavities for nesting (Lindenmayer et al., 2013b). It is estimated that old-growth or multi-aged mountain ash forest comprised 30–60 per cent of the current ash forest estate in the Central Highlands of Victoria prior to European settlement. Old grown ash forest now comprises 1.15 per cent of this mountain ash forest estate (Lindenmayer et al., 2011; Lindenmayer et al., 2013a). Large areas of the forest estate are regrowth forest with small areas of old forest embedded within them (Lindenmayer et al., 2011).

When the interval between fires is less than that required for stands to reach reproductive maturity (approximately 20 years), mountain ash will be replaced with other species with shorter reproductive periods such as wattle (Lindenmayer et al., 2011).

The 'Black Saturday' fires in 2009 fires burnt 45 per cent of the best Leadbeater's possum habitat within montane ash forest (Lumsden et al., 2013). Post-fire, the species has not been detected at burned sites regardless of fire severity (Lumsden et al., 2013). The threat of another wildfire, even if it is small in scale, is a threat to this species' persistence (VicForests pers. comm., 2014).

Leadbeaters' possum are less abundant on unburned sites where the surrounding landscape has been burned, and suggest a greater level of decline after fire than previously recognised (Lindenmayer et al., 2013c).

Young forest burns at higher severity than mature forest (Lindenmayer et al., 2011). Lindenmayer et al. (2011) outline a number of reasons for this, including increased density of regrowth saplings, lower canopies and therefore lower fuel height for flames, closely spaced tree crowns, the potential for reduced soil and moisture holding capacity of undergrowth, and propose that a landscape fire-trap develops because of the interacting effects of wildfire, logging and the combination of these. Taylor et al. (2014) also found a strong relationship between the age of mountain ash forest and the severity of fire damage, with a higher frequency of high-severity impacts occurring in stands of trees less than seven or greater than 40 years. Attiwill et al. (2013), however, found no support for increased fire severity in younger age class forests from the 2009 fires in the Central Highlands. They note that the largest of these fires (at East Kilmore–Murrindindi, which burnt 100,000 ha) was not consistently greater or lesser in older regeneration than in the most recent regeneration, and that greatest fire severity (measured by crown burn) occurred in the intermediate age classes.

Burned forests are subject to post-fire salvage logging. Salvage logging resembles clearfelling but in the reverse order: the forest is initially burned by unplanned fires and fire damaged stands are then clearfelled with merchantable timber removed. In some cases regeneration burns or mechanical site-preparation methods are used to re-establish eucalypt stands (Lindenmayer and Ough, 2006). The impact of this process is similar to clearfelling, because it involves clearfelling (Lindenmayer and Ough, 2006). Burned hollow-bearing trees in stands subject to salvage logging are exempt from cutting, however their collapse rates are higher because they are subject to increased exposure (Lindenmayer and Ough, 2006).

Fire is also involved in the process of clearfell harvesting. Following clear cutting, logging debris is burned to create a bed of ashes in which the regeneration of a new eucalypt stand takes place (Lindenmayer et al., 2011; Lindenmayer et al., 2013a).

Loss through harvesting and lack of habitat quality in regrowth forest
In the past 40 years, the usual method of logging has been clear-felling (Lindenmayer et al., 2011) and is currently the conventional form of logging in Victorian mountain ash forests (DSE, 2006). Clear-felling is a method of harvesting a coupe in which all merchantable trees, apart from those to be retained for wildlife habitat, are removed in a single operation. In the Central Highlands, harvesting predominantly involves clearfelling in coupes averaging 16.5 hectares (Attiwell et al., 2013). A 'regeneration' or 'slash burn' fire is then usually undertaken of the debris (logging slash) before sowing takes place (DSE, 2006; Attiwell et al., 2013). Hollow-bearing trees retained for 'wildlife habitat' are of little immediate habitat value to Leadbeater's possum when there is no surrounding foraging habitat, but may be used when surrounding foraging habitat vegetation and structure is regrown (i.e. 20 years (LPAG, 2013)).

Vegetation clearance results in an expected direct mortality of Leadbeater's possums and loss of habitat (extent and fragmentation). Leadbeater's possum does not occur in clearfell logged and regenerated montane ash forest where hollow-bearing trees are largely absent (Lindenmayer et al., pers. comm., 2014a). 42,685 hectares of montane ash forest in the Central Highlands has been logged in the past 40 years, including approximately 19,338 hectares since late 1997 Lindenmayer et al. (pers. comm., 2014a).

Old-growth ash forest is prime habitat for Leadbeater's possum. It is estimated that old-growth or multi-aged mountain ash forest comprised 30–60 per cent of the current ash forest estate in the Central Highlands of Victoria prior to European settlement. Old growth ash forest now comprises 1.15 per cent of this mountain ash forest estate (Lindenmayer et al., 2013a).

The dominant eucalypts in montane ash forest do not begin to form hollows until trees are 120 years old (Lindenmayer et al., 2013b) and do not develop hollows suitable for Leadbeater's possum until trees attain 190 years of age (Smith and Lindenmayer, 1988). In many areas, standing dead trees have provided the majority of dens for Leadbeater's possums (Lindenmayer et al., 1991b). However, these trees are subject to a high rate of collapse resulting from natural decay (Lindenmayer et al., 1997; 2012). While loss of hollows due to decay is a natural process, hollows have been and are currently being lost at a greater rate than they are formed due to a reduction in equivalent replacement as a result of clearfelling, fire, and in some cases, altered succession (e.g., Yellingbo). Short-term intervals between fire events and timber harvesting on short rotation cycles do not provide for formation of replacement hollows (Lindenmayer and Possingham, 1995a; 1995b; 1996). As a consequence, the availability of suitable hollows for denning is a limiting factor across much of the range of Leadbeater's possum (Lindenmayer et al., 1997; 2012). In areas of regrowth, for instance in areas burnt during fires in 1930s, trees may not develop hollows suitable for Leadbeater's possums for more than a century (Lindenmayer et al., 1993a,b).

Clearfell logging on 80–120 year rotations means that large old trees never develop on logged and regenerated sites. Selective clearfelling removes targeted existing large trees (including nest hollows), but also accelerates the decay and collapse of non-targeted hollow bearing trees, (Lindenmayer et al., 2013b). The rate of tree fall exceeds recruitment of new hollow-bearing trees within montane ash forests (Lindenmayer et al., 1997).

The impacts of fire go beyond the areas directly burned. Hollow-bearing trees adjacent to areas of logged forest have been found to suffer from accelerated rates of collapse (Lindenmayer et al., 1997).

In existing forests, the quality of Leadbeater's possum habitat may be reduced by:

- loss of hollow bearing trees without equivalent replacement hollows as a result of earlier harvesting;
- habitat fragmentation as a result of timber harvesting or fire,
- altered habitat structure due to altered fire regimes, harvesting regimes or altered hydrology.

Loss of habitat quality – other causes
Loss of habitat quality has resulted in complete abandonment of habitat in some instances, or reduction in population size and reproduction rate (e.g., at Yellingbo during the past nine years).

The Yellingbo Nature Conservation Reserve population of Leadbeater's possum is genetically distinct from the remaining Leadbeater's possums (Hansen, 2008). It occurs in mountain swamp gum dominated forest with a dense midstory of *Melaleuca* and *Leptospermum* species (Smales, 1994). This habitat is subject to ongoing quality decline of eucalypt dieback and reduced regeneration, resulting in an altered, more open forest structure. The major cause of this change is thought to be a result of altered hydrology of the Cockatoo Creek floodplain (Harley and Antrobus, 2007). There is currently estimated to be less than 20 ha of high quality habitat available at Yellingbo. In 2007, an assessment across the reserve indicated that vegetation dieback was present at more than 40 per cent of sites (Harley and Lindenmayer, pers. comm., 2013). Habitat deterioration has resulted in the abandonment of 46 per cent of active territories at Yellingbo during the past nine years (Harley and Antrobus, unpublished data cited in Harley and Lindenmayer pers. comm., 2013). Molecular analyses also indicate that the habitat decline has resulted in population fragmentation within the reserve (Hansen, 2008).

Population monitoring of the lowland population of Leadbeater' possum has been conducted at Yellingbo Nature Conservation Reserve since 1996. Data collected between 1995 and 2004 indicated that the size of the population was stable at 80–100 individuals (Harley et al., 2005). The number of individuals recorded peaked to 112 at 2003. At 2012 the number had dropped to 60 individuals (Harley and Lindenmayer, pers. comm., 2013). Recent reports are that the population has declined to only 42 individuals in 2013 (Arup and Smith, 2013) and in 2014 only 40 individuals (Smith, 2014).

How judged by the Committee in relation to the EPBC Act Criteria and Regulations
The Committee notes it is not necessary to identify a quantitative risk of extinction, but it is important to ensure that judgements about the criteria (for example, whether a reduction in numbers represents a severe decline) are made in the context of risk of extinction. When assessing a species' eligibility against the listing criteria, the Committee exercises its judgement to give practical meaning to the subjective terms of the criteria, by considering information in the context of the species' biology and relevant ecological factors, and having regard to the degree of complexity and uncertainty associated with that context and the information provided. The Committee is informed, but not bound by, indicative thresholds.

Criterion 1: Reduction in numbers (based on any of A1 – A4)

A1. An observed, estimated, inferred or suspected population very severe ≥90%, severe ≥70% substantial ≥50% size reduction over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
- (d) actual or potential levels of exploitation
- (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

A2. An observed, estimated, inferred or suspected population very severe ≥80%, severe ≥50% substantial ≥30% 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.

A3. A population size reduction very severe ≥80%, severe ≥50% substantial ≥30%, 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.

A4. An observed, estimated, inferred, projected or suspected population size reduction very severe ≥80%, severe ≥50% substantial ≥30% 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.

Criterion 1 establishes trend through estimates of quantitative change by comparing a baseline of a variable to the same variable over the period of time of three generations lengths. The comparison provides for an estimated decline over time. The time of comparison varies among the four options of this criterion with A1 and A2 including the past, A3 the future, and A4 the past to the future. Within each of these, decline may be observed, estimated, inferred or suspected for population size based on any one variable described in (a) – (e).

Eligible for listing as Critically Endangered (based on A2(c), A3(c))

Evidence:

The period of time over which decline is considered (three generation lengths) for Leadbeater's possum is 18 years.

Application of A1–A4 for Leadbeater's possum:
Causes of population reduction in Leadbeater's possum have not ceased and may not be reversible. Therefore A1 is not applicable and the Committee will consider has therefore considered declines only within the options described under A2, A3 and A4. Under these, 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.

Application of (a)–(e) for Leadbeater's possum:
The variables that can be considered in Criterion 1 for population size reduction include direct observation (a) (not applicable for A3) and index of abundance (b); area of occupancy, extent of occurrence and/or quality of habitat (c); levels of exploitation (d); or effects of an introduced biological threat (e).

While there are estimates of current numbers of individuals of Leadbeater's possum for the whole species (e.g., LPAG, 2013; Lindenmayer et al., pers comm., 2014a, see also Criterion 3), the methodology used for these estimates cannot be applied to the past to provide baseline numbers for comparison of change resulting in a quantitative threshold. While there are instances of numbers of individuals in specific locations declining over time (e.g., Yellingbo, Mt Bullfight, Lake Mountain) and these indicate decline in the species at these locations, they do not provide for quantitative estimates of decline for the whole species. There are therefore inadequate data to provide for quantitative levels of declines over time for the whole species using 'direct observation' (a) and 'index of abundance' (b) for population size for this criterion.

There are no data to provide for quantitative declines for Leadbeater's possum based on (d) levels of exploitation, or (e) effects of an introduced threat.

Analyses for Leadbeater's possum under Criterion 1 therefore focus on decline in Leadbeater's possum based on decline in area of occupancy, extent of occurrence and/or quality of habitat (c). Analyses based on (c) – decline in area of occupancy, extent of occurrence and/or quality of habitat have be undertaken for A2 and A3. There are not adequate baseline data to provide for additional further analyses under A4. Details of these analyses are provided in Appendix 1 and are summarised below.

Information sources for analyses under Criterion 1
Decline in area of occupancy, extent of occurrence and/or quality of habitat for Leadbeater's possum under Criterion 1 is primarily focused on three causes:

- decline as a result of fire,
- decline as a result of harvesting, primarily as clearfelling but also including thinning, and
- decline in habitat quality due to loss, without equivalent replacement, of hollow-bearing trees.

Leadbeater's possum is a habitat specialist, with one of the most restricted distributions of any Australian mammal (Lindenmayer, 2013). While alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum have been termed 'potential habitat' and 'suitable forest' (e.g., LPAG 2013; 2014a, b) for Leadbeater's possum, not all of this forest is suitable habitat. Lindenmayer et al. have undertaken large scale vegetation surveys in the central highlands of Victoria since 1987 (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000). Their data layers indicate that at 1987 and 1989 montane ash forest was represented by 171,200 ha, but of this only 6.7 per cent was predicted to support suitable habitat for Leadbeater's possum. Lumsden et al. (2013) also note that while there are 43,501 ha of unburnt ash forest protected in parks and reserves within the Central Highlands at 2013, not all this area is likely to be suitable and occupied by Leadbeater's possum, with modelling based on post-2009 fire surveys estimating that the possum is likely to only occupy 15,000 ha.

Loss due to future fire
The last decade has seen a significant and measurable increase in the number, intensity and area burnt by bushfires. Projections suggest that this situation will continue to escalate (DSE, 2008). Wetter forests, including the Central Highlands and the Otway Ranges burn less frequently and often only following periods of extended drought. Over the last century, major fire events in the state of Victoria, including 1939 Black Friday, 1983 Ash Wednesday, 2003 Alpine Fires and the 2006/07 Great Divide Fires have occurred during extended periods of drought (DSE, 2008). Each of these fires burnt over 1 million hectares state-wide (DSE, 2008).

DEPI (2013) note that bushfire risk is difficult to quantify, and where and when they will occur is largely unknown. Modelling to quantify bushfire risk across Victoria was undertaken by DEPI (2013) to develop bushfire risk mitigation strategies. The model could not incorporate risk to ecological values because sub-models that quantify bushfire effects on ecological values were not sufficiently advanced to be incorporated. As a result, estimation of risk was limited to risk to property. Results noted that bushfire risk to property varies considerably between regions. East Central, the region that includes the Central Highlands, has a significant proportion of the state's bushfire risk to property (31 per cent). This region had a residual risk near the maximum level (100 per cent) for many years (20) prior to the 2009 bushfires, and after the 2009 fires the residual risk dropped to near 40-50 per cent as a result of the reduction in fuel loads. Residual risk, however, has rapidly increased since 2009 (modelled to be at between 70–75 per cent by 2015) even after planned burning on public land (DEPI, 2013).

Lumsden et al. (2013) and LPAG (2013; 2014b) note that over the last century, bushfires have occurred in the Central Highlands on average once every ten years. As Leadbeater's possum is confined to a relative small area, a single large fire can impact on a significant proportion of the population (LPAG, 2014b). This frequency and intensity of wildfires is likely to increase under climate change scenarios, which predict increased rates of extreme climatic events (Lumsden et al., 2013) and thereby increasing the risk to Leadbeater's possum (LPAG, 2014b).

Of the 195,000 ha of ash forest and snow gum woodlands considered to be 'suitable forest' for Leadbeater's possum, 68,000 ha (35 per cent) was burnt in 2009 (LPAG, 2013), and 45 per cent of the best Leadbeater's possum habitat within montane ash forest (Lumsden et al., 2013). A single large fire can impact on a significant proportion of the population of Leadbeater's possum (DEPI, 2014). VicForests (pers. comm., 2014) note that the threat of another wildfire, even if it is small in scale, is a threat to this species' persistence. Lumsden et al., (2013) note that the 2013 Aberfieldy fire could have severely affected the remaining strongholds for Leadbeater's possum in the Baw Baw region if it had started on the western side of Thompson Dam instead of the eastern side, noting that a single fire could have had a significant impact on one of the remaining strongholds for the species. The Baw Baw Plateau was not affected by 2006/7 or 2009 fires, but is a continuous forested area and an area less than a quarter in size of that burned in the 2009 fires. This smaller size and its continuity makes it susceptible to extreme damage should a fire reach this location.

A fire to the Yellingbo population would significantly reduce the genetic diversity of the species.

Noting this likelihood and potential damage, Lumsden et al. (2013) incorporate future fire scenarios of 25 and 50 per cent of Leadbeater's possum reserve system burnt by bushfire by 2020 into their modelling of population viability. They noted that if the fire was larger, for example equivalent to the 1939 fires, the impact would be even greater, and if there was more than one fire, the risks would be compounded.

If we assume the prediction of one fire every ten years (following Lumsden et al., 2013; LPAG, 2013; 2014b), and these are independent events across an area, the probability of at least one fire occurring over the period 2013 to 2031 is around 85 per cent, with the potential to further reduce ash or snow gum woodland in the range of Leadbeater's possum. The chance of more than one fire occurring is 55 per cent. The magnitude of any future fire occurring between now and 2031 and its impact on existing ash forest and Leadbeater's possum habitat, however, is unable to be quantified.

Given the likelihood of fire, but the unknown and unquantified area likely to be impacted, the Committee has considered a range of potential scenarios to determine possible impacts to area of occupancy/extent of occurrence. Scenarios include no fire, low to medium likelihood of fire impact (e.g., of 12.5 and 20 per cent), and a 50 per cent likelihood of fire impact. A 35 per cent loss from fire scenario is also included, because this is equivalent to the area lost to ash forest and snow gum woodland 'suitable forest' in the 2009 fires. This range of potential losses are applied to the area estimates (to 'predicted habitat' and 'suitable forest') that remain following loss from harvest and loss of habitat quality.

The Committee notes that the fire damage scenarios included in its analyses are relatively conservative, given:

- 34–36 per cent of potential ash forest habitat / suitable forest ash was lost in the 2009 fires (Lumsden et al., 2013; LPAG 2013; 2014a),
- 45 per cent of the 'best habitat' in the reserve system was lost during the 2009 fires (Lumsden et al., 2013; LPAG 2013),
- modelling of future loss to the reserve system from fire by Lumsden et al. (2013) included:
    - fire scenarios of 25 and 50 per cent loss
    - within a timeframe of 7 years (to 2020).

The analyses of future loss from fire scenarios explored here in Criterion 1, estimate losses to the maximum of 2031 i.e., within 18 years. This approach is more conservative in terms of likelihood.

The Committee notes that risk of fire occurring within an area often drops immediately following fire (e.g., as demonstrated in DEPI, 2013) and that fires are not independent events, but notes also that the impacts of fire can be cumulative within an area. The analyses provide for one fire of various magnitudes within the time periods considered, but as occurrences of fires reduce the likelihood of subsequent future occurrence (at least in the short-term), the consequence of any subsequent fire to the remaining reduced habitat is much greater. The analyses, like those of Lumsden et al. (2013), assume future fire is independent of previous fires, but the Committee notes that any subsequent fire would have compounding impact.

Details of these analyses are provided in Appendix 1. This Appendix provides the detail for options considered most appropriate for the data available for Leadbeater's possum. The analyses in Appendix 1 for Criterion 1 are limited to the subpopulation within the Central Highlands and do not include data or analysis of the remaining lowland subpopulation of Leadbeater's possum in Yellingbo (which are currently thought to occupy as little as 50 ha (LPAG, 2013)).

Analysis A2 (past 18 years from 1995)

Analysis A2a provides estimates of loss of the predicted occupied habitat from 1989 to 2013 (Lindenmayer et al., pers. comm., 2014a). Suitable habitat at the baseline at 1989 is estimated to be 11,470 ha, which declines to only 2,225 ha by 2013 as a result of loss from fire, harvesting and loss in habitat quality from loss of hollow-bearing trees. This is a decline of over 80 per cent decline, which is considered to be very severe (Table 1).

In this estimation of remaining suitable habitat, Lindenmayer et al. (pers. comm., 2014a) have noted previously suitable habitat has been lost and become unsuitable through the loss of hollow-bearing trees. Where 6.7 per cent of montane ash forest was suitable in 1989, the loss of hollow-bearing trees has resulted in only 3.1 per cent being currently suitable (independent of other losses from fire and harvesting). This represents a 53.7 per cent loss of habitat from this cause, and is a complete loss of habitat use by Leadbeater's possum (rather than a habitat quality decline where habitat may still be used but at a lower capacity than high quality habitat). It is presumed that in the remaining habitat that is used by Leadbeater's possum, there is an additional decline in quality of a lower density of hollows. Such decline has not been included within this assessment and may, therefore, provide for an underestimation of decline. These losses are also conservative because they do not include the loss of potentially suitable habitat that occurs as narrow strips, edge effects, or the fragmentation of habitat by roads and tracks that the possum cannot cross. The Committee is uncertain about any over-estimation of loss from potential double counting (e.g., habitat lost from hollow-decline and subsequent burn). This analysis uses data from 1989 (rather than 1995) and therefore may include a degree of over estimation of loss.

The Committee notes that the analysis of predicted suitable habitat overestimates loss because it considers loss over a larger time period (the baseline begins at 1989 rather than 1995), but as it does not include reduced habitat quality from loss of hollow-bearing trees, habitat lost as a result of edge effects and, loss of habitat as strips and fragmentation by roads it also underestimates loss.

Analysis A2b provides estimates of loss for the much larger area of 'suitable forest' (from data provided by VicForests pers. comm., 2014; LPAG, 2014a) for all ash forest (comprising mountain ash, alpine ash, shining gum and snow gum forests) within the home range of Leadbeater's possum and within the Central, Dandenong and Central Gippsland Forest Management Areas. 'Suitable forest' at the baseline 'since 2000' is 204,400 ha. Two options of loss from the decline of hollow-bearing trees have been provided in the analysis, along with quantitative data on losses (in hectares) from fire and harvesting. The first option is a 22 per cent loss based on abundance at 1997 being 5.1 hollow-bearing trees per hectare to 4 per hectare in 2013 (Lindenmayer et al., pers. comm., 2014a). Using this decline of 22 per cent, the overall decline in 'suitable forest' from this, fire and harvesting is 44 per cent, which is considered to be substantial. The second option is a 53.7 per cent loss following that found by Lindenmayer in A2a. Using this decline, the overall loss from fire, harvesting and loss of habitat from loss of hollows is 67 per cent, which is considered to be severe (Table 1). The data for losses from harvesting and fire provided by VicForests (pers. comm., 2014) are provided 'from 2000'. This time period is shorter than that considered for A2a and is therefore an underestimate for the 18 year time period considered for this assessment. This analysis uses data from 'since 2000' (rather than 1995) and therefore may include a degree of underestimation of loss.

Results of A2 are shown in Table 1.

Table 1. Summary outcome of assessment under A2

A2	Type	Assessment period	Baseline area	Total estimated area of occupancy, extent of occurrence and/or quality of habitat decline by 2013
(a)	Predicted 'suitable habitat'	1989 to 2013	11,470 ha	81–83%
(b)	'suitable forest'	'since 2000' to 2013	204,000 ha	44–67%

The Committee notes that both analyses incorporate inaccuracies. Analysis (a) appears to have unknown degrees of overestimation (longer time period than 18 years) and underestimation (it does not include all expected losses). Analysis (b) similarly has unknown underestimation of loss as it does not include loss for the entire 18 year period.

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. The IUCN (2014) note that area of occupancy is included in the criteria in addition to extent of occurrence because it helps to identify those species that are habitat specialists (such as Leadbeater's possum) and these species are considered to have an increased risk of extinction. It also notes that area of occupancy can be a useful proxy for population size because there is generally a positive correlation between area of occupancy and population size. Given this, the Committee considers that decline in the predicted suitable habitat is a closer approximation to decline in population size than is 'suitable forest' or extent of occurrence.

In this instance, where there are different decline rates for these two measures, the Committee considers predicted suitable habitat to be a closer representation to decline in Leadbeater's possum over this time period. The Committee therefore considers that the decline of 81–83 per cent is a closer representation to decline in population size of Leadbeater's possum over this time period, which it considers to be very severe.

A3 (future 18 years to 2031)
Analysis under A3 allows for the use of current estimates of 'suitable habitat/predicted occupied habitat' or 'suitable forest', and predicts into the future.

Analysis A3a and A3b provide estimates of loss from 2013 to 2031 using baselines of the predicted occupied habitat at 2013 of 2,225 ha (Lindenmayer et al., pers. comm., 2014a) and 15,000 ha (of Lumsden et al., 2013). Analysis A3c provides the same analysis but on 'suitable forest' (rather than predicted occupied habitat). Losses from predicted harvesting (with different harvesting rates) and a 63 per cent loss of quality to the remaining unharvested habitat /forest, as a result of a decline from 4 hollow-bearing trees per hectare to 1.5 hollow-bearing trees per hectare in 2035 (Lindenmayer et al., pers. comm., 2014a), are deducted sequentially (to prevent double counting of loss). This area also has the potential to be lost to fire in the 18 year period to 2031, although the quantities of loss are speculative. Given fire history of the region, various potential losses from fire have been included, noting these include loss scenarios less than those of Lumsden et al. (2013) and over a longer time period, and are therefore relatively conservative. As the analysis provides for outcomes from a range of scenarios, including no fire, they do not include the quantitative probability of fire occurring within this time period. The results indicate that should fire damage 50 per cent of area by 2031, overall loss will be greater than 80 per cent, regardless of the various predicted harvest rates or the original baselines used (predicted occupied habitat or 'suitable forest'). This loss is considered to be very substantial. Under the maximum predicted harvest rates the loss is very substantial if fire only damages 35 per cent of habitat to 2031. These results are summarised in Table 2 (with detail provided in Appendix 1).

A revised Action Statement under the Victorian *Flora and Fauna Guarantee Act 1988* for Leadbeater's possum was approved and released in August 2014 (DEPI, 2014). This Action Statement sets out what is intended to be done by the Victorian Government to conserve and manage the species. Action Statements are designed to apply for three to five years, after which time they will be reviewed and updated. The Action Statement (DEPI, 2014) for Leadbeater's possum notes further specific reductions in harvesting activities relative to Leadbeater's possum 'potential habitat' ('potential habitat = 'suitable forest'). These include:

- that all future harvesting activities, including thinning and the construction of new roads, are to be excluded from the timber harvesting exclusion zone around *[verified]* colonies* *[i.e. 200m radius]*,
- harvesting activities will be excluded from within 100 m of modelled old growth ash forests,
- protection from harvesting activities for at least 30 per cent of ash forest (approximately 274 ha) to develop old growth forest,
- additional exclusions with a 200 metre radius (Special Protection Zones) will be established around all verified records of colony sites from the 15 years prior to February 2014, and all new records once the record is verified.
- harvesting will be delayed for two years in areas where modelling (Lumsden et al., 2013) predicts a greater than 0.65 probability of being occupied by Leadbeater's possum. Should Leadbeater's possums be confirmed to occur following surveys *[presumably undertaken across these areas within the two year timeframe?]*, these sites will be confirmed sites and zoned as Special Protection Zones.

* colonies are required to be verified to a standard developed by DEPI.

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.

Table 2. Summary outcome of assessment under A3

	type	Assessment period	baseline area	Estimated total decline – no future fire[1]	Estimated total decline – 35% fire[2]	Estimated total decline – 50% fire[1]
A3(a)	Predicted suitable habitat	2013 to 2031	15,000 ha	65	77–83	87
A3(b)	Predicted suitable habitat	2013 to 2031	2,225 ha	63	77–83	87
A3(c)	'suitable forest'	2013 to 2031	146,660 ha	65	77–83	87

[1]= under all harvest scenarios assessed
[2]= range of total loss under all harvest scenarios assessed

The Committee considers that it is unlikely that no fire will occur by 2031 and, although included here in Table 2 to demonstrate the lower bound of decline under A3, scenarios of no fire will not be considered further for this assessment to 2031.

Given that:
- the Committee's assessments of fire scenarios are relatively conservative to models predicting outcomes based on fire history for the area,
- a 35 per cent impact of fire is similar to the 2009 fires,
- Lumsden et al. (2013) and LPAG (2013) note that over the last century, bushfires have occurred in the Central Highlands on average every ten years
- this assessment is over an 18 year period, and therefore fire has a even greater likelihood of occurring,
- the 18 year period provides for the likelihood of more than one fire occurring within this time period,
- that the intensity and frequency of fire is expected to increase (e.g., DSE, 2008; Lumsden et al., 2013),
- the smaller the area considered, the lower the likelihood of fire impact to that area, however the greater the consequence should it occur,

on balance the Committee considers that decline in population size to 2031 under A3 is estimated, inferred, projected and suspected to be of over 80 per cent and very severe.

Long term projections beyond 2031

After the period under consideration for this criterion, Leadbeater's possum is confidently predicted to decline further.

Beyond 2031 (the limit of consideration for thresholds in this criterion) the rate of decline of hollow-bearing trees and therefore Leadbeater's possums will increase, noting that the rate of decline will increase further towards 2060, and recognising there is likely to be some degree of lagged response. Mountain ash typically do not start forming hollows until they are 120 years old, with the large cavities preferred by Leadbeater's possum typically taking 190–220 years to form (Smith and Lindenmayer, 1988).

The trend for projected abundance of hollow-bearing trees in montane ash forests is for a rapid decline over the coming 20 years, even without further logging and fire, with projections of more than 4 hollow-bearing trees per hectare habitat wide in 2013 to 1.5 per ha by 2035, followed by less than 0.9 per ha by 2060 (Lindenmayer et al., pers. comm., 2014a). Lindenmayer et al., pers. comm. (2014a) project that the amount of suitable habitat for Leadbeater's possum will decline by at least 75 per cent by 2035. This is considered to be an underestimate given that it does not include estimates of the impacts of edge effects on the degradation of habitat suitability created by clearfell logging (and harvesting infrastructure e.g., roads).

Following 2060, the largest cohort of old trees regenerating after the 1939 fires, will begin to develop cavities suitable for occupancy by Leadbeater's possum (Lindenmayer et al., pers. comm., 2014a) and therefore following this time, Leadbeater's possums may begin to rebuild in numbers.

The Leadbeater's possum reserve system was established as a key strategy for conservation of the species. Lumsden et al. (2013) recognise that areas will become increasingly unsuitable for Leadbeater's possum before 1939 regrowth trees mature sufficiently to produce suitable hollows during the next 50–120 years. Increased rates of tree fall and future fires will exacerbate this situation, with models predicting the population in the reserve to fall to critically low levels (Lumsden et al., 2013). Lumsden et al. (2013) undertook population viability modelling (see Criterion 5) to quantify the risk of extinction with risk of extinction defined as the probability of adult females falling below 500 within a 200 year time frame. Overall, the results of their modelled scenarios indicate that, even without further disturbances such as future wildfires and an accelerated loss of hollow-bearing trees, the reserve system does not provide the requisite minimum population requirements. The analysis predicts that the population of Leadbeater's possum within the reserve system has a high likelihood of being at a very low population size which imposes on the species a greater risk of extinction, and that the existing reserve is insufficient to ensure the long-term persistence of the species.

Woinarski et al. (2014) found Leadbeater's possum to be critically endangered based on this criterion (IUCN criterion A) for declines in population size (a) (b) as well as area of occupancy/extent of occurrence/habitat quality (c), in the past, future and past+future (A2, A3, A4), with a rate likely to exceed 80 per cent (thresholds of eligibility for critically endangered). This was based on the following information:

- absence of populations from sites burnt in 2009 suggesting a decline of greater than 40 per cent since 2009,
- monitoring of known subpopulations (e.g., Lake Mountain, Yellingbo) and modelling indicate that the current rate of decline is greater than 50 per cent and suspected to be greater than 80 per cent over the last 18 years,
- this rate is likely to increase over the next 18 years (due to loss of suitable den trees and other habitat deterioration, and the risk of fire).

Burns et al. (2014) undertook a quantitative assessment of the probability of ecosystem collapse of the Mountain Ash Forest ecosystem. They defined the Mountain Ash Forest ecosystem as forest dominated by mountain ash but which may also contain alpine ash, shining gum, or at lower elevations messmate stringybark (*Eucalyptus oblique*), mountain grey gum (*Eucalyptus cypelloarpa*) and red stringybark (*Eucalyptus macrorhyncha*), and differentiation from other ecosystems also dominated by mountain ash (e.g., in other parts of Victoria and Tasmania) by other features including its distinctive vertebrate fauna and fauna, such as Leadbeater's possum – which is unique to this Mountain Ash Forest ecosystem among other forests dominated by mountain ash and restricting it to 157,000 ha within the Central Highlands of Victoria. Burns et al. (2014) defined three potential thresholds for ecosystem collapse of the Mountain Ash Forest ecosystem. One was where the abundance of hollow-bearing trees dropped below one per hectare averaged across the entire Mountain Ash Forest ecosystem. Modelling to 2067 included 39 scenarios. These included no harvesting and no future fire as the best case scenario, and worst case scenario of harvesting and one fire equivalent in extent to that of the 1939 fires. The estimate of decline for the best case scenario (no fire, no harvesting) to 2067 was 78 per cent and the worst case 92 per cent.

The IUCN (2014) notes that an understanding of ataxon and its relationship to its habitat, and the threats facing the habitat, is central to making the most appropriate assumptions about habitat loss and subsequent population reductions. It notes that populations may have a lagged response to habitat loss. The predictions that Leadbeater's possum habitat loss will continue into the future to 2067 suggest that, on balance, a critically endangered listing of population decline is most appropriate for A3 (loss to 2031). A summary of thresholds and listing categories for conclusions for assessments under Criterion a (A2 and A3) is provided at Table 3.

Table 3. Summary conclusions for thresholds assessed under Criterion 1

	Guidance threshold	Listing category
A2	very severe (≥80% decline)	Critically Endangered
A3	very severe (≥80% decline)	Critically Endangered

Conclusion for Criterion 1
The Committee finds that analyses of loss of population size under Criterion 1 (A2 and A3) are very severe under A2 and very severe under A3 and that the species is therefore eligible under this criterion as Critically Endangered.

Criterion 2:

Geographic distribution (based on either of B1 or B2)
B1. Extent of occurrence estimated to be very restricted <100 km^2, restricted <5,000 km^2 or limited < 20,000 km^2
B2. Area of occupancy estimated to be very restricted <10 km^2, restricted <500 km^2 or limited <2,000 km^2
AND
Geographic distribution is precarious for the survival of the species, (based on at least two of a–c)

a. Severely fragmented or known to exist at a limited location.
b. Continuing decline, observed, inferred or projected, in any of the following:
   (i) extent of occurrence
   (ii) area of occupancy
   (iii) area, extent and/or quality of habitat
   (iv) number of locations or subpopulations
   (v) number of mature individuals.
c. Extreme fluctuations in any of the following:
   (i) extent of occurrence
   (ii) area of occupancy
   (iii) number of locations or subpopulations
   (iv) number of mature individuals

Eligible for listing as Endangered (based on B2 (a)+ (b)(iii)(iv)(v))

Evidence:

Geographic distribution - quantitative estimates
Leadbeater's possum is a habitat specialist, with one of the most restricted distributions of any Australian mammal (Lindenmayer, 2013). It occurs in two distinct subpopulations. The lowland subpopulation of Leadbeater's possum at Yellingbo is isolated from the remaining alpine and subalpine colonies The lowland forest habitat used by this subpopulation at Yellingbo covers approximately 181 ha, however, less than 20 hectares provides suitable habitat for Leadbeater's possum (D. Harley 2014, pers. comm. cited in DEPI, 2014).

The remaining possums are patchily distributed (Macfarlane et al., 1997) and occur within alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum within a 70 x 80 km area (5,600 km^2) of the Central Highlands (LPAG, 2013; Lumsden et al., 2013) for which for extent of occurrence is considered to be **'limited'**.

Within this 70 x 80 km range, there are approximately 1,950 km^2 of ‘potential habitat’ (LPAG, 2013) or 204,000 hectares (LPAG, 2014b) of alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum forests (LPAG, 2014b) which, if considered to be extent of occurrence, is considered to be to be **restricted**.

VicForests (pers. comm., 2014) provides that there is 4,032 km^2 of forest (ash and non-ash) within the home range of Leadbeater’s possum and within the Central, Dandenong and Central Gippsland Forest Management Areas. Of this area, ash forest (including mountain ash, alpine ash, shining gum and snow gum forest as ‘suitable forest’ for Leadbeater’s possum) totals 2,044 km^2.

In 2009, approximately 34 per cent (LPAG 2014a) or 35 per cent (LPAG, 2013) of alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum within the 70 x 80 km range of Leadbeater’s possum was burnt. 149,100 ha (1,491 km^2) remains unburnt since 2000 which, if considered to be extent of occurrence, is considered to be to be **restricted**.

Burns et al. (2014) applied the IUCN Red List Ecosystems criteria to assess the Mountain Ash Forest Ecosystem for potential listing as threatened. They defined the Mountain Ash Forest Ecosystem as including that dominated by mountain ash but also may contain alpine ash, shining gum, or at lower elevations messmate stringybark, mountain grey gum and red stringybark and differentiate this ecosystem from others also dominated by mountain ash (e.g., in other parts of Victoria and Tasmania) by other features including its distinctive vertebrate fauna, such as Leadbeater’s possum, and flora. Burns et al. (2014) note that there are approximately 156,700 ha (1,567 km ^{2}) of this ecosystem. The area of minimum convex polygon enclosing all mapped occurrences of this ecosystem was 11,000 km^2, which for extent of occurrence for Leadbeater’s possum is considered to be **‘limited’**.

As discussed in Criterion 1, Leadbeater’s possum is a habitat specialist and not all alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum is suitable as habitat. While this forest has been termed ‘potential habitat’ (e.g., LPAG, 2013; 2014a, b), not all of this forest is suitable habitat for Leadbeater’s possum.

Lindenmayer et al. (pers comm., 2014a) have undertaken large scale vegetation surveys in the central highlands of Victoria since 1987 (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000). Their data layers indicate that at 1987 and 1989 montane ash forest was represented by 171,200 ha. Of this available montane ash forest, only 6.7 per cent was predicted to support ‘suitable habitat’ for Leadbeater’s possum at this time (i.e. approximately 11,470 ha). This estimate was based on measures of the abundance of hollow-bearing trees and the prevalence of an understorey of *Acacia* spp. Reduction in the number of hollow-bearing trees, fire effects and clearfell logging has reduced the amount of suitable habitat to 1.3 per cent of the montane ash forest estate. On this basis, Lindenmayer et al. (pers. comm., 2014a) provide a crude estimate that approximately 2,225 ha remaining ash forest is currently suitable as habitat for Leadbeater’s possum. If this estimate of ‘suitable habitat’ is considered as area of occupancy, this is considered to be **restricted** (<500 km^2). Burns et al. (2014) note that by 2011, the estimated amount of unburnt (since 1903) and unlogged (since 1932) Mountain Ash Forest Ecosystem remaining was 1,700 ha.

Lumsden et al. (2013) undertook a broad scale survey to determine where the species currently occurs, identify population strongholds, and to investigate relationships between environmental variables and probability of occurrence to allow prediction of distribution across the species’ range. The survey sampled across all of the species’ range but only within forest blocks known to contain records of Leadbeater’s possum and/or potentially suitable habitat (containing ecological vegetation classes known to be used by Leadbeater’s possum), to determine where the species currently occurs and identify population strongholds. It investigated relationships between environmental variables and probability of occurrence to allow prediction of distribution across the entire species' geographic range. It was not possible to include forest age class (e.g., old growth forest) within the modelling, as this classification has only been comprehensively mapped in state forest with comparable data not available for most parks and reserves (Lumsden et al., 2013).

Modelling of predicted current strongholds for Leadbeater's possum is provided in Figure 4 of Lumsden et al. (2013). The areas include unburnt habitat mainly in the south of the Central Highlands including the Baw Baw Plateau and its southern slopes, the Toorongo Plateau south of the Upper Yarra Catchment and state forest in the vicinity of Powelltown, parts of Toolangi State Forest, and southern parts of the Upper Yarra National Park. Occupancy by Leadbeater's possum across sampled sites (which included burnt sites) was approximately 16 per cent. Unburnt sites considered as potentially suitable habitat for Leadbeater's possum were selected based on Ecological Vegetation Classes known to be used by Leadbeater's possum (i.e., Montane Damp Forest, Montane Riparian Thicket, Montane Wet Forest, Wet Forest, Cool Temperate Rainforest and Sub-alpine Woodland). Of these, Leadbeater's possum was recorded from 17.4 per cent of the ash sites and half of the snowgum sites (noting there were few snowgum sites sampled). Occupied sites were generally structurally complex. Based on areas that are predicted to have at least a 50 per cent likelihood of the species being present now, Lumsden et al. (2013) estimate that there is approximately 150 km^2 (15,000 ha) of currently occupied habitat, which for area of occupancy is considered to be **restricted** (<500 km^2). There are no indications, however, that these areas of predicted occupation have been tested by subsequent surveys to detect the species and verify these predictions.

Table 4. Summary of estimates for extent of occurrence and area of occupancy for Leadbeater's possum (alpine and subalpine subpopulation).

Data source	Extent of occurrence termed 'suitable forest', 'potential habitat', 'ash forest' or as otherwise specified very restricted <100 km^2 restricted <5,000 km^2 limited < 20,000 km^2	Area of occupancy (as predicted to be occupied, or 'suitable habitat' within ash forest) very restricted <10 km^2 restricted <500 km^2 limited <2,000 km^2
Lumsden et al. (2013)	5,600 km^2	predicted to be occupied 150 km^2
LPAG (2013)	5,600 km^2 and 'potential habitat' 1,950 km^2	
LPAG (2014 b)	5,600 km^2 and 'potential habitat' 2,040 km^2 unburnt ash forest 1,491 km^2	
VicForests (pers. comm., 2014)	'suitable' ash forest 2,044 km^2	
(VicForests pers. comm., 2014 + LPAG, 2014a) and following Criterion 1A2	Maximum available suitable unburnt and unharvested ash forest at 2013 1,466 km^2	
Lindenmeyer et al. pers. comm. (2014a)		suitable habitat 22 km^2
Burns et al. (2014)	11,000 km^2 1,567 km^2	

Table 4 summarises estimates of extent of occurrence and area of occupancy for Leadbeater's possum. All estimates of current extent of occurrence of Leadbeater's possum are over 100 km^2 and less than 20,000 km^2 which the Committee considers are restricted to limited.
The area of occupancy of a taxon is defined as the area within its extent of occurrence occupied by the taxon, reflecting the fact that a taxon will not usually occur throughout the area of its

extent of occurrence, which may contain unsuitable or unoccupied habitats (IUCN, 2014). Given that Leadbeater's possum is a habitat specialist, the Committee considers that among these estimates, the best estimate for current area of occupancy of Leadbeater's possum is the area within unburnt ash forest that is considered likely to be occupied by the possum based on habitat conditions and known habitat preference. Two estimates are available: (1) that 'crudely' estimated by Lindenmayer et al. (pers. comm., 2014a) at 22 km^2 and (2) Lumsden et al.'s, (2013) estimate of 150 km^2. Both of these estimates range between the Committee's guideline thresholds (of between 10 km^2 and 500 km^2) for restricted. In addition, the Committee notes that data are not available to provide for more accurate estimates of area of occupancy using the methodology of 2 x 2 km^2 grid as recommended by IUCN (2014), and that these estimates are, therefore, likely to be underestimates.

Geographic distribution - precariousness

The species is considered to have a geographic distribution that is precarious for its survival for the following reasons:

a) Severely fragmented

Increased extinction risks to Leadbeater's possum result from the fact that most individuals are found in small and relatively isolated subpopulations. Macfarlane et al. (1997) described the distribution of Leadbeater's possum in 1997 as occurring in scattered patches. The species is not uniformly distributed, but occurs in patches of suitable habitat influenced by past wildfires and selective timber harvesting operations (DSE, 2003).

Genetic work indicates that Leadbeater's possum consists of two genetically-distinct subpopulations that have historically occupied different habitats (Hansen, 2008). The small subpopulation at Yellingbo is a surviving remnant of a lowland subpopulation that has historically been, and remains, isolated from others. The remaining possums occupy alpine forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum. Throughout these areas the species is distributed in scattered patches (Macfarlane et al., 1997).

The Leadbeater's Possum Advisory Group (LPAG, 2013) notes that fire and timber harvesting result in unsuitable habitat, leading to isolation of colonies and further fragmentation of the populations, and a reduced genetic diversity at a landscape scale. The Advisory Group identifies the subpopulation at Toolangi as an example of isolation from other populations due to fire having burnt surrounding areas.

The Leadbeater's Possum Advisory Group (LPAG, 2013) notes that old-growth stands of mountain ash contain the highest densities of hollow-bearing trees, which are a critical habitat feature for Leadbeater's possum. The combination of landscape-wide fires and 30 years of salvage harvesting after the 1939 fires has led to there being very little of this old growth forest remaining in the Central Highlands. Lindenmayer et al. (e.g., Lindenmayer et al., 2011; Lindenmayer et al., 2012; Lindenmayer et al., 2013a) estimate that old growth forest comprises around 1.1–1.2 per cent of the mountain ash forest estate, estimated to total 1,887 ha (Lindenmayer et al., pers comm., 2014a), but is confined to small remnant patches embedded within regrowth forest across 147 different patches, giving a mean patch size of 12.8 ha.

Fire causes habitat fragmentation. Leadbeater's possums in 2013 do not occupy sites burnt in 2009 (Lumsden et al., 2013). Lumsden et al. (2013) aimed to determine the extent to which Leadbeater's possum may have persisted in unburnt habitat islands refuges following the 2009 fires. Thirty-seven potential fire refuges were found with intact canopy and understory, and Leadbeater's possum was detected at six of these sites. Lumsden et al. (2013) found that there are likely to be only small numbers of individuals in any occupied unburnt refuges, with doubt about their capacity to persist.

Lindenmayer et al. (1993d) found that linear strips set aside and excluded from wood production include areas on steep slopes and adjacent to streams, or stands of unmerchantable timber set aside for wildlife conservation. These supported fewer species and had a lower probability of containing an animal than sites of similar habitat quality within areas of continuous forest. The number of trees with hollows in contiguous forest occupied by an arboreal marsupial was approximately twice that of trees in retained linear strips. Habitat fragmentation has occurred as a result of:

- division by narrow, approximately 20–100m wide strips between logging coupes which do not support colonies of Leadbeater's habitat (indicated by empirical field data), and
- logging roads and tracks that Leadbeater's possums do not cross (as indicated by radio-tracking work) Lindenmayer et al. (pers. comm., 2014a).

<u>b) Continuing decline is observed, inferred and projected:</u>
A decline in area of suitable habitat relative to the present is outlined in Criterion 1, and threats are continuing. Continuing decline is:

- observed, inferred and projected in (iii) area, extent and/quality of habitat;
- inferred and projected in the (iv) number of locations or subpopulations; and
- inferred and projected in (v) the number of mature individuals.

Decline in area and extent of habitat through loss to harvesting
Areas of 44,700 ha of unburnt ash forest are currently identified as available for harvesting (VicForests, pers. comm., 2014). These do not include areas excluded from harvesting as Special Protection Zones, modelled code exclusions and estimated additional harvesting exclusions. Leadbeater's possums are recorded on harvestable land outside of these exclusion areas. Leadbeater's possum does not inhabit logged and regenerated forest where no hollow-bearing trees have been retained (Lindenmayer et al., 2013b). 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.

Decline in area and extent of habitat and number of locations or subpopulations due to likelihood of fire
Over the last century, bushfires have occurred in the Central Highlands on average every ten years (LPAG, 2013; Lumsden et al., 2013). An additional bushfire occurring in the Central Highlands within the next ten years is likely, with the potential to further reduce ash or snow gum woodland in the range of Leadbeater's possum and therefore contribute to Leadbeater's possum population decline. While the magnitude of any future fire and its impact on existing ash forest is unable to be quantified, further decline is considered to be projected and inferred.

Decline in area and extent of habitat due to prescribed burning
The Victorian Government has committed to implement all recommendations from the 2009 Victorian Bushfires Royal Commission, which include an annual state-wide target of burning a minimum of five per cent of public land in Victoria. This target includes National Parks and Reserves and other public land. Fire operational plans for the years 2013/14 to 2015/16 have been made available detailing plans to undertake approved burns of 276,295, 312,886 and 425,038 hectares (respectively) across Victoria over this three year period. A small proportion of these burns may be planned within habitat areas of Leadbeater's possum excluded from harvesting (http://www.depi.vic.gov.au/fire-and-emergencies/planned-burns/fire-operations-plans/current-approved-fop).

Decline in habitat quality due to decline of abundance of hollow-bearing trees
There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's possum (e.g., Lindenmayer at al., 1991b; Lindenmayer et al., 2013c; Lindenmayer et al., pers. comm., 2014a). A decline in the number of hollow-bearing trees therefore corresponds to a decline in the number of mature individuals of Leadbeater's possum.

Lumsden et al. (2013) find that, in contrast to the 1939 fires, it is predicted that there will be limited rebound in population numbers after the 2009 fires. While there were extensive areas of old growth forest prior to the 1939 fires, the large living trees that survived the fire and the large fire-killed dead trees were of sufficient size to provide suitable hollows. The 1939 regrowth areas that were burnt in 2009 lost the majority of dead stags. The live trees that were killed are considered unlikely to be large enough to provide suitable hollows. Any that do provide hollows, are predicted will remain standing for only a short period of time (Lindenmayer et al., 2012; Lumsden et al., 2013). The population is predicted to continue to decline until areas of 1939 regrowth forest become sufficiently mature to provide adequate tree hollows (Lumsden et al., 2013), i.e. until at least 2067 (Lindenmayer et al., 2012).

Based on long-term monitoring (e.g., Lindenmayer et al., 1990; 1993a; 1997; 2011; 2012) Lindenmayer et al. (pers. comm., 2014a) estimate the abundance of hollow-bearing trees will decline in the future from more than four per ha ecosystem wide in 2013 to 1.5 per ha by 2035. This estimate represents more than a 63 per cent decline in habitat quality to 2035. The rate of decline then increases, with less than 0.9 per ha ecosystem wide by 2060. The largest cohort of old trees regenerating after the 2039 fires will not begin to develop cavities suitable for occupancy by Leadbeater's possum until after 2060 (Lindenmayer et al., pers. comm., 2014a). Burns et al. (2014) modelled future abundance of hollow-bearing trees using thirty-nine scenarios of 'no fire', and 'small, medium, and large fire regimes' as well as projections of clearfell logging under the 2011–2016 Timber Release Plan (DSE, 2011). They found a projected severe decline in the average number of large old hollow-bearing trees across the mountain ash forest of approximately 3.77 ha^{-1} in 2011, to 0.29–0.82 ha^{-1} by 2067. The best case scenario of no fire or logging was 78 per cent decline relative to 2011, and worst case (with fire equal in extent to the 1939 fire) of 92 per cent decline. Burns et al. (2014) find a greater than 92 per cent chance that the Mountain Ash Forest ecosystem will reach a collapsed state (defined as below 1 hollow-bearing tree per hectare averaged across the ecosystem), by 2067.

A consequential decline in the number of mature individuals of Leadbeater's possum is therefore projected, noting that the rate of decline increases towards 2060, and recognising there is likely to be some degree of lagged response.

Decline in habitat quality - Yellingbo subpopulation
Of the 50 ha of lowland floodplain forest at Yellingbo (LPAG, 2013), less than 20 ha of high quality habitat is estimated to be currently available (Harley and Lindenmayer, pers. comm., 2013). There are three main causes for this decline in habitat condition: (i) eucalypt dieback related to altered hydrology, (ii) habitat succession towards an older age-class that is more open in structure, and (iii) a lack of eucalypt regeneration (Harley and Antrobus, 2007).

Dieback of the tree canopy of mountain swamp gum was first noted in the 1970s. In 2003 dieback was estimated to affect more than 40 per cent of mountain swamp gum forest along Cockatoo Creek (Turner, 2003). It has been estimated that around 90 per cent of the swamp habitat is currently in poor condition (VEAC, 2012).

Fifty-six per cent of active territories at Yellingbo have been abandoned during the past ten years as a result of habitat deterioration. Vegetation dieback is present at more than 52 per cent of sites across the reserve (Harley pers. comm., 2014). Mid-story species necessary for movement of Leadbeater's possum are declining in stem density and do not form a continuous canopy. Some are heavily grazed (by deer) and are not regenerating to a density desirable as Leadbeater's possum habitat. There is a low abundance of denning hollows in the reserve (Harley et al., 2005).

Molecular analyses indicate that population fragmentation within the reserve has already occurred (Hansen, 2008). Reproductive rates have also declined at Yellingbo. The mean percentage of colonies (denning groups) where the dominant adult female had pouch young or was lactating has declined from 65 ± 9 per cent during 2001 – 2007 to 47 ± 24 per cent during 2008 – 2012 (Harley and Antrobus, unpublished data cited in Harley and Lindenmayer pers comm., 2013

Population monitoring of the lowland population of Leadbeater' possum at has been conducted at Yellingbo Nature Conservation Reserve since 1996. Data collected between 1995 and 2004 indicated that the size of the population was stable at 80–100 individuals (Harley et al., 2005). The number of individuals recorded peaked to 112 at 2003. At 2012 the number had dropped to 60 individuals (Harley and Lindenmayer, pers. comm., 2013). Recent reports are that the population has declined to only 42 individuals in 2013 (Arup and Smith, 2013) and in 2014 only 40 individuals with concerns expressed about the population's genetic health (Smith, 2014).

Reversal in the decline of these conditions will be difficult and may not be achievable, and therefore there is an expected continuing decline inferred and projected in (iii) area, extent and/quality of habitat; inferred and projected in the (iv) number of locations or subpopulations; and inferred and projected in (v) the number of mature individuals at Yellingbo.

The Yellingbo Nature Conservation Reserve population of Leadbeater's possum is genetically distinct from the remaining Leadbeater's possums (Hansen, 2008). Loss of this subpopulation would be a significant loss to genetic diversity of the species.

Decline in numbers of mature individuals
Some Leadbeater's possums have been found to occur in a small number of unburnt fire refuges (16 per cent of sites surveyed with intact canopy and understory) (LPAG, 2013). These animals have been suggested as possible sources of recolonisation of burnt areas once regenerated habitat becomes suitable. Previous population viability analyses suggest that single, isolated populations exceeding 200 animals are needed to have a high probability of long term persistence (Lindenmayer et al., 1993b). As there are likely to be only small numbers of individuals in these occupied unburnt refuges, there is doubt about the capacity of these isolated colonies to persist (Lumsden et al., 2013).

Population viability analysis was undertaken by Lumsden et al. (2013) to evaluate if the reserve system, established as one of the key strategies for the conservation of Leadbeater's possum, was sufficient to support the long-term conservation of the species. The results of this modelling found that all scenarios had more than a five per cent chance of the number of adult females falling below 500 individuals in the future. In the best case modelled scenario i.e., without further future fires or further loss of hollow-bearing trees, there was a 73 per cent probability of the population falling below 500 adult females within the reserve system. All other modelled scenarios with habitat loss and/or future fires, had an even higher probability that the population would fall below 500 adult females in the future, thereby providing a high degree of certainty of future decline. This population viability analysis predicts that the population of Leadbeater's possums in the reserve system will steadily decline until later this century, even in areas not burnt during the 2009 fires, as dead nest trees will continue to collapse without replacement, in contrast to the 1939 fires.

The long term viability of the lowland population at Yellingbo is doubtful, given its current population size of only 40 individuals (Smith, 2014) and that population viability analyses indicate populations of 50 individuals or fewer were predicted to be highly vulnerable to extinction within the next 100 years (Lindenmayer et al., 1993b).

Decline in numbers of mature individuals - Loss of genetic diversity
Population genetic analyses have been undertaken on the two largest populations of Leadbeater's possums prior to the 2009 fires: the Lake Mountain (159 individuals for which genetic material was available for testing) and Yellingbo (198 individuals). Effective population size[1] (N_e) for each of these subpopulations was found to be 57 and 7 respectively (Hansen et

[1] N_e, 'effective population size' is defined by Frankham et al. (2004). It can be likened to the number of animals that successfully contribute genetic material to the next generation, providing a proxy of the number of breeding animals in a stable population. It is rarely as large as the census population size.

al., 2009). Hansen (Hansen, 2008; Hansen and Taylor, 2008; Hansen et al., 2009) found that the Lake Mountain population was likely to represent a single genetic unit with other nearby populations (Cambarville, Marysville and Mt Margaret) and also found a strong signal of historical decline (most likely coinciding with climatic changes at the end of the Pleistocene). These past range contractions may exacerbate current population processes (Hansen pers. comm., 2014).

c) Extreme fluctuations.
Extreme fluctuations can be said to occur in a number of taxa where population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude. Population trajectories must show a recurring pattern of increases and decreases representing changes in total population size. Populations that undergo extreme fluctuations are likely to have highly variable growth rates, and therefore likely to be exposed to higher extinction risks than populations with lower levels of variability (IUCN, 2014). While Leadbeater's possums appear to have rebuilt following the extensive fires of 1939, and have again suffered a reduction in numbers following the 2009 fires, there is no indication that Leadbeater's possum has undergone 'extreme fluctuations'. Modelling indicates that, in contrast to the 1939 fires, hollow-bearing trees on which Leadbeater's possum depend, will continue to decline in abundance and not rebuild until after 2067 (Lindenmayer et al., 2012; Lumsden et al., 2013), with future bushfires in the species' range further exacerbating this situation (LPAG, 2014b). Leadbeater's possum therefore does not meet this subcriterion.

Conclusion for Criterion 2
As the species has a restricted area of occupancy and the species is considered to have a geographic distribution that is precarious for its survival based on (a) and (b), the species is considered to be eligible for listing as Endangered.

Criterion 3:

The estimated total number of mature individuals is very low <250, low <2,500 or limited<10,000; **and** either of (A) or (B) is true

(A) evidence suggests that the number will continue to decline at a very high rate (25% in 3 years or 1 generation, whichever is longer, up to 100 years), high rate (20% in 5 years or 2 generations, whichever is longer, up to 100 years) or substantial rate (10% in 10 years or 3 generations, whichever is longer, up to 100 years); or

(B) the number is likely to continue to decline and its geographic distribution is precarious for its survival (based on at least two of a – c):
- a. Severely fragmented or known to exist at a limited location.
- b. Continuing decline, observed, inferred or projected, in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) area, extent and/or quality of habitat
  - (iv) number of locations or subpopulations
  - (v) number of mature individuals.
- c. Extreme fluctuations in any of the following:
  - (i) extent of occurrence
  - (ii) area of occupancy
  - (iii) number of locations or subpopulations
  - (iv) number of mature individuals

Eligible for listing as Endangered (based on limited and B(a)+(b)(iii)(iv)(v))

Evidence:

Numbers of individuals
Leadbeater's possum is cryptic, being nocturnal, fast moving and inhabiting forest canopy and sub-canopy (Smith and Hartley, 2008). Accurately estimating population size is therefore difficult. Survey techniques require intensive resourcing (e.g., Lindenmayer, 1996a). Initial estimates of the total number of mature individuals of Leadbeater's possum were provided by Menkhorst (2008) who estimated 2000 individuals for the montane populations and 200 individuals at Yellingbo.

Leadbeater's possums in montane ash forest have been monitored as part of a long term monitoring program since the 1980s (e.g., Lindenmayer et al., 1997, 2011, 2012). Monitoring has also been ongoing at targeted strongholds such as Mt Bullfight, Lake Mountain, Mt Baw Baw and Yellingbo (Harley, 2005, Harley and Antrobus, unpublished data via Harley and Lindenmayer pers. comm., 2013). Lindenmayer (1996b) notes that while others had estimated the montane population at between 1000 and 5000 individuals, his estimation at that time was 4000 individuals based on the extent of suitable habitat, the mean abundance of possums on such sites, and the fact that the species is absent from 40 per cent of apparently suitable areas (Lindenmayer, 1996b).

Leadbeater's possum have been monitored at three sub-alpine targeted sites – Lake Mountain, Mt Bullfight and Mt Baw Baw; Lake Mountain and Mt Bullfight were burnt in 2009. The Lake Mountain site was thought to contain up to 300 individual Leadbeater's possums prior to the 2009 fires, with only six individuals found following extensive surveys after the 2009 fires (Harley and Antrobus, unpublished data, cited in Harley and Lindenmayer pers comm., 2013). Surveys at Mt Bullfight suggested that the population comprised fewer than 50 individuals following the 2009 fires (Harley and Antrobus, unpublished data, cited in Harley and Lindenmayer pers comm., 2013).

Subsequent surveys (Lumsden et al., 2013) included the use of call playback and thermal imaging cameras to detect presence, with a probability of detecting the species' presence on occupied sites of up to 80 per cent when there was no wind (Lumsden et al., 2013). Findings from these surveys were consistent with earlier post fire findings (e.g., Lindenmayer et al., 2013), with no possums detected in any area burnt during the 2009 fires irrespective of fire intensity, including those sites where the understory was burnt but the canopy remained intact.

Based on the post-2009 fire surveys of occurrence, Lumsden et al. (2013) undertook occupancy modelling to identify population strongholds and investigate relationships between environmental variables and probability of occurrence. Modelling was designed to account for the possibility of non-detection during surveys. Lumsden et al. (2013) do not attempt to provide estimates of numbers of colonies or individuals in their report, the purpose of these surveys was not to estimate population numbers (LPAG, 2014a). However, the Leadbeater's Possum Advisory Group extrapolated population numbers from these data. It doing so it notes (LPAG, 2014a) a number of levels of uncertainty and assumptions, including bias associated with surveying on roads from where all surveys were conducted, uncertainty in the call playback survey technique, and that the survey method does not enable determination of the number of individuals. The Committee notes that these assumptions and the technique have yet to be independently tested for accuracy and therefore has a high level of uncertainty. LPAG (2014a) notes that the focus for robust decisions should be on population trends rather than absolute numbers, given these uncertainties. Nonetheless, they estimate there may be 1,500–4,500 (LPAG, 2013) or 1,578–4,384 (LPAG, 2014b; DEPI, 2014) colonies present in the Central Highlands 'based on the number of adult breeding females'. LPAG (2014a) notes that that this survey method only detected presence or absence, that the number of animals present in each colony of Leadbeater's possums can vary substantially, and the current average colony size in different environments is unknown. If applying a conservative average colony size of 2.5 individuals to estimate 'a potential number of individuals' in the Central Highlands, the 'predicted number of individuals' range from 3,945–10,960 (LPAG, 2014 a, b; DEPI, 2014) (or approximately 3,750–11,250 in LPAG, 2013).

Lindenmayer et al. (pers. comm., 2014a) notes that direct estimation of numbers of individuals is problematic and notes the potential for overestimation using the survey methods of Lumsden et al. (2013) by as much as 3–5 times. Lindenmayer et al. (pers. comm., 2014a) note that using playback calls may have a larger sound catchment than estimated by others who have previously used this technique and is likely to have drawn in animals from distances of as much as 400–500m, especially because the lack of continuous habitat in these forests means that colonies are unlikely to have territory boundaries with neighbouring colonies. Patten (pers. comm., 2014) notes the use of thermal imaging for population surveys of arboreal mammals has not been undertaken previously and its accuracy requires further investigation.

In the use of this criterion for number of remaining individuals, the IUCN (2014) notes: '*mature individuals that will never produce new recruits should not be counted*'. Leadbeater's possums live in small groups of between two to twelve individuals containing one breeding pair (Lindenmayer, 1996a). A snap shot of colony composition of nine colonies in 1978 (Smith, 1984) found one of each colony size of 2, 3, and 6, three colonies of 4 individuals and three of 5 individuals (median= colony size of 4). The mating system typically results in a 3:1 (m:f) sex ratio across the species (Smith, 1980; Lindenmayer and Possingham, 1995a). If this represents a monogamous pair in each colony and two non-reproductive animals – the percentage of mature breeding individuals is up to 50 per cent of total estimated population (50% is likely to represent a maximum).

Lindenmayer et al. (pers. comm., 2014a) provide 'a crude' estimate of maximum total numbers of individuals as 3,125. This estimate is based on availability of suitable habitat, which is estimated by Lindenmayer et al. (pers. comm., 2014a) to be 2,225 ha at the end of 2013, and based on field survey data (e.g., Smith and Lindenmayer, 1988), the long-term mean abundance of animals per ha of suitable forest is 1.4 animals. Given that the species is colonial and colonies include non-breeding individuals, the number of breeding individuals is likely to be less that any estimate of total number of individuals. However, because population structure within the current population of Leadbeater's possum is unknown, the estimated number of mature individuals relative to a total population size of 3,125 is unable to be estimated. If using the rationale of mature breeding individuals are up to 50 per cent of total population, as outlined above; the percentage of mature breeding individuals is 1,563.

Population genetic analyses have been undertaken on the two largest populations of Leadbeater's possums prior to the 2009 fires: the Lake Mountain and Yellingbo. Effective population size (N_e) provides a proxy of the number of breeding individuals in a stable population. Using microsatellite genetic markers, which provide a measure of recent population processes, N_e for these subpopulations was found to be 57 for Lake Mountain and 7 for Yellingbo (Hansen et al., 2009), which translates to 36 per cent of the known population at Lake Mountain and 4 per cent of the population at Yellingbo.

Because genetic similarities cluster the Lake Mountain population with nearby populations of Cambarville, Marysville and Mt Margaret, the patterns from the genetic sample at Lake Mountain might be inferred for the broader region. If 36 per cent of the broader population are breeding individuals, this equates to approximately:

- 1,350 breeding individuals, if based on the lower estimate of 3,750 total individuals of LPAG (2013), or
- 1,125 breeding individuals, if based on the estimate of 3,125 total of Lindenmayer et al. (pers. comm., 2014a).

Hansen pers. comm. (2014) notes caveats around extrapolating beyond the study area, as population processes may differ between habitats, and N_e is sensitive to rates of population growth and decline. It is therefore likely that the estimated total number of mature individuals is at least limited (<10,000) with population genetics suggesting that within these estimates breeding individuals may be low (<2500).

Table 5. Summary of estimated numbers of individuals and numbers of breeding individuals

	Estimated numbers	If 3:1 sex ratio = 50% mature breeding individuals**	If 36% of the broader population are breeding individuals
Menkhorst (2008)	2000 + 200	1,100	
Lindenmayer (1996b)	4000	2,000	
LPAG (2013)	3,750–11,250	3,000–9,000*	1,350–4,050
LPAG (2014 a, b), DEPI (2014)	3,945–10,960	3,156–8,768*	1,420–3,946
Lindenmayer et al. (pers. comm., 2014a)	3,125	1,563	1,125

* estimated as two breeding individuals in a colony, from the estimated number of colonies provided.
** 50% of the population being breeding individuals is likely to represent a maximum

Table 5 summarises the estimates of individuals and breeding individuals. The number of mature breeding individuals of Leadbeater's possums in the Central Highlands is at least limited (<10,000) and is very likely to be restricted (<2,500).

Population monitoring of the lowland population of Leadbeater's possum at has been conducted at Yellingbo Nature Conservation Reserve since 1996. Data collected between 1995 and 2004 indicated that the size of the population was stable at 80–100 individuals (Harley et al., 2005). The number of individuals recorded peaked to 112 at 2003. At 2012 the number had dropped to 60 individuals (Harley and Lindenmayer, pers. comm., 2013). Recent reports are that the population has declined to only 42 individuals in 2013 (Arup and Smith, 2013) and in 2014 only 40 individuals (Smith, 2014).

(A) Rate of decline

Generation length for Leadbeater's possum is six years. To meet part A of this criterion, evidence needs to suggest that the number of Leadbeater's possums will continue to decline at:

- a very high rate (25% in 3 years),
- a high rate (20% in 12 years), or
- a substantial rate (10% in 18 years).

While the population has been predicted to continue to decline in the future (see Criterion 5), the Committee does not have access to quantitative data to determine the rate of decline in the population over the periods required by part A of this criterion.

Or (B) Continuing decline and precariousness

To meet part B of this criterion, evidence needs to suggest that the number of Leadbeater's possums is likely to continue to decline and its geographic distribution is precarious for its survival (based on a variety of options outlined in the criterion). The Committee has assessed this already in Criterion 2, and found that the species is likely to (B) continue to decline and that its geographic distribution is precarious for its survival (see Criterion 2) based on severe fragmentation (a) and continuing decline (b) observed, inferred and projected in (iii) area, extent and/or quality of habitat, (iv) number of locations or subpopulations, and (v) number of mature individuals).

Conclusion for Criterion 3

Based on this evidence, the Committee considers that the number of mature breeding individuals of Leadbeater's possums is likely to be at least limited and is very likely to be restricted, the number is likely to continue to decline and the species' geographic distribution is precarious for its survival and is therefore eligible for listing under this criterion as Endangered.

Criterion 4:

Estimated total number of mature individuals:

(a) Extremely low < 50
(b) Very low < 250
(c) Low < 1000

Not found to be eligible for listing in this category

Evidence:

If using the IUCN (2014) guidelines for defining mature individuals for the criteria, '*mature individuals that will never produce new recruits should not be counted*' and '*in the case of biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals'*.

As discussed in Criterion 3, the mating system of Leadbeater's possum typically results in a 3:1 sex ratio across the species (Smith, 1980; Lindenmayer and Possingham, 1995a). As described in Criterion 3, the estimates of the number of mature individuals are provided in Table 5. The highest threshold for eligibility under this criterion is 1000 mature individuals. All estimates of number of mature individuals are greater than 1000 (Table 5). These estimates are not considered to be low, very low or extremely low under this criterion.

Criterion 5:

Probability of extinction in the wild based on quantitative analysis is at least:

(a) 50% in the immediate future (i.e. 10 years or three generations, whichever is longer, up to a maximum of 100 years); or

(b) 20% in the near future (i.e. 20 year or five generations, whichever is longer, up to a maximum of 100 years); or

(c) 10% in the medium-term future (i.e. within 100 years).

Eligible for listing as Vulnerable (5c)

Evidence:

Leadbeater's possum has been the focus of a number of studies using Population Viability Analysis over the past two decades demonstrating the vulnerability of the species to extinction (Lindenmayer et al., 1993b; Lindenmayer and Possingham, 1995 a,b, 1996; Lindenmayer and Lacy, 1995). Analyses have been used to predict trends in populations of Leadbeater's possum by patch size, connectivity (Lindenmayer and Lacey, 1995; Lindenmayer and Possingham, 1995a) and other factors such as spatial scale, wildfire (Lindenmayer and Possingham, 1995b) and logging (Lindenmayer and Possingham, 1996). As the general rate of annual loss of trees with hollows is more than 3–5 per cent annually, Leadbeater's possum could be lost from large areas by 2040s. In areas of old-growth forest, where rate of hollow loss is lower, populations of 200 animals or more experienced a less than 10 per cent decline in predicted genetic variability and therefore, where suitable habitat can be maintained, may persist in the long term (e.g., 100 year projection). Lindenmayer et al., (1993b) note that old-growth forest patches of 600 ha should support a 'population' of 200 animals (old-growth forest being dominant overstory trees >120 years old, Lindenmayer et al., 2013a). Lindenmayer and Lacy (1995) however, note that while these populations may be demographically stable, more than this number of individuals might be required to avoid significant decline in genetic variability over 100 years, as demographic and genetic stability occur at different 'population' sizes. Small, isolated populations are vulnerable to inbreeding depression (Lindenmayer et al., 1993b). 'Populations' within isolated patches of 20 ha or less are very susceptible to extinction, even in the absence of wildfires, but the probability of persistence approached 100 per cent in patches of 250 ha (Lindenmayer and Possingham, 1995b). 'Populations' of 20 or fewer animals were characterised by very rapid rates of extinction and most failed to persist for longer than 50 years (Lindenmayer and Lacey, 1995). The probability of extinction of isolated populations remained above 60 per cent even for a single patch size of 1,200 ha once wildfire was included in the modelling. Predicted values for the probability of extinction were sensitive to inter-relationships between the frequency of fires and the proportion of habitat patches that were burnt during a given fire event (Lindenmayer and Possingham, 1995b).

The timeframe over which these analyses are assessed is 100 years (Lindenmayer and Lacy, 1995; Lindenmayer et al., 1993b) or greater. Quantitative probability of extinction is included, however the populations modelled are based on small subpopulations that examine minimum population size viability under differing scenarios e.g., with founding populations of 25, 50, 100 individuals and differing environmental variability (with values raging from minimal (1) to moderate (20)). There are scenarios modelled that indicate that an examined 'population' will have a greater than 100 per cent probability of extinction with 100 years or less, however, these analyses do not attempt to examine the probability of extinction for the whole species, as is the intent of Criterion 5. These analyses do not provide the specific quantitative probabilities required for meeting the thresholds of Criterion 5.

Some previous population strongholds have been found to have significantly declined to the point at which they are unlikely to be viable. For instance, the population at Lake Mountain has been reduced to less than 10 individuals following the 2009 fires (Harley and Lindenmayer, pers. comm., 2013; DEPI, 2014). Mount Bullfight supported Leadbeater's possums in sub-alpine woodland habitat, but surveys since the 2009 fires indicate that approximately 30–50 individuals survive in three distinct areas (Harley and Antrobus unpublished data cited in DEPI, 2014). The long term viability of the lowland population at Yellingbo is doubtful, given its current population size of only 40 individuals (Smith, 2014). Lindenmayer et al. (1993b) found that populations of fewer than 50 individuals were predicted to be highly vulnerable to extinction within a 100 year timeframe, while populations of 200 animals or more were considered to be genetically and demographically stable over a 100 year period.

Lindenmayer et al. (2012) undertook transition probability matrices of large trees with cavities through increasingly decayed condition states. They project severe decline in large trees with cavities by 2039, with decline continuing until at least 2067. These projections were noted as being highly optimistic due to the number of assumptions included in the analysis (e.g., paucity of future fire and logging) and the lack of cavity bearing trees is likely to be more severe than indicated in the projections. Lindenmayer et al. (2012) suggest that similar severe declines are expected for cavity-dependent species such as Leadbeater's possum.

Population viability analysis of Leadbeater's possum was undertaken by Lumsden et al. (2013) to evaluate if the reserve system established as one of the key strategies for the conservation of Leadbeater's possum was sufficient to support the long-term conservation of the species.

Lumsden et al. (2013) used survival and fecundity rates from models previously developed by Lindenmayer et al. (1993b), Lindenmayer and Possingham (1995a, b; 1996), and Lindenmayer and Lacy (1995) and the impact of fire to Leadbeater's possum by fire models of Lindenmayer and Possingham (1995a, b). The modelling examined the impact of historic and more recent wildfires (i.e., fires in 1939, 1983, 1990, 2007 and 2009) on Leadbeater's possum populations, the increased rate of loss of hollow-bearing trees reported by Lindenmayer et al. (2012), and potential impacts of future fires. The model predicts changes in the size of the Leadbeater's possum reserve population over time based on the number of adult females from prior to the 1939 fires into the future. The reserve was established to incorporate priority areas for Leadbeater's possum by including the highest quality habitat of old growth forest (compared to 1939 regrowth where dead hollow-bearing trees were collapsing) (Lumsden et al., 2013). There are no data that provide the number of females possums prior to 1939. The model therefore includes a variety of initial numbers of adult females, with the average being the adult carrying capacity as prescribed by the fire models of Lindenmayer and Possingham (1995a, b).

Lumsden et al. (2013) assessed the probability that the number of adult females would fall below 500 individuals within a 200 year time frame. A 200 year time frame was selected because this related to the time it takes to develop hollows suitable to Leadbeater's possum, and 200 years is equivalent to 40 generations of Leadbeater's possum – a key time frame for assessing threatened species (Schaffer, 1981; Reed et al., 2003 cited in Lumsden et al., 2013). 500 individuals is a population size at which, declines below this level are considered to be more susceptible to loss of genetic variation and population changes due to unfavourable environmental conditions and catastrophic events (Lacy, 2000 cited in Lumsden et al., 2013). Scenarios were modelled with various combinations of habitat loss and future fires. All modelled scenarios resulted in a high probability that the population would fall below the critical 500 individual population size within the 200 year timeframe. 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.

To be eligible for listing under this criterion, the species needs to have a quantitative probability of risk of extinction within set timeframes (e.g., 50 per cent probability). Generation length for Leadbeater's possum is six years. Probability of extinction in the wild based on quantitative analysis for Leadbeater's possum must be at least:

(a) 50% in 18 years (critically endangered);
(b) 20% in 30 years (endangered); or
(c) 10% within 100 years (vulnerable).

The modelling of Lumsden et al. (2013) finds a high probability of extinction (based on a critical population size of 500 individuals) in 200 years. The probability is quantified: There is a 75 per cent chance of the population falling below 500 individuals within a 200 year timeframe when there is no further loss of habitat. Future habitat loss scenarios of 12.5, 25, and 50 per cent (e.g., from loss of hollow-bearing trees) and further additional loss of habitat of 25 and 50 per cent from fires in 2020 are modelled, all indicate a 90 per cent chance or more of extinction (based on a critical population size of 500 individuals) in 200 years. The timeframe over which these analyses are assessed is 200 years, and not within the timeframes considered for this criterion. While it is likely that the data are available, these analyses under the timeframe of 200 years do not provide the specific quantitative probabilities required for meeting the thresholds of this criterion.

Burns et al. (2014) undertook a quantitative assessment of the probability of ecosystem collapse of the Mountain Ash Forest ecosystem. They defined the Mountain Ash Forest ecosystem as forest dominated by mountain ash but which may also contain alpine ash, shining gum, or at lower elevations messmate stringybark, mountain grey gum and red stringybark, and differentiation from other ecosystems also dominated by mountain ash (e.g., in other parts of Victoria and Tasmania) by other features including its distinctive vertebrate fauna and fauna, such as Leadbeater's possum – which is unique to this Mountain Ash Forest ecosystem among other forests dominated by mountain ash and restricting it to 157,000 ha within the Central Highlands of Victoria. Burns et al. (2014) defined three potential thresholds for ecosystem collapse of the Mountain Ash Forest ecosystem. One was where the abundance of hollow-bearing trees dropped below one per hectare averaged across the entire Mountain Ash Forest ecosystem. Burns et al. (2014) found that there was more than a 92 per cent chance of ecosystem collapse/ less than one hollow-bearing tree per hectare ecosystem-wide by 2067 (within 100 years). If less than one hollow-bearing tree per hectare equates to an unviable habitat for Leadbeater's possum, and given that the Mountain Ash Forest is the core habitat of this species, this may be considered to equate to probability of extinction of Leadbeater's possum, and thus meeting at least the 10 per cent likelihood of extinction within the 100 year timeframe for vulnerable under this criterion.

As population viability analyses also indicate a high likelihood of populations less than 50 individuals (such as the remaining Leadbeater's possums in the lowland habitats of Yellingbo), going extinct in the next 100 years (probabilities ranging from 10–100 per cent depending on the environmental variation) (Lindenmayer et al., 1993b), this accounts for all known Leadbeater's possums.

<u>Conclusion for Criterion 5</u>
Given the Mountain Ash Forest ecosystem on which the montane populations of Leadbeater's possum depend, have been estimated to become extinct within the next 100 years with at least a 10 per cent likelihood, and that the only known population of the species outside of this habitat is also predicted to become extinct in the next 100 years, with a greater than 10 per cent likelihood, the Committee considers that Leadbeater's possum meets the eligibility for listing as vulnerable under this criterion.

Public Consultation

Notice of the proposed amendment was made available for public comment for more than 30 business days between from 3 December 2013 to 24 January 2014. Comments received relevant to the survival of the species have been taken into account by the Committee.

Recovery Plan

There is a recovery plan in place for the species: Macfarlane et al. (1997) '*Leadbeater's Possum (Gymnobelideus leadbeateri) Recovery Plan*'. This recovery plan was adopted as a national plan under the *Endangered Species Protection Act 1992* in November 1997. Its objective was to downlist Leadbeater's possum from endangered to vulnerable within ten years based on the IUCN criteria of population trend and size, extent of occurrence, probability of extinction, and the management of habitat towards a target of no more than a one per cent probability of extinction over 250 years throughout the forest within its current range.

This plan was transferred as an adopted recovery plan under the *Endangered Species Protection Act 1992* to an adopted plan under the *Environment Protection and Biodiversity Conservation Act 1999* at the commencement of the Act on 16 July 2000.

The Committee recommends that this plan (Macfarlane et al., 1997) should be retained and updated.

Recovery and Impact avoidance guidance

Primary Conservation Objectives

Increase the total population size and number of locations of subpopulations of Leadbeater's possums.

1. Maintain, protect, restore and enhance existing habitat, especially key habitat attributes
2. Establish habitat links that include key habitat attributes between known population sites
3. Enable recovery of additional sites to increase habitat and population size
4. Provide for the establishment of additional populations.

Important populations

All populations of Leadbeater's possum are important.

The smaller sized Yellingbo lowland population is genetically distinct from the montane population and represents an important source of genetic diversity for the species, and is therefore important for the species as a whole.

Important habitat for the survival of the species

The key habitat attributes of Leadbeater's possum across all forest types (LPAG, 2013), and therefore important habitat for the survival of the species, are:

- Hollow-bearing trees (for nest sites and refuge) with large internal dimensions in the order of 30 cm in diameter are a critical habitat feature for Leadbeater's possums (LPAG, 2013), particularly and almost exclusively large old trees (Lindenmayer et al., 2013a; Lindenmayer et al., pers. comm., 2014a).
- Density of hollow-bearing trees is recognised as a critical habitat feature (e.g., DEPI, 2014). There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's possum (e.g., Lindenmayer at al., 1991c; Lindenmayer et al., 2013c; Lindenmayer et al., pers. comm., 2014a), with nest hollow availability the limiting factor to population size. Density of less than one hollow-bearing tree per hectare is considered to represent ecosystem collapse for the Mountain Ash Forest ecosystem (Burn et al., 2014).
- Predominance of smooth-barked eucalypts (with loose bark hanging in strips providing shelter for insect prey and material for nests) or gum-barked eucalypts (related to foraging behaviour) (Lindenmayer, 1996a; Harley, 2004a;b;c).
- Forest types of Leadbeater's possum are most commonly ash forest typically dominated by mountain ash, alpine ash and shining gum.
- The species is also known to occur in subalpine woodlands and lowland swamp forest dominated by snow gum or mountain swamp gum (Smith and Hartley, 2008) with *Melaleuca* spp or *Leptospermum* spp in the middlestory (Harley et al., 2005).
- A structurally dense interlocking canopy or secondary tree layer of continuous interconnecting structure (to facilitate movement) (Lindenmayer, 1996a; Harley, 2004a;b;c), and
- A wattle understory (providing food) (Smith and Lindenmayer, 1988; Menkhorst and Lumsden, 1995; DSE, 2013).

Leadbeater's possum colonies are territorial, defending areas of 1–3 hectares (Smith, 1984). Leadbeater's possums appear to have critical minimum habitat size of around 12 ha (Lindenmayer et al., pers comm., 2014b). As the species indicates long-term site fidelity (Lindenmayer et al., 2013a), habitat where the species currently occurs is important habitat to maintain.

Habitats considered most likely to be currently occupied by Leadbeater's possums are characterised by lush, unburnt vegetation in gullies, located in areas that have relatively low summer temperatures and high summer rainfall (Lumsden et al., 2013). An optimum habitat is an uneven-aged ash forest with a dense understory of wattle trees and a supply of hollow-bearing trees of between 4.2 – 10 per 3 ha (Smith and Lindenmayer, 1988).

Information required, research and monitoring priorities-

All populations

- Investigate options to establish an effective means of detection, including further independent testing of the call-back survey technique and its assumptions for estimating population numbers of Leadbeater's possums, to understand and reduce uncertainty.
- Undertake surveys and consolidate this data with existing data, and undertake an integrated monitoring program to provide increased understanding of:
    - abundance of the whole species
    - location of strongholds
    - occupied habitat across all habitat types
    - areas of key habitat attributes
    - population statistics and trends
    - threats and threat trends
- Identify and map habitat (including areas with key habitat attributes and occupied habitat)
- Improve understanding of habitat survival to identify landscape features and habitats that are resilient to natural disturbance processes such as bushfires.
- Evaluate the effectiveness of actions to support the recovery of Leadbeater's possum through an adaptive management process
- Investigate population structure and genetic diversity and the potential effects of fragmentation between colonies
- Investigate the feasibility of insurance populations and translocations including:
    - Genetic viability of the captive breeding program for the lowland subpopulation
    - Feasibility of maintaining genetic distinction of the lowland subpopulation
    - Wild to wild and captive to wild translocation options (should suitable habitat be available).

Lowland subpopulation:

- Identify requirements for a planning regime that provides for appropriate suite of habitat structure (i.e., that simulates nature regeneration).
- Research appropriate regeneration techniques to simulate natural regeneration of mountain swamp gum and mid-story species in the floodplain of Yellingbo (including manipulative research trials), and the identification of quantitative vegetation condition targets.
- Identify former hydrological regime(s) (e.g., complete investigation through groundwater bores, track surface flow) to identify ideal conditions for future potential application, and
- Investigate techniques/applications to provide for restoration of former hydrological regime (e.g., manipulate water flow on the floodplain by weirs, earthworks).
- Explore/investigate the potential to provide for expansion of suitable lowland habitat to a network including other lowland patches, to reduce the risk to the population at this single isolated site, including identifying other sites that may be suitable for use by lowland colonies (or modified to become so).

Management actions required

All subpopulations

- Protect occupied habitat and areas with key habitat attributes from incompatible development activities such as road and track construction or maintenance in or adjacent to habitat, and recreational development in parks.

- Prepare fire management plans to inform fire operations, planning, suppression and management.
- Implement fire management measures to protect Leadbeater's possum colonies and habitat (particularly those that appropriately minimise the risks of high intensity fires)
- Develop fire recovery protocols to be enacted during and following fire or other disturbance that affect known colonies
- Maintain, protect, restore and enhance habitat (known occupied habitat, predicted occupied habitat, and potential future habitat)

<u>Montane populations:</u>

- Provide for protected habitat linkages between known or modelled-predicted occupied habitat and colonies.
- Prevent further decline and rebuild the population through protecting all current and future Leadbeater's possum habitat.

<u>Lowland population:</u>

- Undertake management planning to provide for long term priority planning with targets (e.g., 10 year, 20 year plan) for application of management actions for habitat restoration and to address key threats to the lowland subpopulations
- Apply targeted vegetation management planning that provides for appropriate habitat structure and restoration, such as regimes for patch clearance / opening up of patches or other disturbance for regeneration.
- Control and minimise feral grazers that destroy saplings and prevent revegetation and habitat succession.
- Control and minimise weed species (e.g., phragmites) that compete and prevent revegetation and habitat succession.
- Apply / restore the former or most appropriate hydrological regime along Cockatoo Creek and Macclesfield Creek (e.g., manipulate water flow on the floodplain by weirs, earthworks).
- Provide for additional and/or insurance populations as determined appropriate following investigations under 'Information required, research and monitoring priorities'.

Recommendations

(i) The Committee recommends that the list referred to in section 178 of the EPBC Act be amended by **transferring** from the endangered category to the **critically endangered** category:

Gymnobelideus leadbeateri

<u>AND</u>

(ii) The Committee recommends that the current recovery plan should be retained and updated.

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.

Threatened Species Scientific Committee

2/12/2014

References cited in the advice

Arup T and Smith B (2013). Edge of existence. 21 July 2013 The Age. Downloaded 13/10/14 from http:// www.theage.com.au/victoria/edge-of-existance-20130720-2qb5s.html.

Attiwill PM, Ryan MF, Burrows N, Cheney NP, McCaw L, Neyland M and Read S (2013). Timber harvesting does not increase fire risk and severity in wet eucalypt forests of southern Australia. Conservation Letters 00: 1–14.

Bilney RJ, Cooke R and White JG (2010). Underestimated and severe: small mammal decline from the forest of south-eastern Australian since European settlement, as revealed by a top-order predator. Biological Conservation 143: 52–59.

Burns EL, Lindenmayer DB, Stein J, Blandchard W, McBurney L, Blair D and Banks SC (2014). Ecosystem assessment of mountain ask forest in the Central Highlands of Victoria, south-eastern Australia. Austral Ecology. doi: 10.1111/aec.12200

Cronin L (1991). Key Guide to Australian Mammals. Balgowlah, NSW: Reed Books.

DEPI (2013). Victorian Bushfire Risk Profiles. A foundational framework for strategic bushfire risk assessment. Victorian Government Department of Environment and Primary Industries, East Melbourne. Downloaded 1/10/2014 from http://www.depi.vic.gov.au/__data/assets/pdf_file/0012/235101/Victorian-Bushfire-Risk-Profiles_WEB2.pdf.

DEPI (2014). 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. Downloaded 12/8/14 from http://www.depi.vic.gov.au/__data/assets/pdf_file/0009/272574/Leadbeater-Possum-Action-Statement-2014.pdf.

DSE (2003). Flora & fauna Guarantee Action Statement #62 – Leadbeater's Possum *Gymnobelideus leadbeateri*. Victorian Government Department of Sustainability and Environment. Downloaded 28/3/14 from <http://www.dse.vic.gov.au/__data/assets/pdf_file/0016/103147/062_Leadbeaters_Possum_1995.pdf>.

DSE (2006). Timber Harvesting Forest factsheet. Victorian Government Department of Sustainability and Environment. Available Downloaded 15/7/13 from <http://www.dse.vic.gov.au/__data/assets/pdf_file/0019/102088/Clear_Felling_Harvesting.pdf>.

DSE (2008). Living with Fire, Victoria's Bushfire Strategy. State Government Victoria Department of Sustainability and Environment. Victorian Government, Melbourne.

DSE (2011). Timber Release Plan 2011–2016. Department of Sustainability and Environment. Downloaded 10/10/2014 from http://www.vicforests.com.au/files/spnwlcwfup/2011--2011-2016-schedule_jun-15.pdf.

DSE (2013). Survey Standards: Leadbeater's Possum Habitat Zones (Central Highlands Forest Management Plan). Department of Sustainability and Environment (Victoria).

Frankham R, Ballou J, Briscoe D (2004). A Primer of Conservation Genetics. Cambridge University Press, UK.

Hansen BD (2008). Population genetic structure of Leadbeater's possum *Gymnobelideus leadbeateri* and its implications for species conservation. PhD Thesis, Monash University, Clayton, Australia.

Hansen BD and Taylor AC (2008). Isolated remnant or recent introduction? Estimating the provenance of Yellingbo Leadbeater's possums by genetic analysis and bottleneck simulation. Molecular Ecology 17: 4039–4052.

Hansen BD, Harley DKP, Lindenmayer DB and Taylor AC (2009). Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. Molecular Ecology 18: 3346–3362.

Hansen BD (2014). Personal communication on the eligibility of Leadbeater's Possum for listing as critically endangered. Submission 19 Provided to the Department of the Environment, by email (17/1/2014.

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

Harley DKP (2004b). Patterns of nest box use by Leadbeater's Possum (*Gymnobelideus leadbeateri*): applications to research and conservation. Pp. 318–329 in R. Goldingay and S. Jackson eds. The Biology of Australian Possums and Gliders. Surrey Beatty and Sons, Sydney.

Harley D (2004c). A survey for Leadbeater's Possum *Gymnobelideus leadbeateri* in lowland swamp forest at Bunyip State Park. Victorian Naturalist 121: 158–163.

Harley D (2014). Personal communication by email (20/11/14) to the Department of the Environment.

Harley DKP and Antrobus J (2007). Population monitoring of Leadbeater's possum at Yellingbo Conservation Reserve – 2005. Unpublished Report for Parks Victoria.

Harley DKP and Lill A (2007). Reproduction in a population of the endangered Leadbeater's possum inhabiting lowland swamp forest. Journal of Zoology 272(4): 451-457.

Harley DKP and Lindenmayer DB (2013). Personal communication, by email (30/1/2013) to the Department of Sustainability, Environment, Water, Population and Communities.

Harley DKP, Worley MA, Harley TK (2005). The distribution and abundance of Leadbeater's possum *Gymnobelideus leadbeateri* in lowland swamp forest at Yellingbo Nature Conservaton Reserve. Australian Mammalogy 27: 7–15.

IUCN (2014). Guidelines for using the IUCN Red List Categories and Criteria. Version 11. Prepared by the Standards and Petitions Subcommittee of the International Union for Conservation of Nature.

Jelinek A, Cameron D, Belcher C and Turner L (1995). New perspectives on the ecology of Lake Mountain: the discovery of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy in sub-alpine woodland. Victorian Naturalist 112: 112-115.

Lacy RC (2000). Considering threats to the viability of small populations using individual-based models. Ecological Bulletins 48: 39–51.

LPAG (Leadbeater's Possum Advisory Group) (2013). Fact sheet – Leadbeater's Possum. Department of Environment and Primary Industries, Victoria. Downloaded 22/10/13 from <http://www.depi.vic.gov.au/environment-and-wildlife/wildlife/leadbeaters-possum>.

LPAG (Leadbeater's Possum Advisory Group) (2014a). Leadbeater's Possum Recommendations: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security. 20 January 2014. Downloaded 10/10/14 from http://www.depi.vic.gov.au/__data/assets/pdf_file/0004/258214/Leadbeaters-Possum-Advisory-Group-Recommendations-Report_UV.pdf.

LPAG (Leadbeater's Possum Advisory Group) (2014b). Technical Report. 23 January 2014. Downloaded 10/10/14 from http://www.depi.vic.gov.au/__data/assets/pdf_file/0019/258220/Leadbeaters-Possum-Advisory-Group-Technical-Report.pdf.

Lindenmayer DB (1989). The ecology and habitat requirements of Leadbeater's possum. PhD Thesis, Australian National University, Canberra, 438pp.

Lindenmayer DB (1996a). Forest pattern and ecological processes: A synthesis of 25 years of research. CSIRO Publishing, Collingwood Victoria.

Lindenmayer DB (1996b). Wildlife and woodchips. Leadbeater's possum: a test case for sustainable forestry. University of New South Wales Press: Sydney.

Lindenmayer D (2013). Can Leadbeater's Possum be saved? Parkwatch 254: 12–13.

Lindenmayer DB and Meggs RA (1996). Use of den trees by Leadbeater's possum (*Gymnobelideus leadbeateri*). Australian Journal of Zoology. 44: 625-638.

Lindenmayer DB and Ough K (2006). Salvage logging in the montane ash eucalypt forests of the Central Highlands of Victoria and its potential impacts on biodiversity. Conservation Biology 20: 1005–1015.

Lindenmayer DB and Possingham HP (1995a). The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south eastern Australia – VII. Modelling the persistence of Leadbeater's possum in response to modified timber harvesting practices. Biological Conservation 73: 239–257.

Lindenmayer DB and Possingham HP (1995b). Modelling the impacts of wildlife on the viability of metapopulations of the endangered Australian species of arboreal marsupial, Leadbeater's Possum. Forest Ecology and Management 74: 197–222.

Lindenmayer DB and 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.

Lindenmayer DB, Smith AP, Craig SA and Lumsden LF (1989). A survey of the distribution of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy in the Central Highlands of Victoria. Victorian Naturalist. 106: 174-178.

Lindenmayer DB, Cunningham RB, Tanton MT, Nix HA and Smith AP (1990). The conservation of arboreal marsupials in the montane ash forest of the Central Highlands of Victoria, southeast Australia: II The loss of trees with hollows and its implications for the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae). Biological Conservation 54: 133–145.

Lindenmayer DB, Cunningham RB, Nix HA, Tanton MT and Smith AP (1991a). Predicting the abundance of hollow-bearing trees in montane ash forests of south-eastern Australia. Australian Journal of Ecology 16: 91-98.

Lindenmayer DB, Cunningham RB, Tanton MT and Smith AP (1991b). The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, South East Australia: III The habitat requirements of Leadbeater's possum *Gymnobelideus leadbeateri* and models of the diversity and abundance of arboreal marsupials. Biological Conservation 56: 295–315.

Lindenmayer DB, Cunningham RB, Donnelly CF, Tanton MT and Nix HA (1993a). The abundance and development of cavities in *Eucalyptus* trees: a case study in the montane forests of Victoria, southeastern Australia. Forest Ecology and Management 60: 77–104.

Lindenmayer DB, Lacy RC, Thomas VC and Clark TW (1993b). Predictions of the impacts of changes in population size and environmental variability on Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae) using population viability analysis: an application of the computer program VORTEX. Wildlife Research 20: 67–86.

Lindenmayer DB, Nix HA, McMahon JP, Hutchinson MF and Tanton MT (1993c). The conseration of Leadbeater's possum, *Gymnobelideus leadbeateri* (McCoy): a case study of the use of bioclimatic modelling.

Lindenmayer DB, Cunningham RB, and Donnelly CF (1993d). The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, South East Australia: IV The presence and abundance of arboreal marsupials in retained linear habitats (wildlife corridors) within logged forest. Biological Conservation 66: 207–221.

Lindenmayer DB, Cunningham RB and Donnelly CF (1997). Decay and collapse of trees with hollows in eastern Australian forests: impacts on arboreal marsupials. Ecological Applications 7: 625-641.

Lindenmayer DB, Cunningham RB, Donnelly CF and Franklin JF (2000). Structural features of old growth Australian montane ash forests. Forest Ecology and Management 134: 189–204.

Lindenmayer DB, Hobbs RJ, Gene E, Likens CJ, Krebs CJ and Banks SC (2011) Newly discovered landscape traps produce regime shifts in wet forests. Proceedings of the National Academy of Sciences 108(38): 15887–15891.

Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Laurence WF, Stein JAR and Gibbons P (2012). Interacting factors driving a major loss of large trees with cavities in a forest ecosystem. PLOS ONE 7: 1–16.

Lindenmayer DB, Blair D, McBurney L, and Banks S (2013a). New restoration forest management prescriptions to conserve Leadbeater's possum and rebuild the cover of ecologically mature forest in the Central Highlands of Victoria. Version 2. Fenner School of Environment and Society, The Australian National University, Canberra ACT. Available 15 October 2014 at: http://fennerschool-associated.anu.edu.au/documents/NewManagementPrescriptions.pdf.

Lindenmayer DB, Blair D, McBurney L, Banks SC, Stein JAR, Hobbs RJ, Likens GE, and Franklin JF (2013b). Principles and practices for biodiversity conservation and restoration forestry: a 30 year case study on the Victorian montane ash forests and the critically endangered Leadbeater's possum. Australian Zoologist 36: 441–460.

Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll D, Smith AL and Gill AM (2013c). Fire severity and landscape context effects on arboreal marsupials. Biological Conservation 167: 137–148.

Lindenmayer DB, Blair D, McBurney L, Banks S (2014a). Personal communication on the eligibility of Leadbeater's possum for listing as critically endangered 29 January 2014. Submission 9 Provided to the Department of the Environment, by email 29/1/2014.

Lindenmayer DB, Blair D, McBurney L, Banks S (2014b). Personal communication -Comments on the Leadbeater's possum action statement produced on 29 July 2014. Provided to the Threatened Species Commissioner at the Department of the Environment, by letter 16/9/2014.

Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadic 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.

Macfarlane M, Smith J and Lowe K (1997). Leadbeater's Possum Recovery Plan. Department of Natural Resource and Environment, Victoria.

Menkhorst P (2008). *Gymnobelideus leadbeateri*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Downloaded on 11 July 2013.

Menkhorst P and Lumsden L (1995). Leadbeater's Possum. Pp 104–107 *in* Menkhorst P (ed.) Mammals of Victoria: Distribution, Ecology and Conservation. Oxford University Press, Melbourne.

Patten T (2014). Personal communications on the eligibility of Leadbeater's Possum for listing as critically endangered. Submission 51 Provided to the Department of the Environment, by email 23 January 2014.

Rawlinson PA and Brown PR (1977). The fairy possum. Early pessimism – recent optimism – future realism. Wildlife in Australia 14: 74–79.

Reed DH, O'Grady JJ, Brook BW, Ballou JD and Frankham R (2003). Estimates of minimum viable population sizes for vertebrates and factors affecting those estimates. Biological Conservation 113: 23–34.

Shaffer ML (1981). Minimum population sizes for species conservation. Bioscience 31: 131–134.

Smales IJ (1994). The discovery of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy, resident in a lowland swamp woodland. Victorian Naturalist 111: 178-182.

Smith AP (1980). The diet and ecology of Leadbeater's possum and the sugar glider. PhD Thesis, Monash University, Melbourne.

Smith AP (1984). Demographic consequences of reproduction, dispersal and social interaction in a population of Leadbeater's Possum. Pp 359–373 *in*: Smith A and Hume I (eds) Possums and Gliders. Chipping Norton, NSW: Surrey Beatty & Sons.

Smith, B (2014). Healesville: Leadbeater's possum death fuels fear. The Age. 3 June 2014. Downloaded 13/10/14 from http://www.theweeklyreviewcity.com.au/story/1805356/healesville-leadbeater-s-possum-death-fuels-fears/events-calendar-city.

Smith AP and Hartley D (2008). Leadbeater's Possum *Gymnobelideus leadbeateri*. Pp 226–228 in van Dyck S and Strahan R (eds) The Mammals of Australia. Third Edition. Reed New Holland, Sydney.

Smith AP and Lindenmayer D (1988). Tree hollow requirements of Leadbeater's possum and other possums and gliders in timber production ash forests of the Victorian Central Highlands. Australian Wildlife Research 15: 347–62.

Strahan R (1998). The Mammals of Australia, Third Edition. Sydney, NSW: Australian Museum and Reed New Holland.

Taylor C, McCarthy MA and Lindenmayer DB (2014). Nonlinear effects of stand age on fire severity. Conservation Letters: 7: 355.

Turner V (2003). Flora and Fauna Guarantee Action Statement Number 130: Sedge-rich *Eucalyptus camphora* Swamp. Department of Sustainability and Environment, Melbourne.

VEAC (2012). Yellingbo investigation draft proposals paper for public comment, December 2012. Victorian Environmental Assessment Council. Downloaded 3/4/14 from http://www.veac.vic.gov.au/documents/Yellingbo%20DPP_web.pdf.

VicForests (2014). Personal communication on the eligibility of Leadbeater's Possum for listing as critically endangered. Submission 4 Provided to the Department of the Environment, by mail 10 January 2014.

Wilkinson, HE (1961). The rediscovery of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy. Victorian Naturalist 78: 97–102.

Woinarski J, Burbidge A and Harrison P (2014). Leadbeater's Possum *in* The Action Plan for Australian Mammals 2012. CSIRO Publishing.

Appendix 1
Assessment under Criterion 1

All data and analyses for Criterion 1 have a degree of uncertainty and the available data have different sources and assumptions that provide for some degree of over or under estimation that cannot be quantified. These are described within for each as comprehensively as possible and as understood by the Committee from the information available at the time of this assessment.

The assessments that follow have attempted to ensure, where possible, that losses due to different causes, in this case fire, harvesting and loss of hollow-bearing trees have not been multiple-counted and consequently overestimate loss. Any potential multiple counting of loss has been indicated where suspected or known.

This is an unavoidable consequence of the limitations of Criterion 1(c) that combines features of area (quantitative area of occupancy/extent of occurrence) and a less quantifiable/measurable 'quality of habitat' – that may overlap, as they do in this case.

Similarly, where harvesting is considered, it is limited (where known) to unburnt harvest rather than post-burn salvage harvest, unless indicated otherwise.

Primary sources of information used for this assessment include:

Lindenmayer et al. pers. comm., (2014a): Lindenmayer and colleagues have used extensive site data over a number of years (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000) to model and estimate the amount of suitable habitat for Leadbeater's possum available at 1989. Declines in 'suitable habitat' to 2013 caused by fire, logging, and loss of hollow-bearing trees are provided as percentage loss relative to this habitat. They use this loss to provide what they term to be a 'crude estimate' of current suitable habitat based on this modelling. Lindenmayer et al. (pers. comm., 2014a) also provide data on trend in decline of hollow-bearing trees over the periods 1989–2013, 2013–2035, and 2035–2060. They note that these estimates are underestimates as they do not account for edge effects, the loss of habitat to wide strips between logging coupes, and subdivision causing habitat fragmentation.

VicForests pers. comm. (2014) provide data for area (hectares) within the range of Leadbeater's possum of public forest suitable for Leadbeater's possum (ash forest including mountain ash, alpine ash, shining gum and snow gum). Most of these data are also provided in Appendix 4 of LPAG (2014a). For these forests, data are provided for the quantity burnt and not burnt since 2000. The information on ash forest is further categorised into 'available for harvest' and areas 'never to be harvested'. The non-harvestable areas are divided into those managed as 'parks and reserves', areas of Special Protection Zones, and exclusions.

VicForests pers. comm. (2014) also provide estimates of the area (ha) per annum harvested since 2009, and 'projected are to be harvested pa post 2013'. LPAG (2014a) clarify that the 'projected' harvest is from 2017, following the transition to lower harvest levels outlined in 'VicForests' 2013 Resource Outlook'.

LPAG (2014a, b) provide the table of data sourced from VicForests (as described above, but also provide information previously provided at LPAG (2013) and elsewhere such as that of Lumsden et al. (2014). Where these data differ to that of VicForests, it is assumed here to be due to the baseline being 2009, rather than that of 'since 2000' for VicForests.

These data do not include lowland floodplain forest habitat used by Leadbeater's possum, of which only 20 hectares provides suitable habitat conditions for the possum (D. Harley 2014 pers. comm., cited in DEPI, 2014).

Assumptions and data limitations
Data available to the Committee for its use in assessment under Criterion 1 have come from different sources. Given that the criterion is a comparison of variables over time, it requires data from different years, or predictions into the future. In many cases data is available for a single point in time but is not comparable to data in the past. For Leadbeater's possum, estimates of (c) area of occupancy, extent of occurrence and/or quality of habitat for the present time are difficult to determine and highly variable. The species is difficult to detect and estimates of occupancy and habitat may incorporate biases based on statistical assumptions (e.g., from sampling) as well as bias from sampling errors. These are exacerbated when projecting from these into the past or future.

Data for future circumstances are invariably speculative and uncertain, and relies on a number of assumptions. Data from different sources are rarely comparable, particularly if there are assumptions or biases built into their collection. Much of the data or estimates are not in the public domain and/or not independently verified or peer reviewed.

Area of occupancy, extent of occurrence, habitat quality
Criterion 1 provides for reduction in population size based on a decline in area of occupancy, extent of occurrence, and/or quality of habitat. The relationship between these and population size may be linear (and used as a direct proxy for population decline), but there may also be lagged response of the population to a decline in its habitat (IUCN, 2014). The relationship between loss of habitat quality and either occupation or population density may not be able to be estimated into the past or future. Combining estimates of decline in area of occupancy and extent of occurrence (where data may be spatial and quantifiable), with estimates of habitat quality (not spatial, less quantifiable) to provide for a single quantitative estimate of decline relative to the thresholds of the criterion is also difficult.

Some declines from threats may overlap spatially over time. For example, fire and harvesting may occur on areas where decline in habitat quality has occurred, harvesting may occur in areas affected by fire. Efforts in the analysis have also been made to reduce the occurrence of double counting these losses where possible.

The analyses undertaken for Criterion 1 for area of occupancy and extent of occurrence use data described as 'estimates of occupied habitat' or 'suitable habitat' within the Central Highlands (e.g., Lindenmayer and collegues; Lumsden et al., 2013), which differ significantly from estimates of 'suitable forest' within the Central Highlands (VicForests pers. comm., 2014; LPAG 2013, 2014a,b).

Efforts have been made whenever possible to separate assessments using these different source estimates of area of occupancy and extent of occurrence in analyses for Criterion 1, given they are not compatible data.

Assessment based on A2 (past)

The period of time over which decline is considered for A2 is within a past 18 years (three generation lengths). In this instance, the 18 year period 1995–2013 is chosen to provide for inclusion of best available Leadbeater's possum data from the 'present' (2013). This period includes declines observed, estimated, and inferred as a result of fire, harvesting and loss of habitat quality.

There are different sources of data that provide different and incompatible information on which this assessment can be based. Given this, assessments will be presented separately. These are outlined as (a) and (b) below and undertaken as differing assessments. There are two sources of information which provide comprehensive estimates of current /potential area of occupancy or extent of occurrence and comparable estimates from the past close to, or within, the 18 year time frame considered (3 generation lengths) for this criterion:

a) Lindenmayer et al., pers. comm. (2014a). Comparisons of declines here are provided as percentage declines relative to forest at the year 1989. Lindenmayer et al., pers. comm. (2014a) provide data on decline in quality of habitat due to loss of hollow-bearing trees. The period 1989 to 2013 is 24 years used in this assessment rather than the 18 period required for this assessment, will therefore potentially provide an overestimate of decline for the whole 18 year period.

b) VicForests pers. comm. (2014) and LPAG (2014a) use a different baseline to that of Lindenmayer et al., pers. comm., (2014a). These provide data on area lost to fire and fire disturbance (in hectares) 'from 2000' to the present (2013) and include change due to the 2006/07 and 2009 fires (combined). This source also provides past harvest rates for some of these years. Assessment under A2 using this data will consider the 18 year period from 2013 to 1995, but data is only provided 'from 2000'. This shortened timeframe will therefore potentially provide an underestimate of decline for the whole 18 year period.

These data sources will be used for the following two assessments under A2. Additional or alternative information is included within these analyses where comparable.

LPAG (2013; 2014a) provide different estimates of the percentage of forest lost to fire. The estimates of LPAG (2013; 2014a) are instead based only on the 2009 fires, rather than fires 'since 2000' [of VicForests pers. comm., (2014); LPAG (2014a)]. In addition, these have a 'pre 2009' baseline of 195 000 ha, with a loss of 68,000 ha to fire of 34% (LPAG, 2014a) or 35% (LPAG, 2013). The timeframe for this change is only four years, and will be an underestimate of decline relative to the similar alternative data provided by VicForests. This data will therefore not be used for this A2 assessment (but will be included within subsequent assessments with more relevant timeframes).

a) Using data of Lindenmayer et al. (pers. comm., 2014a)

'Suitable habitat' available at 1995

Hollow-bearing trees with large internal dimensions in the order of 30 cm in diameter are a critical habitat feature for Leadbeater's possums (LPAG, 2013) and are required within ash forest to support colonies of the possum. There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's possum (e.g., Lindenmayer at al., 1991c; Lindenmayer et al., 2013c; Lindenmayer et al., pers. comm., 2014a), with nest hollow availability limiting population size. An understory of wattle is also a required component of Leadbeater's possum habitat (Smith and Lindenmayer, 1988; Menkhorst and Lumsden, 1995; DSE, 2013).

Lindenmayer et al. (pers. comm., 2014a) have undertaken large scale vegetation surveys in the central highlands of Victoria since 1987 (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000). Their data layers indicate that in1987 and 1989 montane ash forest was represented by 171,200 ha. Of this available montane ash forest, only 6.7% was predicted to support 'suitable habitat' for Leadbeater's possum at this time (i.e. approximately 11,470 ha). This estimate was based on measures of the abundance of hollow-bearing trees and the prevalence of an understorey of *Acacia* spp.

This data, based on 'suitable habitat', is therefore likely to represent area of occupancy for Leadbeater's possum.

Loss from habitat decline (loss of hollows) 1989 to 2013
In 1997, the abundance of hollow-bearing trees was estimated to have occurred as 5.1 hollow-bearing trees per hectare and by 2013 had declined to 4 per hectare ecosystem-wide (Lindenmayer et al., 2012; Lindenmayer et al., pers. comm., 2014a). From repeated studies of the rate and spatial extent of decay and collapse of hollow-bearing trees throughout montane ash forest, Lindenmayer et al. (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000) estimate that of 6.7% of ash forest predicted to support potentially suitable habitat in 1989, by 2014 this will decline to 3.1% (= loss of 3.6% (absolute loss)).

Loss from fire 1989 to 2013
Lindenmayer et al. (pers. comm., 2014a) estimate that of the 6.7% possum-suitable habitat in montane ash forest, around 1.4% has been lost to fire or fire disturbance since 1989.

Loss from harvesting 1989 to 2013
Lindenmayer et al., (pers. comm., 2014a) estimate that 19,338 ha of montane ash forest in the Central Highlands has been lost to harvesting since late 1997, including areas predicted to support suitable Leadbeater's possum habitat. This estimated loss from harvest does not include post burn salvage harvest.

They also estimate that clearfell logging since 1989 has lead to 0.6% of the montane ash forest predicted to support suitable habitat being lost. They note that this is a conservative estimate because this does not also include the loss of other areas that have been rendered uninhabitable by harvesting – i.e. areas left as narrow strips (of approximately 20–100 m wide) that are unlikely to support Leadbeater's possum (Lindenmayer et al., 1993) and areas fragmented by logging roads and tracks that may have rendered areas too small for Leadbeater's possums.

Table 1 summarises the decline in 'suitable habitat' for Leadbeater's possum from fire, harvesting and loss of quality from 1989 to the present following Lindenmayer et al. (pers. comm., 2014a).

Table 1. Declines in 'suitable habitat' from 1989–2013 based on data from Lindenmayer et al. (pers. comm., 2014a).

'Suitable habitat' at 1989 is 6.7% of 171,200 ha =11,470 ha (baseline)	Of 11,470 ha		'Suitable habitat' remaining at 2013 (1.1% of 171,200 ha)	loss (relative to 11,470 ha baseline)
Estimated loss by 2013:	Loss			
-habitat quality from loss of hollows*	3.6%	6,163 ha		53.7%
-fire and fire disturbance*	1.4%	2,397 ha		20.9%
-harvesting*	0.6%	1,027 ha		9.0%
Total loss by 2013	5.6%	9,587 ha		
Total			1,883 ha*	83%
Lindenmayer et al. (pers. comm., 2014a) calculates:	5.4%		2,225 ha	81%

[*these % estimates attempt to allocate a % loss to each threat independent of each other, and may include some small degree of multiple counting]

The decline of 'suitable habitat' for Leadbeater's possum over the past 18 years through fire, harvesting, and a reduction in availability in hollow-bearing trees estimated primarily by data collected over a number of years (since 1987) and modelled and tested Lindenmayer et al. (e.g., Lindenmayer, 1989; Lindenmayer et al., 1990; 1991a, b; 2000) is therefore over 80%. This is considered by the Committee to be very severe.

b) Using baseline data of VicForests pers. comm. (2014) and LPAG (2014a)

Suitable forest available at 1995
While the assessment above at (a) uses data that focuses on 'suitable habitat' for Leadbeater's possum, data of VicForests pers. comm. (2014) and LPAG (2014a) includes all ash forest, including mountain ash, alpine ash, shining gum and snow gum forest within the home range of Leadbeater's possum within the Central, Dandenong and Central Gippsland Forest Management Areas. This data is provided noting that this forest type is 'suitable forest' for Leadbeater's possum. However, 'suitable forest' is an overestimate of suitable habitat for Leadbeater's possum, because not all ash forest is suitable for use by Leadbeater's possum (e.g., Lindenmayer et al., 1990; 1991a, b; 2000; Lumsden et al., 2013) with Lindenmayer et al. (pers. comm., 2014a) estimating that in 1987 and 1989 only 6.7% of montane ash forest in the Central Highlands was 'suitable habitat' for Leadbeater's possum.

There are no precise data available to the Committee that provide the baseline amount of montane ash forest available to Leadbeater's possum at 1995 (i.e. 18 years prior to the 'present' 2013). 'Since 2000', there was 204,400 ha ash forest (including mountain ash, alpine ash, shining gum and snow gum forest) considered to be suitable forest types for Leadbeater's possum within the home range of Leadbeater's possum and within the Central, Dandenong and Central Gippsland Forest Management Areas (VicForests pers. comm., 2014).

Decline from fire:
Leadbeater's possums do not occupy burnt sites regardless of fire intensity (Lindenmayer et al., 2013a; LPAG, 2013; Lumsden et al., 2013). Of the 204,400 ha 'available forest' for Leadbeater's possum 'since 2000', 55,300 ha (27%) has been burnt since 2000 (VicForests pers. comm., 2014). A total area of 149,100 ha ash forest remains unburnt at 2013 (Table 2).

Table 2. Loss of 'suitable forest' from fire 1995 to 2013 (area data from VicForests pers. comm. (2014) 'since 2000')

		Loss at 2013 from burn 'since 2000'
Ash forest total	204 400 ha	
Burnt since 2000	55 300 ha	27%
Remaining (unburnt) since 2000	149 100 ha	

Loss to harvesting
Of this unburnt 149,100 ha remaining ash forest/'suitable forest':

- 44,700 ha are available for harvesting (VicForests pers. comm., 2014). Ash or snow gum woodland available for harvesting excludes parks and reserves, Special Protection Zones, stream buffers and steep slopes and non-mapped exclusions.
- 104,400 ha are excluded from harvesting (VicForests pers. comm., 2014) (Table 3).

Table 3. Remaining unburnt 'suitable forest'/ash forest available for harvest (area data from VicForests pers. comm. (2014) 'since 2000')

Total unburnt ash forest at 2013	149,100 ha
Unburnt ash forest excluded from harvesting total	104,400 ha
Unburnt ash forest available for harvest	44,700 ha

VicForests (pers. comm., 2014) estimated that of the 44,700 ha area of harvestable ash forest 'since 2000', 610 ha has been harvested or thinned per annum since 2009 i.e., approximately 2,440 ha over 4 years to 2013, representing a further decline of 1.2% in 'suitable forest' since fires due to harvesting. 42,260 ha unharvested forest within the 'harvestable' areas is therefore 'suitable forest' at 2013 in addition to that of the ash forest excluded from harvesting (104,400 ha) (Table 4).

Table 4. Unburnt 'suitable forest' at 2013.

excluded from harvesting total		104,400 ha
available for harvest minus harvested area (i.e. 2,440 ha) at 2013	44,700 ha – 2,440 ha	= 42,260 ha
'suitable forest' at 2013		= 146,660 ha

Table 5 provides the loss to 2013 from fire and harvest relative to the 204,400 ha baseline (VicForests pers. comm., 2014) which is 28%.

The Committee notes that Lindenmayer et al. (pers. comm., 2014a) estimate that 19,338 ha of 'montane ash forest in the Central Highlands' has been lost to harvesting since late 1997, including areas predicted to support suitable Leadbeater's possum habitat. If this amount is compared to the 204,400 ha ash forest available 'after 2000' of VicForests (pers. comm., 2014), this would represent a decline of 9.5%. These data are not comparable, for instance, this harvest estimate is since 1997 rather than since 2000, and may include areas subsequently lost to 206/7 and 2009 fires, but this provides an upper extreme potential of harvest and is included in Table 5.

Table 5. Loss from fire and harvest (relative to baseline of 204,400 ha)

	Harvested by 2013	% loss due to harvest relative to original 204,400 ha ash forest	% loss relative to original 204,400 ha ash forest
Harvest per annum since 2009 (over 4 years) (VicForests pers. comm., 2014) 610 ha	2,440 ha	1.2%	28%
Harvest since 1997* Lindenmayer et al. (pers. comm., 2014a)	19,338 ha	9.5%	36%

* noting the harvest estimated here is not directly comparable to the baseline of VicForests (pers. comm., 2014).

Decline due to loss of habitat quality (loss of hollow-bearing trees):
The abundance of hollow-bearing trees in 1997 is estimated to have been 5.1 hollow-bearing trees per hectare ecosystem-wide. By 2013 the abundance is estimated to be 4 per hectare (Lindenmayer et al., 2012; Lindenmayer et al., pers. comm., 2014a). This represents a decline in quality of habitat (of 22%) for Leadbeater's possum over this period of time. This loss is applied to the remaining 'suitable forest' following loss from fire and harvesting. Table 6 provides the total estimated loss from fires, harvesting and loss of quality if a 22% decline from loss of hollow-bearing trees is added to the declines estimated at Table 5. Lindenmeyer et al., (pers. comm., 2014a) also note a complete loss of habitat through loss of hollow-bearing trees from 1989 to 2013 of 55.7% (i.e. see Table 1). This loss is also included in Table 6.

Table 6. Estimated declines from fire, harvest and loss in habitat quality to from 1995 to 2013 (from 204,400ha).

Harvest per annum since 2009 (VicForests pers comm., 2014)	Loss from fire	Harvested by 2013	% loss from fire and harvest relative to original 204,400 ha ash forest	Remaining	Total loss following an additional 22% loss in quality of the remaining 'suitable forest'	Total loss
610 ha	55,300 ha (27%)	2,440 ha (1.2%)	28%	146,660 ha	Loss of 22% in quality (loss of 32,265 ha) =114,395 ha	44%
					Loss of 53.7% (loss of 78,756 ha) =67,904 ha	67%

Decline from 1995 to 2013
Using 204,400 ha of ash forest as a baseline, decline by fire, habitat quality, and harvesting results in an overall decline in 'suitable forest' for Leadbeater's possum of 44% or 67% (depending on the loss used for decline in hollow-bearing trees (Table 6)). The Committee considers this decline to be substantial to severe.

Assessment based on A3 (future)

The period of time over which decline is considered for A3 is a future 18 years. Data on change in area of occupancy, extent of occurrence and/or quality of habitat from a future period to a period further into the future is speculative and therefore to reduce the level of uncertainty, the period chosen includes the present (as 2013 with data provided for this assessment) to enable inclusion of known information about the present time (rather than some other future time). The period from 2013 to 2031 therefore includes the future, with declines projected and suspected due to:

- projected harvesting
- projected decline in tree hollows
- inferred/suspected extent of occurrence due to likelihood of future fire damage.

Like the assessment at A2, there are various sources of information which are not necessarily compatible, that can be used to inform the assessment under A3.

There are three sources of information which provide area estimates to estimate area of occupancy, extent of occurrence of Leadbeater's possum at 2013:

- Lindenmayer et al., pers. comm., (2014a)
- VicForests pers. comm., (2014) and LPAG (2014a)
- Lumsden et al. (2013)

Each of these is included in the following assessment.

There is one source of information on projected harvest rates: with three potential projected declines from harvesting provided by VicForests pers. comm. (2014) + LPAG (2014a).

There is one source of information on projected decline in tree hollows (Lindenmayer and colleagues) which is considered to be decline in habitat quality. There are no data available that can provide quantitative estimates of future decline as a result of fire. A range of potential declines due to likelihood of loss in area of occupancy and/or extent of occurrence due to fire are therefore considered.

These are all included within the following analyses, where able, to estimate decline in area of occupancy, extent of occurrence and/or quality of habitat from 2013 to 2031.

Estimates of area of occupancy and/or extent of occurrence of Leadbeater's possum at 2013
a) Using occupancy modelling, Lumsden et al. (2013) predict that within the 'ash forests of the Central Highlands', there are only approximately 15,000 ha of forest currently occupied by Leadbeater's possum.

b) In 1989, a total of 25 of 370 field sites (6.7%) surveyed as part of a large-scale vegetation survey were predicted to support suitable habitat for Leadbeater's possum (Lindenmayer, 1989). Reduction in the number of hollow-bearing trees, fire effects and clearfell logging has reduced the amount of suitable habitat to 1.3 per cent of the montane ash forest estate. On this basis, Lindenmayer et al. (pers. comm., 2014a) provide a crude estimate that approximately 2,225 ha remaining ash forest is currently suitable as habitat for Leadbeater's possum.

c) Following the rationale provided at A2 based on data from VicForests pers. comm. (2014): there are 104,400 ha of unburnt ash forest within the range of Leadbeater's possum that are protected through parks and reserves, Special Protection Zones, and harvest exclusions (VicForests pers. comm., 2014). Within the unburnt 44,700 ha available for harvesting, an estimated minimum of 2,440 ha is estimated to have been harvested or thinned since 2009 leaving less than 42,260 ha unharvested ash forest at present. Therefore, there are currently approximately 146,660 ha of ash forest within the range of Leadbeater's possum that could be considered to be 'suitable forest' for Leadbeater's possum.

There are therefore three estimates of the area of occupancy or extent of occurrence of Leadbeater's possum at 2013, as provided in Table 7.

Table 7. Estimated available area of occupancy, extent of occurrence (ha) available for Leadbeater's possum at 2013.

Source and type of estimation	Estimated available area of occupancy, extent of occurrence
a) Estimated occupied forest at 2013 (Lumsden et al., 2013)	15,000 ha
b) Predicted available 'suitable habitat' (Lindenmayer et al., pers. comm., 2014a)	2,225 ha
c) Maximum available 'suitable forest' (unburnt and unharvested ash forest) (VicForests pers. comm., 2014 + LPAG, 2014a) and following A2	146,660 ha

Estimated loss of area of occupancy, extent of occurrence from 2013 to 2031 due to harvesting
At 2013, it is estimated that there are 42,260 ha of unburnt ash forest available for harvesting (following data presented at A2). This is the maximum possible harvest by 2031 and is used for assessment under (c).

The average rate of harvest and thinning of both burnt and unburnt ash forest from 2009 to 2013 was around 1,265 ha per annum (VicForests pers. comm., 2014; LPAG, 2014b). The amount harvested and thinned within unburnt ash forest between 2009 to 2013 was 610 ha per annum (and 655 per annum in burnt forest).

VicForests (pers. comm., 2014) estimates that 500–1000 ha ash forest is projected to be harvested per annum after 2013. LPAG (2014b) notes that this is a reduction in harvest rate implemented in ash forests within the range of Leadbeater's possum in response to the 2009 fire, and will be from 2017 as outlined in VicForests' 2013 Resource Outlook. Neither of these sources provide a distinction between harvest rates in burnt and unburnt forest for this future harvest.

Given the uncertainty from when this rate will commence (i.e., either 'post 2013', or 'from 2017') it is assumed here that the former rate (of 610 ha pa) will continue to 2017 within unburnt ash forest. The following assessment will provide the loss due to harvest and thinning in unburnt ash forest (containing potential Leadbeater's possum habitat) using this rate to 2017. From 2017 to 2031 the rate of harvest will use the predicted reduced rate of 500 ha and 1000 ha pa. The Committee notes, however, that this rate is assumed to be across all ash forest within the range of Leadbeater's possum, and unlike the former rate of 610 ha pa, includes burnt and unburnt ash forest. This will therefore provide for an overestimation of harvest, and loss of 'suitable forest' over the years 2017 to 2031.

Three harvest rates are therefore included:

- 3050 ha (harvested at 610 ha per annum from 2013 to 2017) + 6,500 ha (when harvested at the lower rate of 500 ha/annum from 2017 to 2031) =9,550 ha
- 3050 ha (harvested at 610 ha per annum from 2013 to 2017) + 13,000 ha (when harvested at the higher rate of 1000 ha/annum from 2017 to 2031) =16,050 ha
- All harvestable forest (i.e. 42,260 ha) might be harvested between 2013 and 2031.

The three scenarios of loss from harvesting equate to 6.5%, 10.9% and 28.8% loss respectively relative to the 146,660 ha available at 2013. Table 8 provides the remaining extent of occurrence/area of occupancy to the original baselines at 2013 of (a) Lumsden et al. (2013) and (b) Lindenmayer et al (pers. comm., 2014a) following the application of the declines (%) under the three scenarios relative to the baseline of (c) (VicForests pers. comm., 2014 + LPAG, 2014a).

(a) Of the 15,000 ha of habitat estimated by Lumsden et al. (2013) to be occupied at 2013 using occupancy modelling, current strongholds include habitat mainly in the south of the Central Highlands including the Baw Baw Plateau and its southern slopes, the Toorongo Plateau south of the Upper Yarra Catchment and state forest in the vicinity of Powelltown, parts of Toolangi State Forest, and southern parts of the Upper Yarra National Park (Lumsden et al., 2013). 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). 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 or 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.

(b) Similarly, of the 2,225 ha remaining suitable habitat for Leadbeater's possum estimated by Lindenmayer et al. (pers. comm., 2014a), some is expected to occur within areas projected for harvesting. The Committee is unaware of the quantity of harvestable forest that could be harvested by 2031 within these areas estimated to be occupied or estimated as 'suitable habitat' for Leadbeater's possum at 2013 indicated by Lumsden et al. (2014) and Lindenmayer et al. (pers. comm., 2014a).

Table 8. Extent of occurrence /area of occupancy Possible lost to harvest from 2013 to 2031

	area estimation at 2013	Loss to harvest from 2013 to 2017	Loss to harvest from 2017 to 2031	Total possible loss to harvest (ha) from 2013 to 2031	lost from harvest since 2013	Area remaining at 2031
a) Lumsden et al. (2013)[1]	15,000 ha				6.5%	14,025 ha
					10.9%	13,365 ha
					28.8%	10,680 ha
b) Lindenmayer et al. (pers. comm., 2014a)[1]	2,225 ha				6.5%	2080 ha
					10.9%	1982 ha
					28.8%	1584 ha
(c) Maximum available unburnt and unharvested ash forest (ha) (VicForests pers. comm., 2014)	146,660 ha					
(c) When harvested at 610 ha to 2013 (610 x 5)		3,050 ha				
c)* If harvested at min projected rate from 2017 (500 ha x 13 years)			+6,500 ha	=9,550 ha	6.5%	137,110 ha
c)* If harvested at high projected rate from 2017 (1000ha x 13 years)			+13,000 ha	=16,050 ha	10.9%	130,610 ha
c) If all harvestable unburnt ash forest is harvested				=42,260 ha	28.8%	104,400 ha

[1] loss from harvesting is applied to baseline areas of (a) and (b) at the three percentage declines found for harvest rates relative to baseline area of (c). This assumes the application of harvesting is neither avoiding or concentrating on these areas considered to be Leadbeater's possum habitat by these authors.
* harvest rate provided does not distinguish between burnt and unburnt forest harvesting. Thus this loss may include some double counting of loss from harvest and fire, and therefore be a slight over-estimation.

Estimated decline in habitat quality from 2013 to 2031 due to loss of hollows

There have been significant losses of hollow-bearing trees in past decades (LPAG, 2013). The combination of the loss of existing hollow-bearing trees and a lack of formation of new hollows is predicted to lead to a severe shortage of hollows in the next 30–70 years (LPAG, 2013).

Hollow-bearing trees with large internal dimensions in the order of 30 cm in diameter are a critical habitat feature for Leadbeater's possums (LPAG, 2013). Leadbeater's possums are more likely to occur in areas with higher densities of hollow-bearing trees, such as areas with more than two or three hollow-bearing trees per hectare (LPAG, 2013). There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's possum (e.g., Lindenmayer at al., 1991c; Lindenmayer et al., 2013c; Lindenmayer et al., pers. comm., 2014a), with nest hollow availability limiting population size. A decline in the number of hollow-bearing trees therefore corresponds to a decline in the number of mature individuals of Leadbeater's possum, noting there may be a lagged response.

Lindenmayer and colleagues have undertaken extensive vegetation surveys since the 1980s to study the rate and spatial extent of decay and collapse of hollow-bearing trees throughout the montane ash forests of the Central Highlands of Victoria. Based on empirical data and modelling of the ongoing collapse of hollow-bearing trees between 1983 and 2012 in unburned areas (see Lindenmayer et al., 1990, 1997; Lindenmayer and Wood, 2010; Lindenmayer et al., 2012), Lindenmayer et al. (pers. comm., 2014a) estimate the decline of hollow-bearing trees will be from more than four per ha ecosystem wide in 2013 to 1.5 per ha by 2035. Because Leadbeater's possums are less likely to occur in areas with less than two or three hollow-bearing trees per hectare (LPAG, 2013), this represents a significant decline in habitat quality. A decline from 4 to 1.5 hollow-bearing trees per hectare from 2013 to 2035 represents a decline in habitat quality of 63% ecosystem-wide over this time. A further decline of 63% relative to that remaining following harvest from each of the original habitat estimates at 2013 are provided at Table 9. These percentage declines are applied to remaining area after harvesting (so as not to double count).

Table 9 provides the estimated remaining area after these combined losses, and a combined percentage loss.

Table 9. Estimated loss of habitat quality due to loss of hollow-bearing trees 2013–2031

Source of estimate	After harvest/ unharvested area remaining at 2013	63% loss of habitat quality (from remaining area)	Loss (from harvest and quality)
(a) following Lumsden et al. (2013) baseline of15,000 ha			
If harvested at min. projected rate	14,025 ha =6.5% loss	5,189 ha	65%
If harvested at max. projected rate	13,365 ha =10.9%	4,945 ha	67%
If all available harvestable forest is harvested	10,680 ha =28.8%	3,952 ha	74%
(b) following Lindenmayer et al. (pers. comm., 2014a) baseline of 2,225 ha			
If harvested at min. projected rate	2,080 ha =6.5% loss	770 ha	65%
If harvested at max. projected rate	1,982 ha =10.9%	733 ha	67%
If all available harvestable forest is harvested	1,584 ha =28.8%	586 ha	74%
(c) following VicForests (pers. comm., 2014) baseline of 146,660 ha			
*If harvested at min. projected rate	137,110 ha =6.5% loss	50,731 ha	65%
*If harvested at max. projected rate	130,610 ha =10.9% loss	48,326 ha	71%
If all available harvestable forest is harvested	104,400 ha =28.8%loss	38,628 ha	74%

* harvest rate provided does not distinguish between burnt and unburnt forest harvesting. Thus, this loss may include some double counting of loss from harvest and fire, and therefore be a slight over-estimation.

Loss due to fire 2013–2031

Scenarios include no fire, low to medium likelihood of fire impact (e.g., of 12.5% and 20%), and a 50% likelihood of fire impact. A 35% loss from fire scenario is also included, because 35% loss was that lost to ash forest and snow gum woodlands 'suitable forest' from the 2009 fires. These potential reductions are applied to the estimated areas remaining following loss from harvest and quality loss (i.e. if fire occurs at the end of the 18 year period). These are included in Table 10. The range of decline from these causes range from 63% to 87%.

Table 10. Loss to remaining area of occupancy/extent of occurrence after harvesting, loss of hollow-bearing trees (loss of quality) and from a range of potential fire scenarios from 2013 to 2031 (fire impacts to the area already harvested and loss of quality).

	Area remaining at 2031 after harvest	Area remaining at 2031 after harvest and 63% loss of quality	Area remaining at 2031 after further loss from fire (% loss to post harvest, post quality area)	% total loss
a) Estimated occupied habitat at 2013 (ha): 15,000 ha[1] (following Lumsden et al. , 2013)	14,025 ha	5,189 ha		
If 0% lost through fire by 2031			5,189 ha	65%
If 12.5% lost through fire by 2031			4,540 ha	70%
If 20% lost through fire by 2031			4,151 ha	72%
If 35% lost through fire by 2031			3,373 ha	77%
If 50% lost through fire by 2031			2,594 ha	83%
a) Estimated occupied habitat at 2013 (ha): 15,000 ha[2] (following Lumsden et al. , 2013)	13,365 ha	4,945 ha		
If 0% lost through fire by 2031			4,945 ha	67%
If 12.5% lost through fire by 2031			4,327 ha	71%
If 20% lost through fire by 2031			3,956 ha	74%
If 35% lost through fire by 2031			3,214 ha	79%
If 50% lost through fire by 2031			2,472 ha	83%
a) Estimated occupied habitat at 2013 (ha): 15,000 ha[3] (following Lumsden et al. , 2013)	10,680 ha	3,952 ha		
If 0% lost through fire by 2031			3,952 ha	74%
If 12.5% lost through fire by 2031			3,458 ha	77%
If 20% lost through fire by 2031			3,162 ha	79%
If 35% lost through fire by 2031			2,569 ha	83%
If 50% lost through fire by 2031			1,976 ha	87%
b) Estimated 'suitable habitat' at 2013 (ha): 2,225 ha[1] (following Lindenmayer et al. pers. comm., 2014a)	2,080 ha	770 ha		
If 0% lost through fire by 2031			820 ha	63%
If 12.5% lost through fire by 2031			674 ha	70%
If 20% lost through fire by 2031			616 ha	72%
If 35% lost through fire by 2031			500 ha	77%
If 50% lost through fire by 2031			385 ha	83%
b) Estimated 'suitable habitat' at 2013 (ha): 2,225 ha[2] (following Lindenmayer et al. pers. comm., 2014a)	1,982 ha	733 ha		
If 0% lost through fire by 2031			733 ha	67%
If 12.5% lost through fire by 2031			641 ha	71%
If 20% lost through fire by 2031			586 ha	74%
If 35% lost through fire by 2031			476 ha	79%
If 50% lost through fire by 2031			367 ha	83%
b) Estimated 'suitable habitat' at 2013 (ha): 2,225 ha[3] (following Lindenmayer et al. pers. comm., 2014a)	1,584 ha	586 ha		
If 0% lost through fire by 2031			586 ha	74%
If 12.5% lost through fire by 2031			513 ha	78%
If 20% lost through fire by 2031			469 ha	79%
If 35% lost through fire by 2031			381 ha	83%
If 50% lost through fire by 2031			293 ha	87%
c)* Estimated 'suitable forest' at 2013 (ha): 146,660 ha[1]	137,110 ha	50,731 ha		
If 0% post harvest and quality lost though fire by 2031			50,731 ha	65%
If 12.5% lost through fire by 2031			44,390 ha	70%

If 20% lost through fire by 2031			40,585 ha	72%
If 35% lost through fire by 2031			32,975 ha	77%
If 50% lost through fire by 2031			25,365 ha	83%
c)* Estimated 'suitable forest' at 2013 (ha): 146,660 ha[2]	130,610 ha	48,326 ha		
If 0% lost through fire by 2031			48,326 ha	67%
If 12.5% lost through fire by 2031			42,285 ha	71%
If 20% lost through fire by 2031			38,661 ha	74%
If 35% lost through fire by 2031			31,412 ha	79%
If 50% lost through fire by 2031			24,263 ha	83%
c) Estimated 'suitable forest' at 2013 (ha): 146,660 ha[3]	104,400 ha	38,628 ha		
If 0% lost through fire by 2031			38,628 ha	73%
If 12.5% lost through fire by 2031			37,997 ha	74%
If 20% lost through fire by 2031			30,902 ha	79%
If 35% lost through fire by 2031			25,108 ha	83%
If 50% lost through fire by 2031			19,314 ha	87%

[1] at minimum harvest rate (6.5% loss)
[2] at maximum harvest rate (10.1% loss)
[3] at maximum possible harvest (28.8% loss)
* the harvest rate provided post 2013/ after 2017 does not distinguish between burnt and unburnt forest harvesting. This loss may, therefore, include some double counting of loss from harvest and fire, and therefore be a slight over-estimation.
Areas burnt would include areas already included to have lost habitat quality, and therefore the total loss is slightly overestimated.
As the analysis provides for outcomes from a range of scenarios, including no fire, these results do not include the quantitative probability of fire occurring within this time period.

Assessment based on A4 (past and future)

The period of time considered for A4 is a three generation length period (18 years) including both the past and the future. Because most data on change in area of occupancy/extent of occurrence and quality is available from the periods that include the 2006/7 and 2009 bushfires, this assessment under A4 incorporate times that include these events.

LPAG (2013; 2014a) provide data for hectares of forest lost during the 2009 fires relative to 'area of potential habitat'. The 'area of potential habitat' as 100% range of Leadbeater's possum is provided by LPAG (2013) as 195,000 ha. However, there is no indication of whether this 'potential habitat' is unburnt and prior to 2009 (in which case a proportion would be unsuitable) or current post 2009 'potential habitat' excluding burnt areas.

As Lindenmayer et al. (pers. comm., 2014a) data uses a baseline of 1987 and 1989, and their estimations of harvest lost relative to this baseline is from late 1997, the 18 year period potentially for consideration here under A4 would only extend to 2015. Because the result from assessment over this time period would be very similar to that provided under A2 (to 2013), analysis using this 1997 baseline data will not be considered further for A4. Analyses for this subcriterion using data 'since 2000' of VicForests (pers. comm., 2014) similarly, do not provide data that would be different from analyses under A2, with the 18 year period under consideration extending to 2018. There are no additional known baseline data for just prior to 2006 or 2009 to provide for consideration of change in area of occupancy/extent of occurrence and quality for A4.

There are therefore inadequate data to provide for baselines alternative to those already considered under A2 and A3. Assessment under A4 is therefore not evaluated here.

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Document 2

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Draft only

National Recovery Plan for Leadbeater's possum (*Gymnobelideus leadbeateri*)

February 2016

The Species Profile and Threats Database pages linked to this recovery plan is obtainable from: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Cover photo: Tamara Leitch and Claire McCall

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1. SUMMARY

Background

This Recovery Plan replaces the initial (1997) Recovery Plan for Leadbeater's possum *Gymnobelideus leadbeateri*. Leadbeater's possum is a phylogenetically distinctive species and is the only mammal species endemic to Victoria.

This Plan recognises that although substantial research and conservation achievements have been made associated with the previous Recovery Plan and other initiatives, the status of Leadbeater's possum is declining severely, such that it has recently (April 2015) been up-listed to Critically Endangered under national legislation. Based on the extent of recent, current and projected decline, the 2015 Australian *Threatened Species Strategy* listed this species as one of only two mammal species with 'emergency' priority for conservation management.

This Plan focuses particularly on the main threat to this species – decline in the extent, quality and connectivity of suitable habitat, with this decline due mostly to historic, current and projected severe bushfire and changed fire regimes, timber harvesting and loss of hollow-bearing trees. Conservation planning for Leadbeater's possum is a long-term proposition and commitment. Because of the impacts of historic fire and other disturbances, the availability of suitable habitat is predicted to decline for at least another 40-50 years, such that it will be extremely challenging to achieve recovery of this species in the short term. Actions taken now to enhance its conservation status are unlikely to reverse the current decline in the extent of its suitable habitat or of its population over the 10-year period of this plan, but they will help to slow this rate of decline. And importantly, actions taken or not taken now will affect its likelihood of extinction over a 50 to 100 year timeframe.

Recovery Plan context

The recovery objectives and actions proposed here are informed by a set of general principles and requirements. These include:

(1) that the pre-eminent purpose of this Recovery Plan is to stop the decline and support the recovery of Leadbeater's possum so that its chances of long-term survival in nature are maximised;

(2) that recovery objectives and actions delineated here are informed appropriately by a very substantial evidence base arising from intensive research that has spanned several decades and is ongoing, and that evidence from research should continue to inform recovery actions;

(3) that while existing recovery actions have contributed to some conservation advances, they have been, and are likely to continue to be, insufficient to recover the species, hence a substantially new or more committed management response is required;

(4) that the overwhelming majority of the known population of Leadbeater's possum is confined to the Central Highlands montane ash forest, and that the development of effective conservation management actions – including reducing the risk of landscape-scale fire – for this species in this region is most critical to the species' likelihood of recovery;

(5) but that, on current trends, there is an unacceptably high risk of extinction for the species in this region, especially through extensive bushfire, and hence there is a need to try to spread this risk through attempts to establish subpopulations of the species in the most suitable habitat outside this region;

(6) that conservation effort needs to attempt to secure both the Central Highlands (montane ash and snow gum) subpopulations and the lowland swamp forest subpopulation (an Evolutionarily Significant Unit), with this latter one particularly at risk of imminent extinction;

(7) that conservation success will not be achieved by management actions alone, but will depend also upon refinement and complementarity of existing and future planning and policy settings, such that these contribute appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature; and

(8) that there remain important uncertainties about some candidate conservation management actions (such as translocation, effective fire mitigation options, accelerated hollow development), so this Recovery Plan should address these knowledge gaps and be flexible, responsive to new information, and capable of adaptive management.

Long-term recovery objective

> *To increase the extent, quality and connectivity of currently and prospectively suitable habitat, and its occupancy by Leadbeater's possum, in order to maximise the probability of persistence of the species.*

This long-term objective would require the following outcomes:

- the total population size of Leadbeater's possum stabilises and then increases over a 20-50 year period from now;
- risks to Leadbeater's possum from catastrophe (notably extensive, severe bushfire) are managed effectively through securing viable subpopulations across an area that is at least as extensive as its distribution immediately prior to the 2009 bushfires;
- the extent and continuity of high quality habitat and old-growth forest is substantially increased;
- there is an ongoing commitment, with appropriate resourcing, to effective and enduring management of threats to this species, including effective management that results in a pattern of bushfire frequency and severity that is less detrimental to this species (and its forest environment) than that presently prevailing;
- the distinctive subpopulation in the lowland swamp forest is retained and its population size and the extent and suitability of its habitat are substantially greater than at present.

Recovery Objectives, Actions and Performance Criteria for the lifetime of this Plan

<u>Objective 1</u>: All relevant existing and future planning and policy settings are reviewed and where required, refined and implemented in a manner that contributes appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature.

> *Action 1.1. Review and, where required, revise existing relevant planning and policy settings to ensure that they provide for maximising the chances of long-term survival of Leadbeater's possum.*
>
> *Action 1.2. Ensure that future relevant planning and policy settings provide for maximising the chances of long-term survival of Leadbeater's possum.*
>
> *Action 1.3. Ensure coordination between relevant planning and policy settings to maximise the chances of long-term survival of Leadbeater's possum.*

<u>Objective 2</u>: 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.

Action 2.1. Enhance existing levels of protection for areas in which colonies are not known but may be present, by undertaking pre-harvest surveys in all coupes prior to proposed timber harvesting. If these surveys detect Leadbeater's possum, the colonies must be protected from harvesting.

Action 2.2. Assess the feasibility, risks and cost-effectiveness of fire management options that seek to deliver long-term, strategic and landscape scale enhancement of the extent and quality of current and prospective suitable habitat. Develop and implement fire management that effectively secures and promotes long-term, strategic and effective protection of known colonies and suitable habitat.

Action 2.3. Enhance existing levels of protection for important habitat features by protecting and buffering all live and dead hollow-bearing trees in montane ash forests within the distribution of Leadbeater's possum.

Action 2.4.Review the conservation effectiveness of timber harvesting regulatory prescriptions and related guidelines relevant to the protection of known Leadbeater's possum colonies and habitat, and refine these prescriptions and guidelines to provide more effective conservation outcomes.

Action 2.5. Refine and update occupancy and other relevant distributional and population viability modelling across the full range of the species (incorporating finer-scale mapping of key habitat attributes, such as large hollow-bearing trees and understorey density).

Action 2.6. Based on models developed in Action 2.5, undertake landscape scale land-use planning that provides options for conservation of suitable habitat now and in the future to ensure an acceptably high likelihood of persistence (i.e. at least 99% over 100 year period) for Leadbeater's possum.

Action 2.7. Expand the dedicated 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.

Action 2.8. Assess the practicality and effectiveness of habitat augmentation including the provision of nest boxes, artificially excavated hollows, or manipulation of understorey. Where benefits can be obtained effectively, strategically implement these to enhance the current and projected extent of suitable habitat in the Central Highlands.

Action 2.9. Enhance habitat suitability and extent for lowland swamp forest habitat.

<u>Objective 3</u>: Where there is net long-term benefit (i.e. likelihood of increase in overall population viability), translocate individuals or colonies *within* and adjacent to the known range.

Action 3.1. Identify priority areas within and adjacent to the known range to which translocations may provide benefit to the possum's population viability. Assess the risks, potential impacts upon existing subpopulations, benefits, likelihood of success, *and cost-effectiveness of translocation options. Develop appropriate protocols for use and implementation of translocation (most likely 'wild-to-wild' introductions).*

Action 3.2. Assess the risks, benefits, practicality, cost-effectiveness and consequences of 'gene pool mixing' to increase the viability of the lowland subpopulation.

Action 3.3. Where Actions 3.1 and 3.2 indicate likelihood of net benefit, undertake carefully monitored trial translocations, and – if successful – extend translocations to other priority areas.

Objective 4: Seek to locate, or establish, additional populations *outside* the core range of the Central Highlands.

Action 4.1. Using recently developed survey approaches, survey potentially suitable areas (in Victoria) outside the known range.

Action 4.2. If such surveys locate 'new' existing populations (beyond the Central Highlands), assess their status, population size, genetic affinities, habitat relationships, extent of suitable and prospective habitat and management requirements; and implement such management.

Action 4.3. If such surveys fail to locate existing populations, identify the most suitable candidate areas for translocation.

Action 4.4. Assess the welfare risks, likelihood of success, cost-effectiveness, and potential impacts upon existing populations of translocations to those areas outside the current range considered most practical and likely to result in the establishment of new viable subpopulations. If considered to have significant benefits, implement such translocations.

Objective 5: Targeted research addresses key knowledge gaps such that management options are better informed and management actions more effective.

Action 5.1. Establish an ongoing research forum to enhance existing collaboration among researchers, and between researchers, managers and other interested parties, to make the most effective use of research actions and to identify and address any further key knowledge gaps.

Action 5.2. Undertake research that provides more robust knowledge of key demographic and other ecological characteristics relevant to conservation management, specifically including dispersal characteristics and population size.

Action 5.3. Investigate key aspects of the post-fire ecology of Leadbeater's possum. This research should include at least: (i) assessing current hollow availability and the importance of large dead and any live hollow-bearing trees in the burnt landscape; (ii) investigating hollow development within trees that were 1939 regrowth before being burnt to determine their potential to provide nesting sites into the future; and (iii) investigate persistence of colonies within fire refuges surrounded by burnt areas to determine if they will be effective sources for natural recolonisation or if translocations will be required to accelerate recolonisation of the regenerated burnt areas.

Action 5.4. Design and implement experimental trials that rigorously assess the relative benefits of prescriptions, actions and other management options, in a manner that allows results to inform ongoing refinement of those prescriptions and actions and the Plan itself.

<u>Objective 6</u>: An integrated monitoring program is effectively implemented (and maintained) that publicly reports in a timely manner on possum status, existing and prospective habitat extent, quality and connectivity, and effectiveness of management actions.

Action 6.1. Collate existing monitoring data and programs (for population trajectories, extent and suitability of habitat, and management effectiveness). Maintain, enhance or develop new monitoring programs to ensure an integrated monitoring and survey program across all tenures and management zones and develop an effective public reporting of monitoring results.

Action 6.2. Identify key trigger points or thresholds in monitoring results that would catalyse priority emergency response (and identify such emergency response options).

Action 6.3. Where translocations are proposed, design translocation trials in a manner that allows for reporting on success or failure, and those factors that contribute to this fate. Monitor those trials, and use results to refine the efficacy of translocation protocols, or to assess critically whether they are of net benefit.

Action 6.4. Monitor the extent of success (including cost-effectiveness and collateral benefits) of management actions individually and collectively, and use such information as appropriate to refine actions.

<u>Objective 7</u>: All stakeholders support and where relevant are involved in the implementation of the Plan.

Action 7.1. Establish (or build from existing mechanisms) and maintain an effective recovery team or similar governance model to oversee implementation of the Recovery Plan, and ensure effective and timely operation of such a team.

Action 7.2. Involve the community in Leadbeater's possum recovery.

Action 7.3. Provide enhanced opportunities for the participation of Indigenous groups in research, monitoring, management and other components of this Plan.

Action 7.4. Promote and publicise the Recovery Plan and recovery effort.

<u>Objective 8:</u> Ensure effective and adaptive implementation and management oversight of the Plan including adequate resourcing.

Action 8.1. All partners in the Plan coordinate and adequately resource implementation to achieve objectives through adaptive management and cost-effective delivery.

Action 8.2. Establish appropriate governance and protocols to be able to respond to emergency events.

Action 8.3. Monitor the extent of implementation of management actions.

Action 8.4. Report regularly on performance effectiveness of this Recovery Plan, including a formal review at 5 years, and adapt as required.

2. INTRODUCTION

2.1. Current (2016) conservation status of Leadbeater's possum

Leadbeater's possum is currently listed under the following legislation and advisory lists.

Environment Protection and Biodiversity Conservation Act 1999: Critically Endangered

- uplisted in 2015, previously (from 2000) listed as Endangered;
- eligibility listing criterion 1: A2(c) A3(c) – a *very severe* (>80%) decline in population size over the recent past (i.e. over the last three possum generations (=18 years)) based on decline in the area of occupancy, extent of occurrence and/or quality of habitat, and a projected future (over the next 18 years) *very severe* decline in population size based on these same parameters.

Flora and Fauna Guarantee Act 1988 (Victoria): threatened

Advisory List of Threatened Vertebrate Fauna in Victoria: Endangered

IUCN Red List of Threatened Species: Endangered.

2.2. About this Recovery Plan

This document constitutes the National Recovery Plan for Leadbeater's possum *Gymnobelideus leadbeateri*. The plan considers the conservation requirements of the species across (and beyond) its range and identifies the actions to stop the decline, and support the recovery, of the species such that its chances of long-term survival in nature are maximised.

This plan replaces the previous 'Leadbeater's possum (*Gymnobelideus leadbeateri*) Recovery Plan' (Macfarlane *et al.* 1997) in force since its adoption in November 1997. The objective of the 1997 plan was to downlist Leadbeater's possum from Endangered to Vulnerable within ten years. A recent review of the previous Recovery Plan (http://www.environment.gov.au/biodiversity/threatened/recovery-plans/comment/draft-recovery-plan-leadbeaters-possum) concluded that most recovery actions had been largely implemented over the life of the plan and a range of measures had been introduced to protect Leadbeater's possum habitat. Notwithstanding such effort, the current and projected trends for the species and its habitat are of continuing decline. The review recommended that future recovery actions focus on maintaining and where possible improving the protection of existing and prospective habitat, and continuation of coordinated monitoring for population trends.

Even though there have been substantial ongoing planning and management actions undertaken to protect Leadbeater's possum, including the implementation of all 13 recommendations from the Leadbeater's Possum Advisory Group established in 2013, the beneficial outcomes of these actions have been substantially outweighed by a range of detrimental factors such that the (Threatened Species Scientific Committee 2015) considered there had been a very severe decline in the abundance of Leadbeater's possum since 1997. That decline has caused the conservation status of the species to be uplisted (on 22 April 2015) to Critically Endangered on the list of threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This new Recovery Plan has been developed in response to several key changes over the life of the previous Plan including:

- the continuing and projected decline in the species' population size and the extent and quality of its habitat;
- new information on the species' ecology, distribution, habitat and management;
- lessons learned from the previous Recovery Plan; and
- a need to reassess some policies, management regulations and guidelines to improve the conservation prospects for the species.

This plan builds upon, but seeks to substantially advance from, the set of actions outlined in the 1997 Recovery Plan, and on previous and current conservation measures being undertaken or proposed by the Victorian Government and its agencies, academics and community groups, and it incorporates new research findings on this species.

2.3. Urgent need and emergency response

All Recovery Plans describe priority management needs for species that are threatened with extinction. However, this Recovery Plan has particular urgency and need for extraordinary conservation management responses. This need is explicitly recognised in the Australian government's threatened species strategy (https://www.environment.gov.au/biodiversity/threatened/publications/strategy-home), which identified Leadbeater's possum as one of only two mammal and two bird species requiring 'emergency intervention'. The need for emergency intervention is further reinforced in the Australian government's *Leadbeater's Possum Action Plan* of August 2015 which identified that within one year a new Recovery Plan would be completed, encompassing a package of actions seeking to reverse the decline of Leadbeater's possum (https://www.environment.gov.au/biodiversity/threatened/publications/leadbeaters-possum-action-plan).

In its assessment of the conservation status of this species, the Threatened Species Scientific Committee (2015) concluded that the population of the species (explicitly as informed by data on its area of occupancy, extent of occurrence and/or quality of habitat) had declined by more than 80% over its last three generations (18 years) and, furthermore, that it was projected to decline by more than 80% over its next three generations: collectively, an estimated population decline of more than 96% over a 36 year period, despite a suite of existing conservation planning and management actions.

Evidence of this very severe decline derives from several explicit monitoring and modelling assessments of trends in abundance and habitat availability. Zoos Victoria has monitored the total size of the 'lowland' subpopulation at Yellingbo over the last 15 years, with these results showing a very severe and ongoing deterioration over recent years (from more than 110 individuals in 2003 to fewer than 50 individuals in 2015), notwithstanding a program of substantial and intensive research and conservation management actions (Harley 2012; Harley 2016).

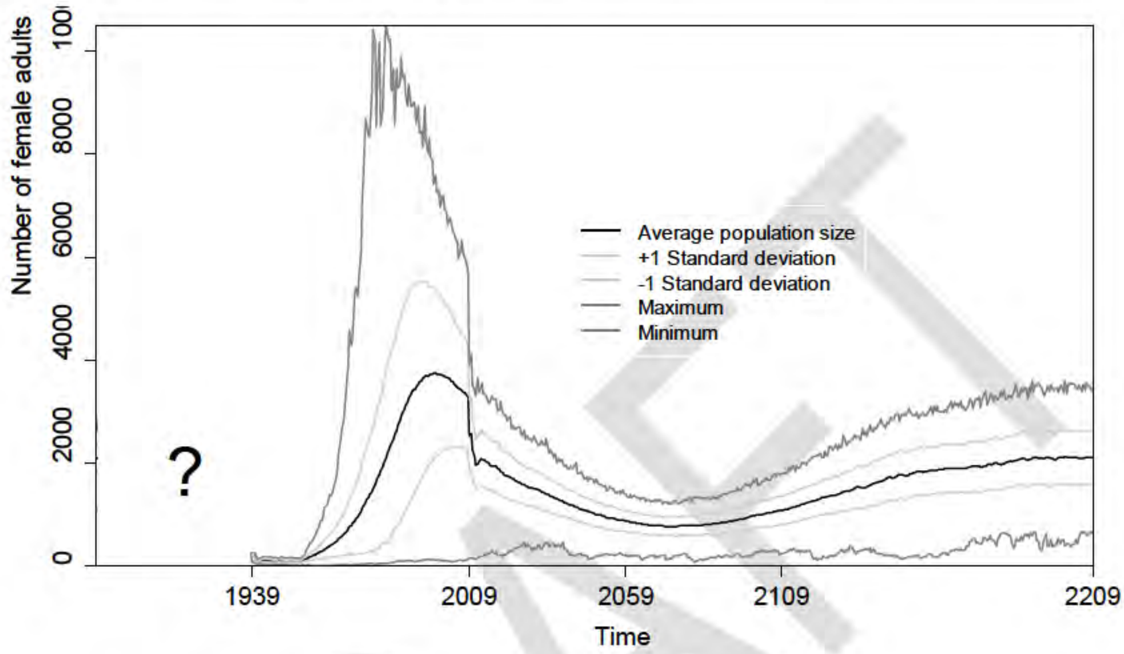
The abundance of Leadbeater's possum has also been monitored in snow gum woodlands on Lake Mountain plateau since 2003, with consistent sampling since 2008 (when there were 28 known colonies with an estimated 200-300 individuals) to 2015 (when there were fewer than 10 remaining individuals) (Harley 2016). Trends in this population are representative of many areas subjected at least in part to the impacts of the extensive and severe 2009 bushfires.

There has been a major (ca. 160 sites) monitoring program for Leadbeater's possum (and other hollow-dependent mammal species) in the Victorian montane ash forest extending for over 30 years, by David Lindenmayer and associates from the Australian National University (Lindenmayer *et al.* 2003). Population trends have varied over this period. Initial results indicated decline in abundance of Leadbeater's possum at monitoring sites over the period 1987 to 2001 (Lindenmayer *et al.* 2003), although no significant trend in abundance was apparent over the period 1997 to 2008 (Lindenmayer *et al.* 2011b; Lindenmayer *et al.* 2014b). Subsequent monitoring of these sites has demonstrated the almost complete loss of possums at all sites burnt by the 2009 bushfires which affected approximately a third of the total potential range of the species, and affected both reserves and state forests (Lindenmayer *et al.* 2013c).

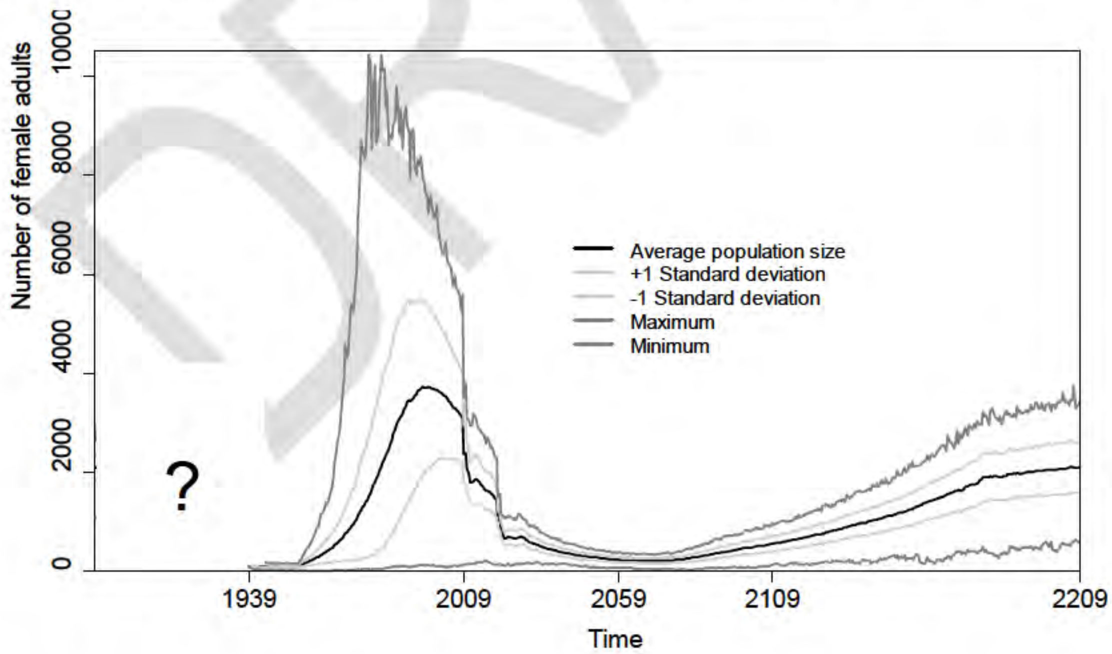
An assessment of past, current and projected trends for the species is also possible through analysis of the availability of its key habitat features, particularly the availability of old hollow-bearing trees. A range of assessments has been developed for such availability in montane ash forests in the Victorian Central Highlands. These consistently describe severe and ongoing reduction in the abundance of hollow-bearing trees, and hence the extent of suitable habitat, with ongoing decline projected for at least another 50 years (Lindenmayer *et al.* 1990b; Lindenmayer *et al.* 2015b). This decline is largely due to the ongoing collapse of large hollow-bearing trees killed in the extensive 1939 bushfires, reduction in mature ash forest extent through historic, ongoing and projected timber harvesting, and the impacts of the 2009 bushfire. Any future extensive bushfire will further exacerbate this severe decline in available habitat.

The population size of Leadbeater's possum in the dedicated Leadbeater's possum reserve system, comprising part of its range, has recently been retrospectively modelled and projected, with such models likely to be broadly representative of trends in the full extent of its range (Lumsden *et al.* 2013) . **Figure 1a** presents such a model for the 'best-case' (and hence unlikely) scenario of no increased habitat decline or future fires. This modelling indicates the assumed major population loss (a population bottleneck) due to the 1939 bushfire, an increase in numbers as the forest regenerated, a gradual decline from the 1990s attributable mostly to incremental loss of hollow-bearing trees killed in the 1939 fires and wattle senescence, then a sharp loss in Leadbeater's possums associated with the 2009 fires and ongoing major declines extending for at least another 50 to 60 years due to continuing decline in habitat extent and quality. Expected future declines become more severe under more realistic scenarios that include at least one severe bushfire. For example, **Figure 1b** presents the outlook for the species when a future 50% decline in hollow-bearing trees and an extensive bushfire burning 50% of the reserve in 2020 (for example) are factored into the model (Lumsden *et al.* 2013). These projections of decline will become more severe when likely climate change is considered.

Figure 1. Examples of modelling of estimated historic and projected population size of Leadbeater's possum (from Lumsden *et al.* (2013)). This modelling is for within the Leadbeater's possum reserve (30,500 ha). The range of values at any time presented in this graph reflects the variation associated with repeated runs of the model. Note that trends rather than absolute population size estimates (in this case, the relative number of adult females) are the most informative aspect of these graphs, as current and especially historic and projected, population sizes are not well resolved. This is particularly the case for the population prior to the very extensive 1939 bushfires (with such high level of uncertainty signified as ? in these graphs).



(a) Modelling assuming no future fires or increased rate of habitat decline.



(b) Modelling under a more likely scenario of at least one major disturbance (in this case a severe fire in 2020 and an increased loss of hollow-bearing trees). Figures 1a and 1b reproduced with permission from '*A new strategic approach to biodiversity management – research component*' (by L Lumsden, J Nelson, C Todd, M Scroggie, E McNabb, T Raadic, S Smith, S Acevedo, G Cheers, M Jemison and M Nicol (2013) Arthur Rylah Institute for Environmental Research, Heidelberg).

Collectively, these monitoring and modelling data demonstrate that the conservation future for Leadbeater's possum is highly precarious. Under current conditions, it is predicted that the species will continue on a severe downward trajectory from its current highly imperilled status for at least another 50 years, before regrowth trees from the 1939 fires start to form hollows (i.e. the next five to six decades may represent a 'bottleneck') after which the Leadbeater's possum habitat extent may increase. Depending upon their severity, incidence and extent, future bushfires will exacerbate these predicted trends for decline, and further delay (or render implausible) any future recovery.

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 for a severe decline. 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.

2.4. Significance of Leadbeater's possum

Leadbeater's possum is taxonomically distinctive as it is the only species in the genus *Gymnobelideus*, otherwise most closely related to the tropical striped possums *Dactylopsila* (Edwards and Westerman 1992; Osborne and Christidis 2001; Cardillo *et al.* 2004). Recognising this evolutionary distinctiveness and its proximity to extinction, it is rated as one of the world's 100 highest priority mammal species for conservation (http://www.edgeofexistence.org/mammals/top_100.php). Leadbeater's possum is also included as one of 12 Australian threatened mammal species accorded high priority in the 2015 Australian Threatened Species Strategy (https://www.environment.gov.au/biodiversity/threatened/publications/strategy-home), and (its lowland subpopulation) is listed as one of the 20 priority threatened species in Zoos Victoria's Fighting Extinction program (http://www.zoo.org.au/fighting-extinction).

Leadbeater's possum has high cultural significance, as one of Victoria's two state terrestrial faunal emblems, and is Victoria's only endemic mammal species. The species is the focus of an active and committed conservation group (Friends of the Leadbeater's Possum), and has substantial community profile and interest.

Leadbeater's possum is an 'indicator', 'focal', 'umbrella' or 'flagship' species for the conservation of its montane ash forest environment and biodiversity more generally (Lindenmayer and Cunningham 1997; Lindenmayer *et al.* 2014b), because the main threats that affect this high profile species are likely to affect many other less iconic species in this ecosystem. Hence, any conservation responses for Leadbeater's possum are likely to benefit many other species, particularly including other hollow-dwelling mammals and birds, such as the sooty owl *Tyto tenebricosa* (listed as threatened under the Victorian *Flora and Fauna Guarantee Act*, and as Vulnerable in its associated advisory list) and greater glider *Petauroides volans* (listed as Vulnerable in the Victorian advisory list).

Conservation measures taken for the Leadbeater's possum may also be expected to benefit its main habitat, mountain ash forest in the Central Highlands, which was recently assessed as a Critically Endangered ecosystem using IUCN criteria (Burns *et al.* 2015). Furthermore, the small subpopulation of Leadbeater's possum in lowland swamp forest has conservation significance as an example of a relictual distribution with importance for the longer-term evolutionary potential for the species, and because the small site at which it occurs (Yellingbo Nature Conservation Reserve) supports both of Victoria's highly threatened terrestrial fauna emblems and has been the subject of substantial conservation effort extending over several decades.

2.5. Consultation

As outlined in the Australian Government's Leadbeater's Possum Action Plan (www.environment.gov.au/biodiversity/threatened/publications/leadbeaters-possum-action-plan), input was sought from key stakeholders from the environment, science and forestry sectors, in developing this draft Plan. Gregory Andrews, the Threatened Species Commissioner facilitated two meetings of key stakeholders, in Melbourne on the 21 October 2015 and 11 December 2015. These meetings enabled stakeholder representatives to discuss and provide comment on their expectations for the Recovery Plan, and provide preliminary feedback on an initial consultation draft of the Recovery Plan. Those comments helped shape the development of this draft Plan for public consideration.

3. BACKGROUND INFORMATION INFORMING RECOVERY ACTION

This section highlights aspects of the biology of Leadbeater's possum that are most relevant to its conservation status and recovery management. Wherever possible the implications for management are drawn out from the biological information below and explicitly stated. More detailed accounts of the species' biology are available elsewhere (Smith *et al.* 1985; Menkhorst and Lumsden 1995; Lindenmayer *et al.* 2015b).

Leadbeater's possum has been the focus of substantial research effort extending for at least 30 years: indeed 'Leadbeater's possum is arguably amongst the best studied endangered animals globally, and certainly in Australia' (Lindenmayer *et al.* 2014a). This research has revealed much of the ecology of this species. However, notwithstanding this research effort, there are still some important knowledge gaps that constrain the evaluation of options for, and impede the implementation of, management responses. Where relevant, these information gaps are also identified below, as priorities for additional research.

3.1. Description of the species

Leadbeater's possum is a small (100-160 g), nocturnal, arboreal possum. It has some superficial resemblance to the far more abundant and widespread (but not closely related) sugar glider *Petaurus breviceps*, but is notably distinct from that species in not possessing a gliding membrane.

3.2. Distribution

Leadbeater's possum is endemic to Victoria. Its former and current distributions are poorly resolved, with a sparse fossil and sub-fossil record, uncertainty about the locations of some historic records, and some uncertainty about the full extent of its current distribution (Harley 2004c).

Because Leadbeater's possum has highly specific habitat requirements, there are very strong linkages between the current status and trends in its habitat extent (and suitability), distribution and population. Accordingly, there is some complementary material presented in these sections below.

3.2.1. Former distribution

The past distribution of Leadbeater's possum is not well defined, but it was formerly more widespread. Fossil deposits are known from near Buchan (in east Gippsland) and the Wombeyan Caves and Marble Arch in south-eastern New South Wales (Harley 2004c).

Sub-fossil deposits (from owl pellets, probably aged about 100-400 years before present) demonstrate that it formerly occurred in foothill and montane forests of south, central and east Gippsland, from which it is not now known (Bilney *et al.* 2006; Bilney *et al.* 2010; Bilney 2014).

Of its known distribution since European settlement, there is a single isolated record from 1909 in north-eastern Victoria ('Sunnyside', Mt Wills) (Brazenor 1932), a specimen held at Beechworth museum but without locality data (Lindenmayer and Dixon 1992), and four records from south-western Gippsland (including Bass River and Koo-Wee-Rup swamp area near Tynong) collected between 1867 and 1910 (Myroniuk and Seebeck 1992; Menkhorst and Lumsden 1995).

Harley (2004c) collated several other historic and recent records unsupported by confirmed specimens, beyond its currently known range. These include a record of hair identified from a fox scat collected in 1975 in the Dartmouth Dam area of north-eastern Victoria (Brunner *et al.* 1976), regarded by Harley (2004c) as 'plausible'; a hair sample reported in 1995 from Black Forest near Macedon (south-central Victoria) (Larwill *et al.* 2003); and single unconfirmed sightings from a few other sites in north-eastern Victoria, the Strzelecki Ranges in south Gippsland, and the Otway Ranges. Some subsequent sampling at most of these sites has failed to corroborate these records (Harley 2004a), but in at least some of these areas, surveys have not necessarily been adequate to detect this species or to discount its presence.

A substantial decline from the past to the current range is evident from the fossil record and from more recent historic habitat loss (especially in its former lowland swamp forest range). Distributional decline is also inferred from bioclimatic modelling, which suggests a range reduction of 88% over the last 250 years (Burgman and Lindenmayer 1998), and from genetic analyses (Hansen *et al.* 2009).

Priority research needs to enhance management:

- A substantial survey effort incorporating new techniques (see 3.2.6. Survey techniques and effort) should be extended to more rigorously evaluate whether Leadbeater's possum occurs in potentially suitable areas (including sites of previous unconfirmed reports) outside the Central Highlands, and to evaluate the extent of current and prospective habitat across this larger range.

3.2.2. Current distribution

Since its 'rediscovery' in 1961, almost all records have been restricted to a ca. 3000 km^2 area (Menkhorst and Lumsden 1995), or about ca. 70 km (north-south) x 80 km (east-west), in the Central Highlands, roughly bounded by Toolangi in the west, Rubicon in the north, Mt Baw Baw in the east and Beenak in the south.

The exception to this core range is the isolated (and remnant) subpopulation in lowland swamp forest at Yellingbo Nature Conservation Reserve, where it occurs in an occupied area of less than 20 ha, along a 6 km riparian strip, ca. 16 km distant from the nearest montane forest population (Smales 1994; Harley 2002; Harley 2004c; Harley *et al.* 2005).

Within its main range in the Central Highlands, it is patchily distributed (Macfarlane *et al.* 1997), with distributional gaps due to areas of unsuitable vegetation types (those that are not dominated by ash forests or by sub-alpine (snow gum) woodlands), or due to temporary or permanent loss of suitable habitat because of loss of hollows, fires or timber harvesting. Its actual current distribution is imprecisely known because sampling effort dictates that not all potentially suitable habitat can be (or has been) surveyed, and because its persistence varies temporally due to hollow abundance, fire, timber harvesting, spatial context and other factors. Recent extensive surveys are helping to increase knowledge of the distribution throughout the Central Highlands (Lumsden *et al.* 2013; Nelson *et al.* 2015; Harley 2016).

Its expected former, current and projected distribution has been modelled based variably on bioclimatic, vegetation, fire history and other spatial context factors (Threatened Species Scientific Committee 2015): all such models will have some constraints, imprecision and interpretational caveats.

The Victorian Leadbeater's Possum Advisory Group (2014b) noted that there was just over 200,000 ha of 'potential habitat' (montane ash forest and snow gum woodland) within the range of Leadbeater's possum. During the 2009 bushfires, 34% of this area was burnt and is currently not suitable for Leadbeater's possum. In addition, approximately 5500 ha of ash forests have been harvested since 2009 and is also currently unsuitable. The remaining ca. 130,000 ha of 'available forest' represents one assessment of the total area of current potential habitat. However, the actual area currently occupied by colonies of Leadbeater's possum is likely to be considerably less than this due to the specialised habitat requirements of this species and because the suitability of potential habitat will vary over time.

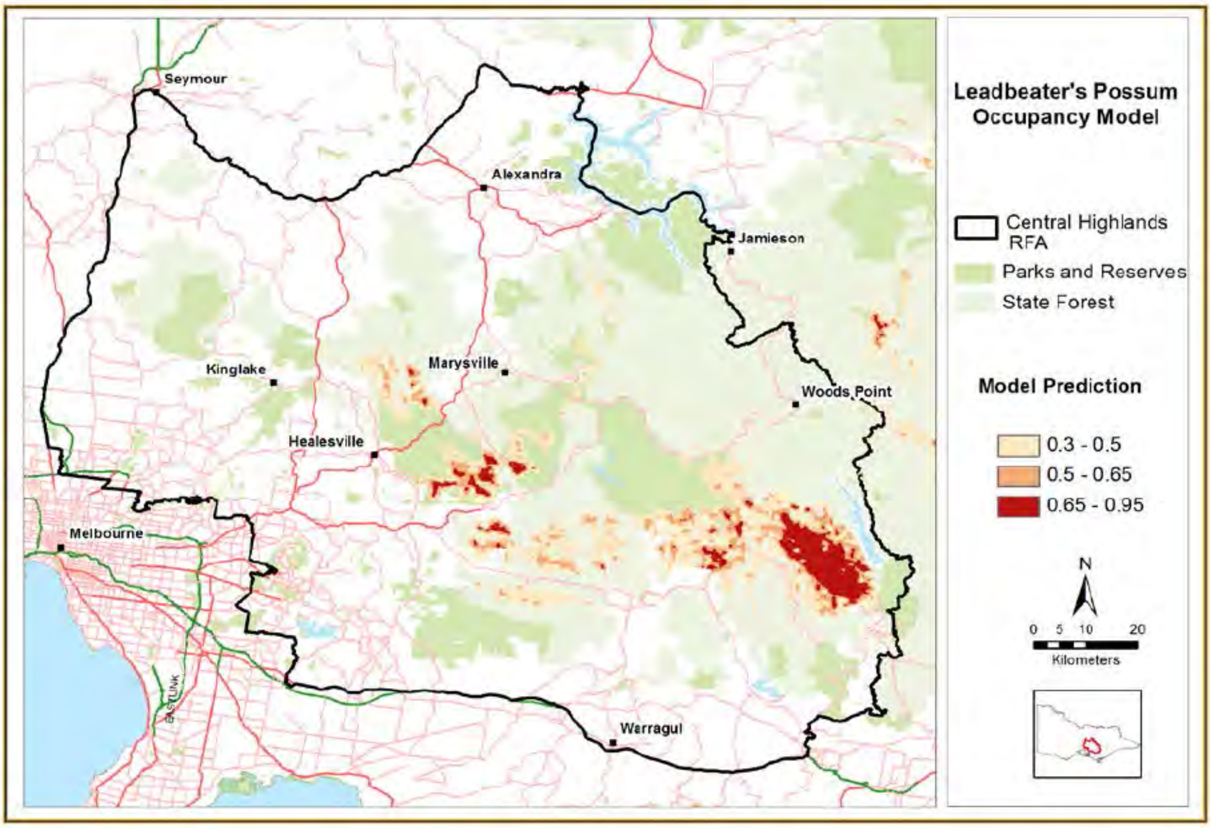


Figure 2. Occupancy model predicting areas most likely to be currently occupied based on stratified sampling in 2012. Figure 2. reproduced with permission from *'A new strategic approach to biodiversity management – research component'* (by L Lumsden, J Nelson, C Todd, M Scroggie, E McNabb, T Raadic, S Smith, S Acevedo, G Cheers, M Jemison and M Nicol (2013) Arthur Rylah Institute for Environmental Research, Heidelberg).

Lumsden *et al.* (2013) developed an occupancy model for Leadbeater's possum based on systematic stratified sampling in 2012 of 180 sites across the Central Highlands, with detection using call playback and thermal imaging cameras. This modelling factored in the impact of the 2009 bushfires and predicted where the species was most likely to occur at the time. It incorporated topographic, climate, fire history and other environmental data, but was unable to include consideration of some of the key habitat requirements (such as hollow-bearing trees and wattle density) as no suitable spatial layers of these features were available. The occupancy model (Fig. 2) suggests that the current 'strongholds' for the species are in the south of the Central Highlands, notably including the Baw Baw Plateau and its southern slopes, the Toorongo Plateau south of the Upper Yarra Catchment, state forest near Powelltown, parts of Toolangi State Forest and southern parts of the Upper Yarra National Park. Based on this model, the total area with at least a 50% probability of occupancy by Leadbeater's possum was 35,764 ha; that with at least a 30% probability of occupancy was 93,825 ha.

Recent surveys are detecting Leadbeater's possums across areas predicted by the occupancy model with a higher detection rate in areas predicted to have a greater than 30% probability of occupancy compared to those with less than 30% (Nelson *et al.* 2015). Preliminary testing of the model suggests that it does not show clear differentiation above 30% occupancy, and this will be tested further in the coming years (Nelson *et al.* 2015).

Based on habitat assessment and long term habitat monitoring, Lindenmayer and colleagues have assessed the extent of montane ash forest, and then the extent of that forest that contained 'potentially suitable habitat' for Leadbeater's possum, with that suitability based on the density of hollow-bearing trees and the prevalence (basal area) of wattle understorey. As so defined, they reported that the extent of montane ash forest in the Central Highlands was 171,200 ha in 1987, of which only 6.7% (i.e. 11,470 ha) was predicted to support 'potentially suitable habitat' for Leadbeater's possum (Lindenmayer 1989; Lindenmayer *et al.* 2015a). Subsequently, much of this habitat has been lost to bushfire, stag collapse and timber harvesting. Using comparable modelling to their assessment of the extent in 1987, they concluded that the area of 'potentially suitable habitat' for Leadbeater's possum had decreased by 2015 to only 1.3% of the montane ash forest (i.e. 2225 ha) (Lindenmayer *et al.* 2015a; Lindenmayer *et al.* 2015b; Threatened Species Scientific Committee 2015).

Clearly, there is a difference of more than an order of magnitude between the current distribution predicted by the Lumsden *et al.* (2013) occupancy model, and that of 'suitable habitat' derived by Lindenmayer and colleagues. Some variation is to be expected based on different sets of assumptions, habitat mapping and other characteristics – for example, the Lindenmayer estimates do not include the area of suitable snow gum woodland habitat which the Lumsden *et al.* (2013) model includes. In addition, the Lindenmayer models may incorporate the likelihood of long-term persistence, rather than simply current occurrence, at a site.

The Threatened Species Scientific Committee (2015) considered that the current area of occupancy was within the range of 1000 to 50,000 ha. Based on IUCN guidelines (IUCN Standards and Petitions Subcommittee 2013) – tallying the number of 2 km x 2 km cells with recent records, and multiplying that tally by four – Woinarski *et al.* (2014) calculated area of occupancy as 28,400 ha, but this estimate included records prior to the 2009 fire, and did not include new records collected since 2012. Recalculating these figures factoring in all recent records and excluding records from the 2009 bushfire area that were recorded prior to the fire, the calculated area of occupancy at December 2015 was 46,400 ha (DELWP unpublished data).

Implications for conservation management:

- Given the current state and prognosis of Leadbeater's possum, all sites at which the species has recently been recorded are important and merit protection; as do all sites at which there is a reasonable likelihood of its occurrence as indicated by occupancy and PVA modelling.

Priority research needs to enhance management:

- Precision in local and regional scale conservation planning will be enhanced with evidence from additional distributional surveys and analysis to further improve the refinement, resolution, complementarity and testing of occupancy and other distributional modelling, including finer-scale mapping of some key habitat attributes (such as large hollow-bearing trees and understory density).

3.2.3. Tenure and land use of the current distribution

The tenure and allocated land-use across the suitable habitat and distributional extent of Leadbeater's possum has been assessed variably, with differences relating to interpretation of suitable habitat and the possum's distribution, and ongoing iterations in the number and total extent of sites protected from timber harvesting.

Almost all of the known distribution of Leadbeater's possum is on public land, managed as state forest or as conservation reserves. Some of the largest reserved areas in this range also serve as closed water catchments.

Of the just over 200,000 ha of 'potential habitat' (montane ash forest and snow gum woodland) within the range of Leadbeater's possum, Leadbeater's Possum Advisory Group (2014b) reported that 34% was in dedicated conservation reserves, 31% was available for timber harvesting and the rest in state forests with some prescribed protective measures through informal reserves (Special Protection Zones) or prescriptions (Table 1).

Table 1. Tenure of lands in 'potential habitat' of Leadbeater's possum, as defined by Leadbeater's Possum Advisory Group (2014b).

Land use	Area (ha)	% of total area
Dedicated reserves (national parks and other permanent formal reserves)	69,200	34
Informal reserves (Special Protection Zones – reserves in state forests managed for environmental protection)	29,300	14
Values protected by prescriptions (state forest available for timber harvesting but excluded from harvesting due to biodiversity, regulatory and operational reasons)	43,300	21
State forest available for timber harvesting and projected to be harvested	62,600	31

The occupancy model likewise concluded that the majority of the predicted distribution is in state forest rather than in conservation reserves (Table 2) (Lumsden *et al.* 2013), in line with this representing the largest component of the area (i.e. 66% of the potential habitat). At >50% likelihood of occupancy, 22% of the 69,200 ha of national parks and conservation reserves in the Central Highlands are predicted to be currently occupied by Leadbeater's possum, and 47% at the >30% level. Within state forest, 15% and 45% of the 135,200 ha is predicted to be occupied at the >50% and > 30% level respectively: i.e. this model indicates that a higher proportion of potential habitat in national parks is occupied than in state forest.

Table 2. Tenure of lands in modelled distribution of Leadbeater's possum, as defined by Lumsden *et al.* (2013).

Land use	Area (ha) with >50% likelihood of occupancy (%)	Area (ha) with >30% likelihood of occupancy (%)
Dedicated reserves (national parks and other permanent formal reserves)	15,243 (42.6%)	32,582 (34.9%)
State forest (all management zones)	20,521 (57.4%)	61,243 (65.1%)
Total	35,764	93,285

A specific ‘Leadbeater's Possum reserve system’ was established in 2008, based on a tenure-blind assessment of ‘high quality’ habitat (predominantly old-growth ash forest) for Leadbeater’s possum. This reserve system mostly (58%) incorporated parts of existing National Parks and other reserves, but also included state forest sites with existing protection measures (Special Protection Zones) (27%), and then added a further ca. 3,000 ha of state forest lands that were not previously specially protected. The total area of the ‘Leadbeater’s Possum reserve system’ is 30,500 ha, comprising 127 habitat patches, all larger than 50 ha (Smith and Morey 2001).

In a recent population and extinction risk model, Lumsden *et al.* (2013) evaluated the historic and projected population trends for Leadbeater's possum. The modelling was focused on the ‘Leadbeater's Possum reserve system’, and more broadly throughout the Central Highlands. They concluded that

> “… even without further disturbance such as future wildfires and an accelerated loss of hollow-bearing trees, the Leadbeater’s possum reserve system does not provide the requisite minimum population requirements. The population is highly sensitive to an accelerated loss of hollow-bearing trees and future wildfires. The analysis predicts that the population of Leadbeater’s possum within the reserve system has a high likelihood of being at a very low population size which imposes on the species a greater risk of extinction” (Lumsden *et al.* 2013) [p. 23].

Even when all parks and reserves within the species range were incorporated into the model, this area was insufficient to ensure the long-term persistence of the species under scenarios incorporating future fires, and additional dedicated reserves, informal reserves and values protected by prescription would be required to reduce the risk of extinction (Lumsden *et al.* 2013).

Implications for conservation management:

- The current reserve system alone is insufficient and inadequate to maintain Leadbeater’s possum, and the species’ recovery will require a substantial increase in the extent of dedicated and informal reserves, plus enhanced management in the remaining areas.

Priority research needs to enhance management:

- Updated population viability and distributional modelling should be undertaken to assess the extent of reserved area required to significantly reduce the risk of extinction of Leadbeater’s possum over the next 100 year period, and (using reserve design principles to maximise outcomes) to identify the most important areas required, or best options, for such reserve expansion.

3.2.4. Recent decline in distribution

Surveys have demonstrated that Leadbeater’s possums have failed to persist in almost all areas burnt in the 2009 bushfire (Lindenmayer *et al.* 2013c; Lumsden *et al.* 2013). That fire burnt extensive areas across much of the distribution of the species, including 34% of the extent of montane ash forest and sub-alpine (snow gum) woodland potential habitat and

45% of the Leadbeater's possum reserve system (Leadbeater's Possum Advisory Group (2014b).

But habitat loss is not only sudden and episodic – there is also ongoing more gradual decline (as indicated in Figure 1). Based on assessments of decline in the abundance of hollow-bearing trees and suitable habitat (Lindenmayer *et al.* 2015b), the Threatened Species Scientific Committee described an ongoing decline in the extent and quality of suitable habitat based on the collapse of large hollow-bearing trees, fire and timber harvesting, with such decline causing an estimated decrease of 81-83% in population size of Leadbeater's possum, over the preceding and future 18 year (i.e. three possum generation) period (Threatened Species Scientific Committee 2015).

3.2.5. Future range

Regardless of habitat loss due to fire or other disturbance, bioclimatic modelling incorporating projected climate change predicts considerable ongoing diminution of the range of the Leadbeater's possum (Lindenmayer *et al.* 1991d) and of its principal habitat, montane ash forest (Burns *et al.* 2015), and the likely increase in fire severity and frequency.

3.2.6. Survey techniques and effort

Conservation planning and management will be most effective when there is a high degree of confidence in known and prospective distribution. For much of its known history, Leadbeater's possum has been an elusive species, largely undetectable using standard mammal survey techniques (such as trapping, spotlighting, hair tubes or predator scats). However, over recent decades, there has been substantial investigation of, and refinement in, targeted survey techniques, now allowing for far more rapid and comprehensive sampling, although all sampling procedures have some interpretational and other constraints.

The long-established sampling and monitoring method is 'stag-watching', which involves a set of observers positioned under large hollow-bearing trees on dusk to observe possums emerging from tree hollows (Seebeck *et al.* 1983; Smith *et al.* 1989). It is a generally reliable, but time- and labour-intensive method, and may be affected by observer experience, density of hollow-bearing trees and height at which animals are emerging (Lindenmayer 2009). However, it is the most appropriate method for determining the number of individuals on a site.

More recently, some surveys have successfully used call playbacks or imitations to lure the possums towards observers, with detection in dense vegetation further improved by the use of thermal cameras (Lumsden *et al.* 2013; Harley 2015b). There may be some caveats with interpretations of results from this method including uncertainty about the distance that responding possums may move to the playback and variability in response rates relating to wind or rain, and to habituation (Lindenmayer *et al.* 2014a), or seasonal or site-specific variation.

Recent studies – in montane ash forests, sub-alpine (snow gum) woodlands and lowland swamp forests – have demonstrated that fixed remote (motion-sensing) cameras, directed at bait stations, can be another cost-effective and efficient survey tool for determining occupancy at a site (Harley *et al.* 2014).

The establishment and regular checking of nest boxes has also progressed recently as a survey and monitoring tool, with particular applicability in sub-alpine woodland and lowland swamp forest habitats (Harley 2006; Harley *et al.* 2014), and with varying success in montane ash forests (Lindenmayer *et al.* 2009; Harley 2016).

There have been substantial recent targeted surveys for Leadbeater's possum, as part of implementing the Leadbeater's Possum Advisory Group recommendations, to facilitate establishing timber harvesting exclusion zones around known colonies. This effort includes targeted surveys by DELWP (Nelson *et al.* 2015), and additional records from other organisations and the community. As a result of this combined intensive and extensive survey effort, the number of sites with confirmed records for this species is increasing. This increased number of records is useful for protection of known colonies, and for refinement of predictive distributional modelling and for population estimation. This increasing number of records reflects the increased and more effective sampling effort but it is unclear if they indicate that the species is more widespread and numerous, and hence more secure, than previously recognised. In addition, the long term viability of colonies of possums reported at many of these newly recorded sites is unknown.

DELWP's targeted surveys were initially planned to occur over a 5 year period but have been accelerated to complete this work within 3 years, with the survey program due for completion by mid-2017. In addition, pre-harvest surveys will be undertaken by VicForests, which commenced in late 2015, using a risk based approach to sample proposed coupes with the greatest likelihood of the species being present.

The Victorian Government has recently developed 'The Leadbeater's Possum Interactive Map' (http://lbp.cerdi.edu.au/possum_map.php) – a resource that provides public access to up-to-date information, including confirmed colonies and the resulting timber harvesting exclusion zones; areas where there is a modelled probability of occupancy by Leadbeater's possum; and sites where DELWP has undertaken targeted surveys. Survey standards have also been developed which outline the various survey techniques and provide guidance on the evidence required to confirm presence of the species at a location and the amount of survey effort required to infer absence (Department of Environment Land Water and Planning 2015b).

3.3. Population size

3.3.1. Estimates of current population size

There is no precise and robust estimate of the total population size for Leadbeater's possum. An exception is for the very small and disjunct subpopulation at Yellingbo, where censuses of all individuals have been undertaken over recent years – its population in 2015 was fewer than 50 individuals (Harley 2015a).

The Threatened Species Scientific Committee (2015) collated relevant recent assessments of population size, noting that all estimates were based on a set of (sometimes different) assumptions relating to distributional extent, area of suitable habitat, density and social group size. These estimates are summarised in Table 3. The inconsistency in these population estimates (and the wide confidence limits, where available) is unsurprising given that projection of estimates is based on sampling within only a small proportion of the potential range, because different estimates use different areas of suitable habitat, because of increasing knowledge and because there may be substantial variation in size of colonies.

Given the inconsistency in their assumptions and knowledge base, variation among these estimates should not be used to infer trends or rates of population decline (or increase).

Table 3. Estimates of population size for Leadbeater's possum.

Source	**Estimated total population**	**Notes**
Smith *et al.* (1985)	7500 ± 2300	Estimate prior to 2009 bushfires; does not include then-undiscovered snow gum woodland or lowland swamp forest subpopulations
Lindenmayer (1996a)	4000	Estimate prior to 2009 bushfires; does not include then-undiscovered snow gum woodland or lowland swamp forest subpopulations
Menkhorst (2008)	2200	Estimate prior to 2009 bushfires; this estimate includes an estimated 200 individuals in the lowland swamp forest subpopulation
Woinarski *et al.* (2014)	(1100)	Estimate subsequent to 2009 bushfires; *estimate for mature individuals only*; includes snow gum woodland and lowland swamp forest subpopulations
Leadbeater's Possum Advisory Group (2014a, 2014b)	3945-10,960	Estimate subsequent to 2009 bushfires; includes snow gum woodland subpopulations
Lindenmayer et al. *pers. comm.* to Threatened Species Scientific Committee (2015)	3125	Estimate subsequent to 2009 bushfires; interpreted here to be for montane ash forest only

Note that all but one of the estimates given in Table 3 relate to total number of individuals. However, the most relevant parameter used in conservation status assessments is the number of mature breeding adults (IUCN Standards and Petitions Subcommittee 2013). This number will be less than the total population size because of the colonial social system of Leadbeater's possum (where only one reproductively active male and female are present in colonies, regardless of the number of individuals in the colony), and because the total population size includes immature individuals.

It is useful to attempt to derive an accurate estimate of population size, in order to better resolve population viability modelling and assessment of conservation status but, to a large extent, the actual population size is a less important conservation management parameter than the population trend, in particular the current and projected rate of population decline.

Priority research needs to enhance management:

Further investigations should be undertaken to provide a robust and reliable estimate of current total population size.

3.3.2. Rates of current and projected population decline

Population trends are largely influenced by changes in the extent, quality and connectivity of suitable habitat, and such changes are considered in more detail in the **Habitat** section below.

Population trends have been described based on population monitoring at some sites, and – more broadly – on population projections based on models of the variation over time in the extent of suitable habitat.

Over the decade up to 2015, regular monitoring of the population at Yellingbo has demonstrated a monotonic decline, with total decline over this period of 62% (Harley 2015a). Given this trend, and its small size, this subpopulation is now at extremely high risk of local extinction.

Population counts were made at several sub-alpine woodland sites prior to the 2009 bushfires, and repeated after those fires. For the Lake Mountain area, an estimated population of 200-300 individuals, based on survey results prior to the fire, was reduced to just six individuals following the bushfire (Harley 2016).

There has been some reporting of changes in the abundance or incidence of Leadbeater's possum from the ongoing and substantial monitoring program established in 1983 for the montane ash forests, but no published overall assessment over the course of that monitoring program to date. Previous analyses of the data indicated an apparent decline of Leadbeater's possum at monitoring sites over the period 1987 to 2001 (Lindenmayer *et al.* 2003), but no significant trend in abundance over the period 1997 to 2007 (Lindenmayer *et al.* 2011b; Lindenmayer *et al.* 2014b). The apparent stability over the latter period may be due to this coinciding with a period of relatively low loss of hollow-bearing trees (14% during this time) (Lindenmayer *et al.* 2011b). Subsequently, there was a marked loss of possums at sites burnt by the 2009 bushfires (Lindenmayer *et al.* 2013c).

Past and future population trends in the Leadbeater's possum reserve system and more broadly across the Central Highlands region have been modelled based on the disturbance-mediated changing extent in the area of suitable habitat (Lumsden *et al.* 2013; Leadbeater's Possum Advisory Group 2014b). These models (e.g. Figure 1 which relate specifically to the reserve system but are probably largely generalisable throughout the distribution) describe the historic population collapse due to the loss of habitat in the extensive 1939 bushfire; the population recovery in the next few decades as mid-storey and eucalypt cover recovered rapidly following fire and the burnt area retained abundant stags (large hollow-bearing trees killed by the fire but remaining standing); then ongoing and continuing decline as stags collapsed and some suitable habitat was logged; further catastrophic population collapse in the area burnt by the 2009 bushfire; and a future of ongoing population decline for at least another 50-60 years due mostly to declining hollow availability and wattle senescence; with possible population increase thereafter as hollow availability (and suitable habitat) again increases. Broadly, this population model is comparable to previous models that predicted marked ongoing population decline, a severe population 'bottle-neck' due to declining extent of suitable habitat, and hence increasing likelihood of extinction for Leadbeater's possum (Lindenmayer *et al.* 1993a; Possingham *et al.* 1993; Lindenmayer and Lacy 1995a; Lindenmayer and Possingham 1995a; McCarthy and Lindenmayer 2000; Lindenmayer and McCarthy 2006).

Note that modelled scenarios (such as Figure 1b) that (realistically) include some future disturbance events result in projections of far smaller population size, and hence substantial increase in the likelihood of extinction, than scenarios without such disturbance (Figure 1a) (Lumsden *et al.* 2013). In addition, the existing models do not consider a range of factors that magnify impacts on declining populations with reducing habitat availability, such as the impacts of increased habitat fragmentation, reduction in genetic heterogeneity because of reduced gene flow and smaller population size, potential increased inter-specific competition for the regionally diminishing number of hollows, and climate change.

Results from all available population (and habitat) monitoring and modelling were interpreted by Threatened Species Scientific Committee (2015) to infer a population decline of more than 80% over the preceding three possum generations (18 years) and to project a further decline in the population size of more than 80% over the next three generations.

3.3.3. Subpopulation structure and genetic variation

Leadbeater's possum comprises two distinct genetic groups, with marked and long-standing distinction in genetic composition between the small lowland subpopulation and all other (montane ash forest and sub-alpine (snow gum) woodland) subpopulations (Hansen *et al.* 2005; Hansen and Taylor 2008). The former is considered an 'evolutionarily significant unit' (ESU) as it is the last surviving remnant (relict) of an otherwise extinct genetic unit, that has historically been, and remains, isolated from others (Hansen and Taylor 2008). It is now inbred (Hansen *et al.* 2009), and will require careful management to retain even its limited levels of genetic heterogeneity.

Subpopulation structuring is not well resolved in the Central Highlands due to the small number of animals that have been genetically sampled. In this area, it is 'remarkably genetically diverse', with evidence of ongoing gene flow (indicating effective dispersal) across much of this range, although with some contrary evidence of recent disruption of gene flow for some sites (e.g. Powelltown), probably due to historic and ongoing habitat fragmentation (Hansen *et al.* 2009). Sub-structuring has also been reported within the Yellingbo subpopulation, indicating that this can occur over small spatial scales and that the species may be highly sensitive to habitat fragmentation (Hansen *et al.* 2009).

Small and isolated subpopulations may be particularly at risk from genetic, stochastic and other factors: for example, even a relatively small bushfire may destroy all habitat in the Yellingbo area (Harley 2015a). Population viability analysis has indicated that discrete subpopulations need to be larger than a threshold of 200 individuals to have at least a 90% chance of persistence over a 100 year period (Lindenmayer and Lacy 1995b; Lindenmayer 2000). It is likely that the distribution of Leadbeater's possum is being increasingly fragmented, with increasingly isolated subpopulations unlikely to maintain such a population viability threshold. For example, the subpopulation at Toolangi is surrounded by areas burnt in the 2009 bushfires and is now likely to be isolated from other subpopulations.

Implications for conservation management:

- As is currently practised (but subject to further risk assessment), the two genetically distinct groups of Leadbeater's possum should be managed separately, with specific objectives and urgent action to retain the lowlands swamp forest ESU. However, given the parlous status of the lowland ESU, there may come a need to enhance its genetic stock.
- Management should seek to actively retain or enhance adequate habitat connectivity within the montane forest habitat through linking reserves and wildlife corridors and artificial connectivity over roads, or if necessary to augment such connectivity through careful translocation.

Priority research needs to enhance management:

- Assess the risks, costs and benefits, and likelihood of success of options for genetic rescue of the Yellingbo ESU, including gene pool mixing between the lowland swamp forest and other subpopulations.

3.3.4. Population monitoring

There are notable current population monitoring programs for Leadbeater's possum in montane ash forest environments, sub-alpine (snow gum) woodlands and lowland swamp forests. The most long-standing of these programs is that undertaken by Lindenmayer and colleagues, based on repeated stag-watching at ca. 160 sites in montane ash forests (Smith *et al.* 1989; Lindenmayer *et al.* 1993b, 1994b; Welsh *et al.* 1996; Lindenmayer *et al.* 1997; Lindenmayer *et al.* 2003; Cunningham and Lindenmayer 2005; Lindenmayer *et al.* 2013c). This monitoring also includes assessments in trends in habitat quality (particularly the abundance of hollow-bearing trees), and of other arboreal possum species. It includes forest sites across a wide range of forest age classes, and includes before-and-after monitoring of sites burnt in the 2009 bushfires. Some progress results have been reported for trends in the abundance of Leadbeater's possum (see section 3.3.2), but more substantial data have been reported to date on marked declining trends in the abundance of hollow-bearing trees, a critical habitat component for Leadbeater's possum (Lindenmayer and Wood 2010; Lindenmayer *et al.* 2012; Lindenmayer *et al.* 2014b).

The much smaller lowland swamp forest subpopulation has been more intensively monitored, mostly with the use of nest boxes and total counts of all individuals, over two decades, with these results also showing a very marked population decline (Harley 2012; Harley 2016).

Population monitoring has also been underway in sub-alpine (snow gum) woodland at Lake Mountain since 2003 and Mt Bullfight since 2010 to monitor local distribution and abundance, post-fire persistence and recolonisation (Harley 2016).

Implications for conservation management:

- Population monitoring has provided a vital contribution to, and measurement of the effectiveness of, management, and existing programs should be retained and expanded including all relevant habitat types and forest ages.

3.4. Habitat

3.4.1. Key habitat features

Broadly, the key habitat features required by Leadbeater's possum are (i) suitable (large) hollows for denning and breeding, at a density that allows for multiple den sites within any single colony home range; (ii) vegetation structure in the form of a sub-canopy or mid-storey layer of more of less continuous or interconnecting foliage cover (to facilitate the possum's foraging and other movement) (Lindenmayer 1996b); and (iii) a floristic composition that includes dominance of smooth-barked eucalypts (especially of species with some loose or decorticating bark that provides shelter for invertebrate prey) (Lindenmayer 1996b; Harley 2004a; Harley 2004c, 2004b), often with an understorey of gum-producing *Acacia* species (Smith *et al.* 1985; Smith and Lindenmayer 1988; Lindenmayer *et al.* 1991b). Additionally, Leadbeater's possums construct a large nest (inside hollows) made mostly out of shredded fibrous bark of some eucalypt and other trees, and the occurrence of trees with such fibrous bark in the home range is also required (Smith and Lindenmayer 1988; Harley 2004b).

Given the long period required to form suitable and sufficiently abundant hollows, the first of these three critical habitat features is closely associated with tree age and size. Hollows used typically have large internal dimensions (ca. 30 cm diameter) (Smith and Lindenmayer 1988). These occur almost exclusively in large old trees (Lindenmayer *et al.* 2013b; Lindenmayer *et al.* 2013c), with Leadbeater's possum typically selecting hollow-bearing trees that are 190-450 years old (Smith and Lindenmayer 1988; Lindenmayer *et al.* 2015a). In contrast, the dense understorey preferred by Leadbeater's possum often occurs in young regenerating forests and optimal habitat occurs in multi-aged forest where the large trees, dead or live, provide hollows and regenerating vegetation provides food and movement pathways (Lindenmayer *et al.* 1990b).

Habitat suitability and occupancy is also influenced by broader spatial landscape context, around individual nest trees (Lindenmayer *et al.* 1990a) and around a forest site. Minimum habitat size is about 12 ha (Threatened Species Scientific Committee 2015), but the likelihood of persistence of Leadbeater's possum in any habitat patch increases substantially with increasing patch area (McCarthy and Lindenmayer 2000; Lindenmayer and McCarthy 2006). At least in montane habitat, there is little use of narrow habitat strips through recently harvested areas (Lindenmayer *et al.* 1993b). A recent (2012) sampling of 37 isolated unburnt mountain ash forest patches (potential refuges, surrounded by recently burnt areas) found Leadbeater's possums in six of these sites (16%), with the smallest occupied patch being 10 ha (Lumsden *et al.* 2013), and small numbers of individuals have persisted in unburnt linear refuges of sub-alpine woodland at Lake Mountain and Mt Bullfight (D. Harley and J. Antrobus *pers. comm.*). Given that these patches have been isolated only since the 2009 fires, it is not known whether colonies will persist and maintain normal demographic processes in these areas, or be able to use them ultimately to recolonise adjacent areas that are currently unsuitable. Furthermore, sampling following the 2009 bushfires found that Leadbeater's possum were significantly less abundant in unburnt sites where fire had approached within 500-1000 m (in comparison to unburnt areas without such proximity to recently burnt areas), suggesting that the detrimental impacts of fire are higher than simply the proportion of the landscape that has been burnt (Lindenmayer *et al.* 2013c).

Most of the core habitat factor requirements are consistent across the three broad habitat types in which the species occurs: montane ash forest (comprising about 96% of suitable habitat), sub-alpine (snow gum) woodland (about 4%) and lowland swamp forest (less than 1%) (Department of Environment and Primary Industries 2014a).

However, there are additional specific factors characteristic of each of these habitat types, as described below.

Implications for conservation management:

- The extent, quality and connectivity of suitable habitat is the critical factor for conservation of Leadbeater's possum, and conservation management actions should focus primarily on factors and actions that serve to increase (or most effectively reduce the rate of decline in) the current and prospective habitat extent, quality and connectivity.

3.4.2. Montane ash forest habitat

The vast majority of the Leadbeater's possum population occurs in montane ash forest, dominated by mountain ash *Eucalyptus regnans*, alpine ash *E. delegatensis* and/or shining gum *E. nitens*, at altitudes from 400 to 1,200 m above sea level (Lindenmayer 1989; Lindenmayer *et al.* 1989). In montane ash forest, Leadbeater's possum occurs at highest densities in multi-aged forest containing several age classes of eucalypts, including live and dead hollow-bearing trees, together with a dense understorey of wattles (notably *Acacia dealbata*, *A. obliquinervia*, *A. melanoxylon* and/or *A. frigescens*) (Lindenmayer *et al.* 1990a; Lindenmayer *et al.* 1991b; Smith and Lindenmayer 1992; Lindenmayer *et al.* 1994b). They also regularly occur in patches of rainforest or montane riparian thickets along gullies embedded within montane ash forests (D. Harley *pers. comm.*; DELWP unpublished data).

In these tall forests, the occurrence and density of Leadbeater's possum is associated with hollow availability. Regression models have shown that there is a significant correlation between the incidence and abundance of Leadbeater's possum and the density of hollow-bearing trees on a site (Lindenmayer *et al.* 1991b; Lindenmayer *et al.* 1994b), although this relationship is less pronounced in reporting of results from recent years (Lindenmayer *et al.* 2011b; Lindenmayer *et al.* 2014b). The absence or low abundance of resident Leadbeater's possums on sites with few potential nest trees is thought to be due mostly to competition for hollows from other species and a requirement by individual colonies of Leadbeater's possum to use more than one den tree (Smith and Lindenmayer 1988; Lindenmayer and Meggs 1996). However, the species may show some flexibility in its selection of nesting sites where there are low numbers of hollow-bearing trees (Lindenmayer *et al.* 2011b).

In the montane ash forests, the abundance of suitable nest trees is tightly correlated with disturbance history (Lindenmayer *et al.* 1990b; Lindenmayer *et al.* 1990c; Lindenmayer *et al.* 1991a; Smith and Lindenmayer 1992). For the dominant mountain ash trees, hollow formation does not start until the trees are about 120 years old, and the hollows with large internal cavities that are preferred by Leadbeater's possum typically do not form until the trees reach 190-220 years old (Smith and Lindenmayer 1988; Lindenmayer *et al.* 1991c).

Peak densities of Leadbeater's possum occur in regrowth forests (15-50 years after bushfire), in which stags supply abundant tree hollows, and there is a high biomass of wattles (20–50% of stand basal area) (Smith and Lindenmayer 1988; Lindenmayer *et al.* 1990a; Lindenmayer *et al.* 1991b; Lindenmayer *et al.* 2000).

Dense regrowth forming at least 15 years after timber harvesting can also provide foraging habitat if there are nesting sites within the regrowth or in adjacent areas (Smith *et al.* 1985; Nelson *et al.* 2015).

In the post-fire (bushfire or regeneration burns after harvesting) successional cycle, the biomass of wattles increases, peaks and then declines as they senesce and die (typically 60-100 years after disturbance), and stags gradually collapse (Lindenmayer *et al.* 2012). Habitat may then be of diminishing suitability to provide for all Leadbeater's possum habitat requirements, until the regrowth cohort of eucalypts becomes old enough to form suitable hollows for Leadbeater's possum (i.e. >190 years).

Bushfire is a key driver of habitat suitability in montane ash forests (and in other habitats used by Leadbeater's possum). In montane ash forest, eucalypt trees may live for several hundred years and increase their hollow availability over this lifespan, however this forest dynamic may be markedly changed by frequent, high intensity and extensive fires. Recent estimates indicate that the extent of mountain ash forest that is 'old-growth' has declined from an estimated minimum of 30% (47,000 ha) at the time of European settlement to ca. 1% (1700 ha) now, with the current extent mostly in very small fragments (Lindenmayer *et al.* 2014a; Burns *et al.* 2015; Lindenmayer *et al.* 2015a). The extent of old-growth in alpine ash forests is even less (0.37% of its extent) (Lindenmayer *et al.* 2014a).

The likelihood that Leadbeater's possums are retained in a context of more frequent bushfire will be dependent upon the age of the forest when burnt, with burnt older forests (i.e. old enough to have trees with hollows) providing better habitat than burnt younger forest. The future relative availability of habitat suitable for Leadbeater's possum will also depend upon the extent to which (inevitable) bushfires leave some unburnt patches (which will be contingent in part on fire severity), the capability and intent of fire management strategies and actions, deliberate management to retain as much mixed-age forest as possible, and the extent of natural or assisted dispersal of Leadbeater's possum across the landscape.

Fire impacts may be exacerbated where salvage logging (the harvesting of fire-impacted trees following bushfire) is practised, as this results in further losses of the critical resource of large hollows (Lindenmayer and Ough 2006; Likens and Lindenmayer 2012; Lindenmayer *et al.* 2012; Lindenmayer and Laurance 2012; Lindenmayer *et al.* 2015a; Lindenmayer *et al.* 2015b).

Furthermore, timber harvesting may affect subsequent fire intensity – younger (post-harvesting) regrowth ash may fuel higher intensity and hence more destructive crown fires, thereby compounding the regional-level and long-term decline in hollow availability. The evidence for this relationship relies largely on assessments of the behaviour of the 2009 bushfire, and the interpretation of this evidence is contested (Lindenmayer *et al.* 2013c; Attiwill *et al.* 2014; Bradstock and Price 2014; Taylor *et al.* 2014).

Habitat suitability and successional pathways differ following bushfire and timber harvesting, most notably with the former typically leaving large dead trees that may contain hollows, and subsequently a more diverse range of tree ages and sizes. In contrast, timber harvesting using clear-felling typically leaves a simpler regenerating forest structure with fewer available hollows (Lindenmayer *et al.* 1990c; Lindenmayer and McCarthy 2002). Typically, such timber harvesting renders the habitat unsuitable for nesting by Leadbeater's possum for at least 150 years (Lindenmayer 2009; Lindenmayer and Possingham 2013), although regenerating forests may provide foraging habitat within 15-30 years if suitable nesting sites are available (on site or nearby). Furthermore, the overall site- and regional-level reduction in hollow availability due to timber harvesting is exacerbated by rotation times that are shorter than the time taken for large hollows to form in regrowth trees (Ball *et al.* 1999; Lindenmayer *et al.* 2015b).

Some harvesting practices are likely to result in detrimental impacts on adjacent unharvested habitat (e.g. retained strips surrounded by recently harvested areas are unlikely to be used by Leadbeater's possum), such that the total area affected is larger than the actual area harvested (Lindenmayer and Laurance 2012; Lindenmayer *et al.* 2015a; Lindenmayer *et al.* 2015b).

The detrimental impacts of timber harvesting on current and prospective habitat suitability for Leadbeater's possum can be reduced to some extent through changes in harvesting practices, notably replacement of clear-felling with 'aggregated retention' or 'variable retention' harvesting (that maintains some mixed age structure in logging coupes: Baker and Read (2011); Neyland *et al.* (2012)), and the use of cooler post-harvesting fires and less reliance on artificial seeding (Lindenmayer and Franklin 1997; Lindenmayer *et al.* 2013b). These harvesting approaches are currently being undertaken in approximately 50% of the area of ash harvested, through implementation of the Leadbeater's Possum Advisory Group recommendations (Leadbeater's Possum Advisory Group 2014a).

Habitat suitability at any site is typically related to the co-occurrence at that site of sufficient hollows (for nesting) and adequate understorey cover (for movements and feeding), but some recent results suggest that these attributes do not necessarily have to co-occur at the site itself – Leadbeater's possums can occur in an area in which there is a close juxtaposition of habitat that provides nesting hollows but not suitable foraging habitat with habitat that provides suitable foraging habitat but few nesting hollows (Lumsden *et al.* 2013). However, further research is required to understand the extent to which Leadbeater's possum can use such spatial variation, and the implications of using separate foraging and nesting area.

Habitat suitability is also related to some topographic and climate features, with highest incidence of Leadbeater's possum in forests on east and south facing slopes (Lindenmayer *et al.* 1990a; Lindenmayer *et al.* 1993c). In a separate habitat modelling study, those montane ash forests considered most likely to be currently occupied by Leadbeater's possums were characterised by lush, unburnt vegetation in gullies, located in areas that have relatively low summer temperatures and high summer rainfall (Lumsden *et al.* 2013).

3.4.3. Decline in habitat extent, suitability and connectivity: montane ash forest

The extent, quality and connectivity of Leadbeater's possum habitat in montane ash forest is undergoing severe ongoing decline. This is a consequence of changing fire regimes, habitat loss due to timber harvesting, and ongoing habitat fragmentation. The extensive 1939 bushfire burnt about 85% of mountain ash forests in the Central Highlands (Burns *et al.* 2015), but left a landscape legacy of standing dead large hollow-bearing trees that formed suitable denning sites for Leadbeater's possum. However, the abundance of these large hollow-bearing trees has declined substantially, partly due to extensive salvage logging, subsequent bushfires and the natural decay and collapse of the remaining stags and other large old trees (Lindenmayer and Ough 2006).

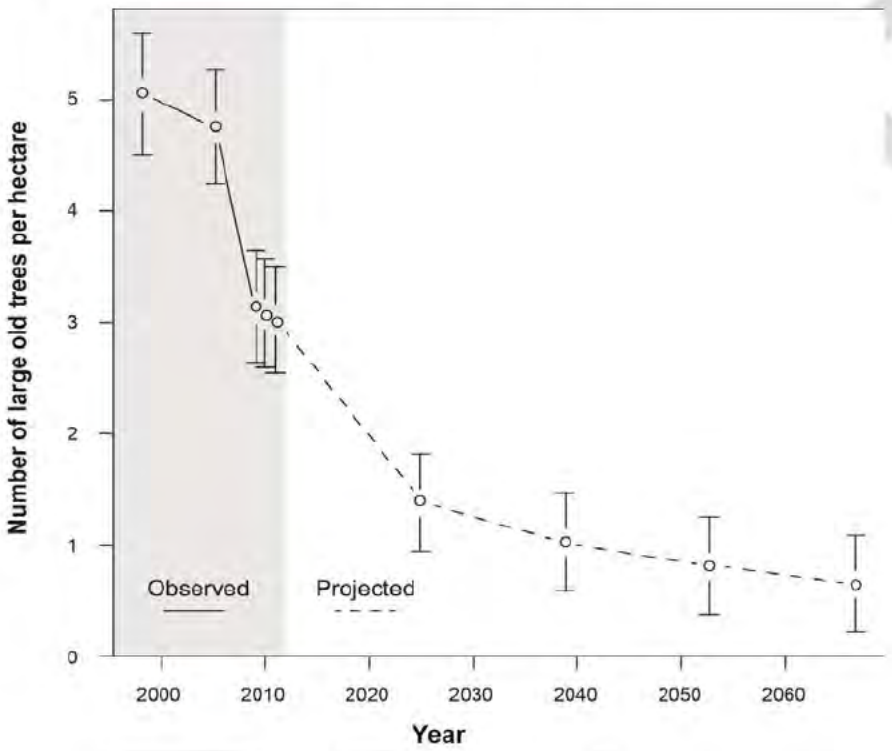


Figure 3. Observed and projected changes in the average density of large hollow-bearing trees in mountain ash forests in the Central Highlands, from Lindenmayer *et al.* (2013b). Figure 3 reproduced with permission from David Lindenmayer.

The persistence of large hollow-bearing trees has been monitored at numerous sites, with this monitoring showing a rapid decline in their abundance across the set of monitored sites (Lindenmayer 1996b; Lindenmayer *et al.* 1997; Lindenmayer 2009; Lindenmayer and Wood 2010; Lindenmayer *et al.* 2011b; Lindenmayer *et al.* 2012; Lindenmayer *et al.* 2015a), with annual rates of collapse of 4.4% of large-hollow bearing trees reported for the period 1983 to 1993 (Lindenmayer *et al.* 1997), and 1.8% for the period 1997 to 2006 (Lindenmayer *et al.* 2011b). Modelling of the rate of decay predicted that most stags (those large trees killed in the 1939 bushfire) will have disappeared within 50 years, leaving a severe future shortage of trees containing suitable hollows for wildlife, with this bottleneck lasting until at least 2075. The observed and projected rate of decline in the density of large hollow-bearing trees in the Central Highlands is illustrated in Figure 3 (Lindenmayer *et al.* 2013b), however recent assessments have revealed a more rapid decline than previously predicted, with 50% of stags collapsing between 1997 and 2015 (D. Lindenmayer *pers. comm.*). The projected low density of large old trees may signify detriment more broadly than to Leadbeater's possum alone: a density of less than one hollow-bearing tree per hectare has been suggested to represent ecosystem collapse for the mountain ash forest ecosystem (Burns *et al.* 2015).

The 2009 bushfires have not had comparable effects to those of the 1939 fires, because much of the montane ash forest that was burnt in 2009 was regrowth from the 1939 bushfires or younger forest (and hence contained few live hollow-bearing trees), and furthermore the 2009 bushfires substantially increased rates of loss of stags remaining after the 1939 fires (Lindenmayer *et al.* 2012; Lindenmayer *et al.* 2015a).

Survival of Leadbeater's possum during the projected bottleneck in hollow-bearing trees will depend on protection of refuge habitats, particularly patches of multi-age and old-growth forest, and individual mature and senescent trees, as well as the success of new methods of creation of hollows, translocations or other management actions. Recovery after the bottleneck is expected to depend on the extent of successful fire management and on changes in silvicultural practices (Smith and Lindenmayer 1992).

The marked historic decline in habitat suitability for Leadbeater's possum is also well illustrated in trends in the extent of old-growth forest, and the changing composition of montane ash forest ages. Recent assessments demonstrate that by far the highest proportion of montane ash forest age class now comprises relatively young regrowth (particularly from the 2009 bushfires, but also following timber harvesting in recent decades), whereas very little of the forest is dominated by stands of trees old enough to form hollows suitable for Leadbeater's possum (i.e. trees dating from prior to 1900) (Fig. 4) (Lindenmayer *et al.* 2015b). However, note that some of the forests dominated by younger stands do contain remnant living old trees or dead stags that contain hollows.

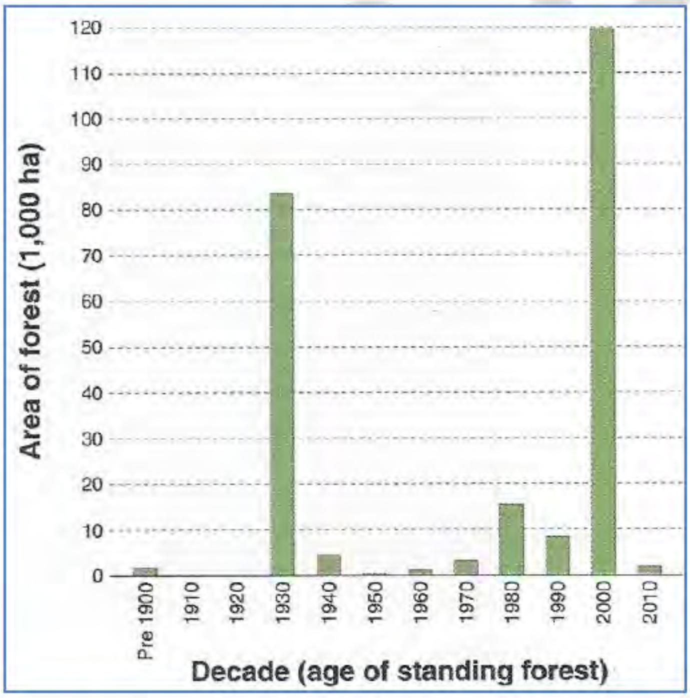


Figure 4. The age class of dominant trees in stands of montane ash forests in the Central Highlands. Decade indicates the date at which the trees germinated. Figure 4 reproduced with permission from '*Mountain Ash: Fire, Logging and the Future of Victoria's Giant Forests"* (by David Lindenmayer, David Blair, Lachlan McBurney and Sam Banks (2015b) and CSIRO Publishing. http://www.publish.csiro.au/pid/7461.htm

Implications for conservation management:

- Management to reduce the likelihood of extensive and severe bushfire will be critical for the long-term persistence of Leadbeater's possum in montane ash forests.
- The 1939 regrowth is, in most areas, the oldest cohort of forest, and hence this age class will be essential for the future restoration of the old growth ash forest estate in the Central Highlands.
- Hollow-bearing trees are scarce and declining in the Central Highlands and will not be naturally replaced for decades. These are therefore a critical resource that requires full protection.
- Although a range of prescriptions are in place to reduce impacts, and new processes (e.g. regrowth retention harvesting) have been introduced, timber harvesting reduces the extent, quality and connectivity of suitable habitat for Leadbeater's possum, and hence increases its risk of extinction. Timber harvesting practices need to continue to adapt to minimise impacts on Leadbeater's possum.

Priority research needs to enhance management:

- Hollow-bearing trees should be mapped across the montane ash forest habitat, using remote sensing techniques (LiDAR and air photograph interpretation) in conjunction with ground truthing. Concurrent mapping of understorey density would provide more complete spatial information to improve distribution models.

3.4.4. Sub-alpine (snow gum) woodlands

Leadbeater's possum is now known from several areas (including the Baw Baw Plateau, Mt Bullfight and Lake Mountain) of sub-alpine woodlands dominated by snow gum *Eucalyptus pauciflora*, particularly where there is a dense mid-storey of mountain tea tree *Leptospermum grandifolium* ('montane riparian thickets') along drainage lines (Jelinek *et al.* 1995; Department of Environment and Primary Industries 2014a; Harley 2016) at altitudes of ca. 1400 m. Within the Central Highlands region, such habitat is relatively restricted, with a total area of ca. 8000 ha, most of which occurs on the Baw Baw plateau (Department of Environment and Primary Industries 2014a).

3.4.5. Decline in habitat extent, suitability and connectivity: sub-alpine snow gum woodlands

The 2009 bushfires markedly affected the extent and quality of sub-alpine woodland habitat at Lake Mountain and Mt Bullfight, and caused the loss of many known colonies. At Lake Mountain, more than 95% of the population known to be present prior to the 2009 bushfires was killed by fire or failed to persist after it (Harley 2016). Post-fire vegetation dynamics are less well known in sub-alpine woodlands than in montane ash forests, but it is likely that it will take several decades for a mid-storey layer of mountain tea tree to regenerate in burnt areas.

Not all areas of snow gum woodland inhabited by Leadbeater's possum were burnt in the 2009 bushfires, with the Baw Baw plateau area notably retaining its suitable habitat and Leadbeater's possum populations.

> *Implications for conservation management*:
>
> - Management to reduce the likelihood of extensive and severe bushfire will be critical for the long-term persistence of Leadbeater's possum in sub-alpine woodlands.

3.4.6. Lowland swamp forest

At Yellingbo the isolated Leadbeater's possum subpopulation occurs in lowland (110 m elevation) habitat that contrasts markedly with the habitat in its main range. In this area, it occurs in riparian and seasonally inundated floodplain environments with forest dominated by mountain swamp gum *Eucalyptus camphora* (with canopy height of 15-25 m) with dense thickets of *Melaleuca* (*M. ericifolia* and *M. squarrosa*) and *Leptospermum* (*L. lanigerum*, *L., scoparium* and *L. continentale*) species (Smales 1994; Harley 2002; Harley 2005; Harley *et al.* 2005; Smith and Harley 2008). The major block of lowland swamp forest at Yellingbo covers an area of ca. 181 ha. However due to habitat degradation less than 20 ha of this currently provides suitable habitat for Leadbeater's possum (Department of Environment and Primary Industries 2014a). In some parts of this small area, suitable and occupied habitat now occurs only in very narrow (<120 m) corridors (Harley *et al.* 2005). Suitable tree hollows may be limiting in this habitat (Harley 2005; Harley *et al.* 2005) but have been compensated for through targeted provisioning of nest boxes (Harley 2004b).

Although there is notable imprecision about the location of the first records of Leadbeater's possum, and most of the habitat around those records is now long cleared, it is likely that the earliest historical records of Leadbeater's possum from the Bass River and Koo-Wee-Rup swamp were also from broadly similar and formerly widespread lowland swamp gum woodlands (dominated by *E. camphora* and/or *E. ovata*) and dense thickets of *Melaleuca* and *Leptospermum* (Harley *et al.* 2005).

3.4.7. Decline in habitat extent, suitability and connectivity: lowland swamp forest

Most of the swamp gum forests in the south-western Gippsland to Healesville region have been cleared, with only very small isolates remaining (McMahon and Franklin 1993; Harley *et al.* 2005).

At Yellingbo, suitable habitat is highly restricted and of declining quality (Turner 2003). About half of the Leadbeater's possum territories are considered to have declining habitat quality and have recently been abandoned by the possums (Harley 2015a). This decline in habitat suitability is due to eucalypt dieback arising from altered hydrology, habitat succession towards an older age-class that is more open in structure, and a lack of eucalypt regeneration (Harley 2015a).

A revegetation project to attempt to halt and reverse this decline in habitat quality and extent has been underway for about a decade (Harley 2015a), with potential to more than double the (currently very limited) area of suitable habitat (Harley *et al.* 2005).

A key risk-spreading strategy to contend with the risk of fire affecting the entire lowland population is to identify suitable lowland release localities beyond Yellingbo where populations could be established through the translocation of captive-bred young (Harley 2016).

Implications for conservation management:

- The current and projected status of the lowland subpopulation of Leadbeater's possum is parlous, and this subpopulation is unlikely to persist without significant ongoing management actions.
- Management to reduce the likelihood of severe bushfire will be critical for the long-term persistence of Leadbeater's possum in lowland swamp forests.
- The extent and connectivity of suitable habitat should be enhanced through revegetation and ongoing use of nest boxes.
- Captive breeding and translocations to comparable suitable habitat in Yellingbo and nearby areas will be required as insurance, with care in taking individuals from the current wild population that such take does not significantly jeopardise the viability of that existing wild population.

3.4.8. Habitat augmentation

In response to the historic, current and projected decline in the extent and quality of habitat across Leadbeater's possum's range, there has been some applied research aimed at augmenting habitat quality.

Nest box provision can provide benefits at localised scale at sites with suitable foraging habitat and vegetation structure but a lack of natural hollows and may be able to increase the likelihood of colonies persisting at such sites. Nest boxes may also be useful during translocations, and at some post-disturbance successional stages.

There have been variable responses of Leadbeater's possum to the provision of nest boxes. The species has made extensive use of nest boxes in lowland swamp forest at Yellingbo, with more than 75% of the total possum population there making regular use of nest boxes for denning (Harley and Spring 2003; Harley 2004b, 2006). High occupancy rates for nest boxes have also occurred in sub-alpine (snow gum) woodland, where Leadbeater's possums have constructed nests in 72 of 119 nest boxes (60%) installed in unburnt habitat (Harley 2016).

In contrast, historically there has been less uptake of nest boxes in montane ash forests, and it has been argued that nest boxes are unlikely to provide a significant boost to habitat quality due to the limited longevity of nest-boxes (Morton *et al.* 2009), and the impracticality of their application over large areas (Lindenmayer *et al.* 1991e; McKenney and Lindenmayer 1994). However, recent improvements in design have increased nest box longevity, and some studies have shown an increased use of nest boxes by Leadbeater's possums in montane ash forests (Harley 2016). In contrast to sub-alpine (snow gum) woodlands and lowland swamp forests, the vegetation structure in montane ash forest makes it more difficult to position nest boxes at heights (of at least 15 m) matching movement pathways for the possum (Harley 2006). Of 155 nest boxes being monitored in montane ash forest as part of 'Project Possum', 32 (21%) currently (as at December 2015) show signs of use by Leadbeater's possum (with typical evidence being distinctive nesting material) (Harley 2016).

As the abundance of suitable natural hollows will decline further in coming decades, other alternative approaches are being investigated to provide nesting sites to supplement existing hollows. Trials are currently underway to investigate if artificial hollows can be excavated in younger trees to simulate the dimensions of natural hollows used by Leadbeater's possum (Leadbeater's Possum Advisory Group 2014b). As at December 2015, initial results show that some Leadbeater's possum colonies use excavated hollows within three months of excavation (Department of Environment Land Water and Planning 2015a), however further monitoring is required to investigate if these are suitable in all seasons and over longer time periods, to evaluate efficacy and to assess cost-effectiveness of any application to broader scale.

Thinning, where the density of stems is reduced by harvesting to increase the growth rate of the remaining stems, has also been suggested as a method to accelerate hollow development. This approach is currently being trialled with the aim of developing forest management strategies at the stand and landscape scale to accelerate the development of key habitat features for Leadbeater's possum (P. Baker *pers. comm.*).

3.4.9. Habitat critical to survival

Given the current Critically Endangered status of Leadbeater's possum, and its predicted severe ongoing decline, including significant risks of extinction, all current and prospective suitable habitat is critical for its survival, and necessary for its recovery.

3.5. Diet

3.5.1. Foraging and diet

Leadbeater's possums mostly forage on the trunks and major branches of eucalypts and mid-storey (or sub-canopy) shrubs. The majority of the diet comprises exudates. These include carbohydrate-rich secretions (lerp and honeydew) excreted by hemipteran insects, and manna, gum and sap exuded by some species of trees (mostly smooth-barked eucalypts) and shrubs (including *Acacia*, *Leptospermum* and *Melaleuca*), sometimes from and due to incisions made by the possums themselves in trunks and branches (Smith 1980; Harley 2005). The nutritional value of plant exudates may vary significantly between different plant species and tree ages, and between different forest types, suggesting that food resource availability may be highly heterogeneous in these forest ecosystems (Lindenmayer *et al.* 1994a). The importance of exudates in the diet indicates that a major factor in determining habitat suitability is the occurrence, abundance and age of particular plant species that provide relatively abundant exudates. Modelling has indicated that food availability may be a critical limiting factor, at least in some forest types and ages (Lindenmayer and McCarthy 2006). However, it is difficult to determine if food is limiting given the varied composition of the species' diet.

Other than exudates, arboreal arthropods (including beetles, spiders and, particularly, large crickets) comprise a significant component of the diet, and make up much of the protein intake (Smith 1980; Smith 1984a; Harley 2005).

Food availability and diet may vary seasonally, with gum comprising a greater proportion of the diet in winter (Smith 1984a), presumably because the abundance of many invertebrates and exudates declines then (Smith 1980; Woinarski and Cullen 1984; Loyn 1985): and there may be an ‘absolute shortage of energy resources (exudates) during late winter and spring’ in montane ash forest (Smith 1984a). Eucalypt nectar and pollen are also taken occasionally (Smith 1984a), and this resource is also highly dynamic, with flowering in mountain ash restricted to trees older than 30 years (and thereafter increasing with age), and trees flowering heavily only every second year (Smith 1984a).

Leadbeater’s possums typically forage singly and diffusely around a communally-shared den site (a ‘central place forager’). Energetic costs of foraging may be high (Smith *et al.* 1982), such that linear strips of habitat may be unsuitable because individuals would have to forage over longer distances than in home ranges of a similar area in continuous habitat in montane ash forest (Lindenmayer *et al.* 1993b). Energetic costs of foraging are probably reduced where there is a near continuous cover of foliage in tall understorey shrubs or eucalypt regrowth, allowing economical travel across this vegetation layer for this non-gliding species.

3.5.2. Food supplementation

There have been some recent limited trials involving the provision of supplementary food to wild Leadbeater’s possums at Lake Mountain and Yellingbo, particularly at Lake Mountain following the 2009 bushfires. Results from these trials have shown that Leadbeater’s possum will use artificially supplied foods (J. Antrobus and D. Harley *pers. comm.*). However, such supplementation is unlikely to have any appreciable benefit other than at the very local level or as an emergency response (Leadbeater’s Possum Advisory Group 2014b).

In some areas, habitat manipulations may be warranted to regenerate understorey, including wattle or tea tree, to increase food availability in areas where nesting resources are available but foraging habitat is lacking. Such manipulation may facilitate recolonisation of currently unoccupied areas once the understorey has regenerated sufficiently. Research on the efficacy of such manipulation is currently proposed by ANU.

Implications for conservation management:

- The energetic costs of foraging relative to the dispersion and nutritive value of available food resources indicate that small fragments and linear strips are less suitable habitat than larger blocks of continuous habitat.
- Food availability may be a limiting factor at some sites or seasons, or after major disturbance. There may be some scope for increasing the likelihood of retaining or increasing colony persistence or increasing productivity, or increasing the likelihood of translocation success, using food supplementation. However, this is likely to be practical and applicable only at local scale and for particularly susceptible or important colonies.

Priority research needs to enhance management:

- Further research would be useful to evaluate where habitat manipulation could be used to increase future food resources, and to assess its cost-effectiveness.

3.6. Social structure

Leadbeater's possums live in small matriarchal communal social groups ('colonies') of two to twelve (but currently more typically two or three) individuals, with colonies normally including only one reproductively active female and male plus young or sub-adult and adult offspring (Smith 1984b; Lindenmayer and Meggs 1996; Harley 2005; Harley and Lill 2007). In high quality habitat, colonies occupy actively defended territories of 1–3 ha (Smith 1984b; Harley 2005), that contain multiple den sites (Lindenmayer and Meggs 1996; Harley 2004b). In the absence of disturbance, colonies have long-term site fidelity (Lindenmayer *et al.* 2013b). Social structures and home range characteristics are less well known for colonies in spatially heterogeneous landscapes, notably where contrasting nesting and foraging habitats abut.

Female dispersal is greater than male dispersal (Smith 1984b) and females (and probably any dispersing individuals) are subject to higher rates of mortality. Dispersal into established colonies is more common than new colony formation in unoccupied habitat. Dispersal is strongly tied to the onset of reproduction, and hence animals are likely to be searching for breeding opportunities when dispersing (Harley *et al.* 2005). There is a biased adult sex ratio, of about three males per female (Smith 1984b; Lindenmayer 1996b).

3.7. Demography and breeding biology

3.7.1. Demography and reproduction

Longevity is typically five to eight years in the wild, with the maximum age recorded being ten years (Smith 1984b; Lindenmayer and McCarthy 2006). Age at first breeding is typically two years (Smith 1980; Lindenmayer *et al.* 1993d; Lindenmayer and Possingham 1995c, 1995a; Harley and Lill 2007). Generation length is considered to be six years (Woinarski *et al.* 2014; Threatened Species Scientific Committee 2015).

However, some demographic characteristics vary among subpopulations in different habitats: for example, the mean reproductive life in adult females in a montane ash forest site was reported to be 1.6 years, but at least 3.3 years at Yellingbo (Smith 1984b; Harley 2005; Smith and Harley 2008).

The reproductive rate is relatively low, with typical litter size of 1 to 2 young per breeding female (and hence per colony) (Harley and Lill 2007). Reproductive success is probably related to food supply (Smith 1984b). Breeding is seasonal in montane ash forests, with most births between May and November, but breeding at Yellingbo occurs year-round (Smith 1984b; Harley 2005; Smith and Harley 2008). A second litter may be produced in any year if the first is lost, or they may breed twice annually, although with reproductive attempts in autumn/winter being less productive than those in spring/summer (Smith 1980, 1984b). Young remain in the pouch for 80-93 days (Harley 2005; Smith and Harley 2008), emerge from the nest at about 111 days, and remain in the natal territory for 7-14 months (for females) and 11-26 months (for males) (Smith 1980, 1984b; Menkhorst and Lumsden 1995). Monitoring at Yellingbo indicated that only about 20% of young survived to acquire breeding status within established groups (Harley 2005; Harley *et al.* 2005).

3.7.2. Captive breeding and translocation

The first captive breeding of Leadbeater's possums was undertaken by Des Hackett in the early 1970s from animals captured in the Central Highlands (Preuss 2006). In 1981-82, these captive animals were transferred to Melbourne Zoo. With progeny from this founder stock, several zoos around the world subsequently bred the species and the captive population peaked at 77 individuals in 1986 (Myroniuk and Seebeck 1992; Myroniuk 1995). While this program was successful in terms of producing generations of offspring, it was not integrated into any broader conservation management strategy. With no designated outlet for young born in captivity, adults were segregated to reduce breeding rates and the population ultimately aged and declined (Harley and Lowry 2013).

In 2012, Zoos Victoria, initiated a new captive breeding program for Leadbeater's possum targeting the lowland subpopulation given its genetic distinctiveness and its extremely high extinction risk in the short-term (Harley 2012). The objectives were to provide insurance against the extinction of the last lowland population, and provide a future source of animals to re-populate restored habitat in Yellingbo and at least two additional populations away from Yellingbo as risk-spreading against fire. In order to minimise impacts on the wild population, the collection rate of founders for captive-breeding has been restricted to 3-6 individuals per year (Harley 2015a). The target for the size of the captive-breeding program for lowland Leadbeater's possum is currently 12 pairs. The current size (as at November 2015) of the captive population is six pairs (14 individuals), and no successful breeding has yet occurred in this population (Harley 2015a). Due to the small number of individuals remaining and the risk of inbreeding, there may be a need for genetic rescue including outbreeding to increase genetic diversity.

There are no current captive breeding populations for the core montane ash forest population.

Three small-scale translocation trials of Leadbeater's possum have been undertaken to date: one in montane ash forest and two in lowland swamp forest at Yellingbo. None of these trials has resulted in the long-term successful establishment of translocated populations. In 1987, there was an unsuccessful attempt to establish captive-bred Leadbeater's possums in montane ash forest (Macfarlane and Seebeck 1991), with the failure potentially due to the presence of resident possums at the release site. In 2002, a female of dispersal age was successfully translocated to an outlying site at Yellingbo with a solitary resident male (Harley 2002), and this resulted in the production of three young prior to the loss of the female, so was successful in the short-term. In 2004, five unpaired wild-caught individuals of dispersal age were translocated into unoccupied habitat at Yellingbo. This trial resulted in some initial persistence but ultimately failed when individuals dispersed from the release sites and were subject to high predation rates (D. Harley and J. Antrobus *pers. comm.*).

A recommendation from the most recent trial was that translocations may be more likely to succeed if established, cohesive social groups, rather than individuals, are moved (D. Harley *pers. comm.*). Techniques to enhance site fidelity post-release in order to reduce dispersal-related mortality are also likely to improve translocation success (D. Harley *pers. comm.*).

Implications for conservation management:

- Translocation is likely to be an important component of an overall conservation management program into the future. Objectives include (i) bolstering the occupancy and persistence in habitat fragments for the lowland population; (ii) maintaining or enhancing genetic heterogeneity of isolated subpopulations; (iii) assisting the recolonisation of suitable but unoccupied habitat within the Central Highlands (such as regenerated fire-affected areas), and (iv) (subject to appropriate risk and cost-benefit assessment) extending the range to suitable habitat beyond the current distribution.

- Given ongoing risks of severe episodic population losses due to extensive bushfire events, a captive insurance population should be maintained for the lowland subpopulation at Yellingbo, at least until additional lowland subpopulations are established.

Priority research needs to enhance management:

- Further research is required to increase the likelihood of success of translocations, such as to establish the number, age, provenance (e.g. wild-caught or captive-bred) and social relationships of animals that can be used to maximise success, and whether nest boxes, predator-avoidance training or food supplementation can be used to increase the success rate. Research should also consider techniques to enhance site fidelity post-release in order to reduce dispersal-related mortality.

3.7.3. Causes of mortality

There is little available information on causes of mortality, but occurrence in sub-fossils deposited by sooty owls (Bilney *et al.* 2006; Bilney *et al.* 2010; Bilney 2014) demonstrates that owls prey on the species; and an unsustainably high level of predation for animals dispersing through unfamiliar areas was thought to have contributed to the failure of one of three trial translocation attempts (D. Harley and J. Antrobus *pers. comm.*).

However, predation has not been a major cause of adult mortality, or driven the current population decline, for the Yellingbo subpopulation (Harley 2015a). From a large sample of individuals that were radio-tracked at Yellingbo, there were just three adult mortality events, all coinciding with the dispersal of new animals into established colonies. One death resulted from female-female aggression, another from predation by a powerful owl *Ninox strenua* and the third from predation by a cat *Felis catus* or fox *Vulpes vulpes* (Harley 2005). The cause of high juvenile mortality at Yellingbo is unknown. Instead, the population decline of Leadbeater's possum at Yellingbo is due to the severe decline in habitat conditions: numerous individuals have died in the wild 'due to habitat decline in their territories' (Harley 2015a).

Disturbance events that dramatically alter the environment can result in direct mortality of individuals. The 2009 bushfire resulted in greater than 95% mortality for Leadbeater's possums on the Lake Mountain plateau (Harley 2016).

Although all known colony sites are now surrounded by a 200 m timber harvesting exclusion zone, if undetected animals are present on a coupe they are likely to be killed during timber harvesting (Lindenmayer *et al.* 2015b).

The main ultimate cause of mortality across the possum's range is episodic habitat loss or gradual reduction in habitat quality associated with disturbance events and regimes. These are discussed in more detail in the **Threats** section below.

4. THREATS

The major threat to the Leadbeater's possum is the ongoing reduction in the extent, quality and connectivity of suitable habitat, with this threat in part a historical legacy, in part a consequence of ongoing actions, and in part a future expectation based mostly on factors which are difficult to control (bushfire).

4.1. Historical causes of decline

Fossil, sub-fossil and historical records demonstrate that the species was formerly more widely distributed (Lindenmayer *et al.* 1991d; Lindenmayer *et al.* 1993d; Bilney *et al.* 2010), however the pattern and timing of historical decline is poorly resolved. Some decline probably occurred prior to European settlement, due to changes in climate and hence fire regimes and habitat extent, but the rate of decline has most likely accelerated since European settlement.

Extensive clearing and landscape modification (including draining of wetlands) – mostly in the decades from the late nineteenth to early twentieth century – removed almost all suitable habitat from the type locality and across the species' lowland range (Macfarlane *et al.* 1997; Harley 2004c; Harley *et al.* 2005). The extent and occupancy of suitable montane ash forest has been diminished historically by changed fire regimes (notably to increased frequency of severe bushfire), associated with ongoing climate change and changes in management (Lindenmayer *et al.* 2011a; Burns *et al.* 2015), and – from the early decades of the twentieth century – reduction in the extent, quality and connectivity of suitable habitat due to the impacts of timber harvesting, including salvage logging to 1960 of large trees killed in the 1939 bushfire (Lindenmayer *et al.* 2008).

4.2. Current threatening processes

The ongoing reduction in the extent, quality and connectivity of suitable habitat has resulted in, and is projected to continue to cause, a reduction in resources required by Leadbeater's possum for shelter, breeding, dispersal, and food availability, and hence to ongoing decline in population size and conservation status. The ongoing reduction in the extent, quality and connectivity of suitable habitat has occurred and continues to occur through a range of drivers:

- impacts of severe fire and changes in fire regime;
- timber harvesting;
- reduction in the abundance of hollow-bearing trees;
- eucalypt dieback and altered hydrology (for the lowland subpopulation).

In turn, ongoing habitat loss has resulted in, and will continue to cause, fragmentation (and thus reduced genetic diversity and viability) of subpopulations.

Furthermore, current and projected climate change is likely to exacerbate the ongoing reduction in habitat extent and quality, particularly through its impacts on the severity and frequency of bushfires.

4.2.1. Impacts of severe fire and changes in fire regime

Fire is a direct and indirect threat to Leadbeater's possum. Monitoring of montane ash forest sites before and after the 2009 bushfires demonstrated that few if any Leadbeater's possums survive in areas burnt by bushfires, regardless of fire severity (Lindenmayer *et al.* 2013c; Lumsden *et al.* 2013). Marked loss due to the 2009 bushfire was also reported for Leadbeater's possum in snow gum woodlands (Harley 2016). Leadbeater's possums are also less abundant on unburned sites where the surrounding landscape has been burned, suggesting that the population reduction effects due to bushfire are disproportionately higher than the fire's extent itself (Lindenmayer *et al.* 2013c; Lindenmayer *et al.* 2015b).

Fire is the primary form of natural disturbance in montane ash forest, and the dynamics of post-fire vegetation succession critically influence habitat suitability for Leadbeater's possum. However, these fire regimes have changed and continue to change in montane ash forests and sub-alpine (snow gum) woodlands, with bushfires now substantially more frequent than prior to European settlement (Lindenmayer *et al.* 2013c). The current pattern of severity and frequency of bushfires is resulting in ongoing diminution in the extent and quality of habitat for Leadbeater's possum.

The impacts of changed fire regime are particularly evident in the reduced extent and increased fragmentation of old-growth forest (i.e. where dominant trees are >120 years old). At around the onset of European settlement, old-growth forest comprised at least 30% and possibly up to 60-80% of the mountain ash forest in the Central Highlands (Lindenmayer 2009). Its proportional extent has been estimated to be only about 1.1% (Lindenmayer *et al.* 2012; Lindenmayer *et al.* 2013a; Lindenmayer *et al.* 2015b).

The most extensive fire in recorded history was in 1939, with this fire burning about 85% of mountain ash forests in the Central Highlands (Burns *et al.* 2015). In 1983, sections of forest within the southern part of the species' range were burnt in a severe bushfire. Regeneration from this fire now provides important habitat for the species. The next extensive bushfire was in 2009, with this fire burning about 34% of the approximately 200,000 ha of montane ash forest and sub-alpine (snow gum) woodlands considered to be potential habitat of Leadbeater's possum, including 45% of the Leadbeater's possum reserve (Leadbeater's Possum Advisory Group 2014b).

Fire and fire regimes have now well-established consequences for the quality and extent of Leadbeater's possum habitat. These impacts vary according to the age and structure of the forest at the time at which it is burnt, the severity of the fire, and the fire's landscape context (largely the amount and connectivity of unburnt patches). In montane ash forests, a severe fire kills most understorey vegetation and canopy trees (but releases their seed, allowing for a regeneration cohort), rendering the habitat unsuitable in the short term for Leadbeater's possum. However, fire may promote the capacity for older trees to form hollows from fire scarring. If large old trees were present prior to the fire, many will remain as stags (or in some cases, as fire-scarred old live trees), providing suitable hollows for Leadbeater's possum. In the period after fire, the abundance of this resource gradually (over decades) diminishes, as the stags collapse.

However, while hollows may be retained in burnt areas, it typically takes about 15 years post-fire before the understorey develops sufficiently to provide the other key component of suitable habitat. In the absence of other disturbance, by about 50 years after fire, the dense tall *Acacia* understorey senesces and thins out, reducing habitat quality again. The cohort of post-fire regeneration eucalypts takes about 120 years to mature sufficiently to start forming hollows suitable for Leadbeater's possum, but – if undisturbed for this period – this cohort ultimately provides the hollows required for future suitable habitat.

If severe fire recurs at shorter intervals than the period required for hollow formation, the more recent fire will have more substantial consequences for habitat quality, as it will eliminate a high proportion of the stags that persisted after the earlier fire (Lindenmayer *et al.* 2011a; Lindenmayer *et al.* 2015b). Furthermore, young trees generally do not stand long after they are burned (Lindenmayer *et al.* 2013c), and areas repeatedly burnt by severe fire will not provide current or future hollow-bearing habitat for Leadbeater's possum. Indeed, if the inter-fire interval is shorter than the time taken for mountain ash trees to reach reproductive age (approximately 15-20 years), they will be lost entirely from stands and be replaced with other species with shorter reproductive periods such as *Acacia* spp. (Lindenmayer *et al.* 2011a).

The less characteristic low intensity fires can stimulate some regeneration but may not kill all canopy trees, resulting in multi-aged stands that provide suitable denning and feeding habitat for Leadbeater's possum (Lindenmayer *et al.* 2000).

The detrimental impacts of fire on Leadbeater's possum habitat have been exacerbated where salvage logging has removed standing trees that survived the fire. Salvage harvesting occurred most extensively after the 1939 bushfire, but also occurred after the 1983 and 2009 bushfires (Lindenmayer *et al.* 2015b). Burned hollow-bearing trees in stands subject to salvage logging are now exempt from harvesting, however their collapse rates are higher because they are subject to increased exposure (Lindenmayer and Ough 2006).

While the most acute detrimental impacts to Leadbeater's possum are due to severe bushfire, some pre-emption, prevention, suppression and recovery fire management measures may also pose some risks to Leadbeater's possum and its habitat. Such actions may include the establishment of networks of fire breaks, and the felling of 'hazardous' large dead trees after fire.

4.2.2. Timber harvesting

Timber harvesting reduces habitat suitability, extent and connectivity in Leadbeater's possum's montane ash forest environments, but does not occur in the far smaller areas of sub-alpine (snow gum) woodland or lowland swamp forest habitat.

About one third of the Central Highlands landscape that is potential habitat for Leadbeater's possum is available for timber harvesting (Leadbeater's Possum Advisory Group 2014b). In the past 40 years, the conventional form of timber harvesting in Victorian ash forests has been clear-felling. Clear-felling is a method of harvesting in which all merchantable trees, apart from those to be retained for wildlife habitat or other values (e.g. water quality), in a defined coupe area are removed in a single operation (Department of Environment and Primary Industries 2014a). The remaining debris is burnt to provide a seedbed to regenerate the new stand of trees. This creates an even-aged area of forest with few or no hollow-bearing trees within the harvested part of the coupe. Harvest rotations are typically 60-80 years and hence the resulting regrowth trees will be harvested before they can develop hollows (which occurs at >120 years). Older forest, including hollow-bearing trees, is therefore restricted to retained areas of forest within or surrounding the coupes. These areas of retained forest contribute to a mosaic of multi-aged forest at a landscape scale.

Since 2014, VicForests has commenced ‘regrowth retention harvesting’, with the intention of undertaking this modified form of harvesting in 50% of the area of ash harvested within the Leadbeater's possum range. Regrowth retention harvesting aims to increase the amount of retained habitat within the coupe by retaining clusters of trees as habitat islands or peninsulas, and is designed to retain stands of trees able to continue to grow on and in time form hollows and Leadbeater’s possum habitat.

The majority of the current timber harvesting in Central Highland ash forests occurs in areas that regenerated after the 1939 bushfires, with small amounts from stands resulting from fires between 1900 and 1938. These forests are classified as regrowth forests and regenerating trees have typically not yet formed hollows.

There is no longer any harvesting of old-growth ash forest in the Central Highlands. All live pre-1900 ash trees are protected from harvesting, whether they are in a patch of old trees (i.e. old-growth forest), or where there are individual older trees scattered through younger forest (i.e. mixed-age forest). Although protected, these retained trees are susceptible to being killed or damaged during regeneration burns or later when exposed to wind storms (Lindenmayer *et al.* 2015b).

Extensive areas of ash forest have been harvested in the Central Highlands in the past 40 years. Leadbeater's possums do not occur in recently clear-felled areas (Lindenmayer *et al.* 2015b), and are unlikely to be present in these areas for at least 10-15 years after harvesting. A total of approximately 38,000 hectares of montane ash forest has been harvested in the Central Highlands since 1978 when clear-felling became the predominant form of harvesting. On average approximately 800 ha of ash forest is currently harvested per year within the range of Leadbeater's possum (figures from 2011/12 to 2013/14: Victorian government data).

As part of timber harvesting planning, VicForests conducts desktop and field assessments for Leadbeater's Possum Zone 1A and 1B habitat. Zone 1A and 1B habitat represents only a small proportion of the area in which Leadbeater's possum occurs (DELWP unpublished data), and prior to 2014, there was no requirement to specifically search for colonies of Leadbeater's possum before harvesting, with all assessments of the likelihood of Leadbeater’s possum occurring in a site to be harvested based on habitat. Some proposed coupes are now being surveyed for Leadbeater’s possum colonies through VicForests’ pre-harvest surveys and DELWP’s targeted surveys. Recent surveys have located colonies of Leadbeater's possum within coupes planned for harvesting (36% of the 42 sites sampled in proposed coupes (Nelson *et al.* 2015)).

Thinning of younger regrowth forests (typically 18-30 years old) occurs in some areas, with the aim of increasing the growth rate of the remaining trees. Although not all trees are harvested, thinning opens up the stand, removing the dense mid-storey connectivity needed by Leadbeater's possum for movement and foraging. However, thinning can accelerate the growth of trees and potentially the formation of hollows in these trees from damage caused during these operations.

Timber harvesting prescriptions have been established with the aim of reducing the impact of harvesting on Leadbeater's possum and other biodiversity values (Department of Environment and Primary Industries 2014b). Additional prescriptions have been recommended to increase protection for Leadbeater's possum and its habitat, especially the large old trees, and to rebuild the extent of old-growth forest (Lindenmayer 2009; Lindenmayer *et al.* 2013a; Lindenmayer *et al.* 2013b; Lindenmayer *et al.* 2015b).

In the Central Highlands, the average gross area of individual coupes is currently approximately 34 hectares, although coupes can sometimes be aggregated into larger areas (Lindenmayer *et al.* 2015b). Not all of the gross area is harvested, with on average approximately 32% of the coupe left unharvested (data from VicForests in 2014-15), due to a range of features, including streamside reserves, steep areas, Leadbeater's Possum Zone 1 habitat and aggregated retention areas. These areas retain some older forest, and can allow younger forest to mature. Post-harvesting regeneration that is surrounded by sufficient retained (older) habitat to support colonies could then form a spatial mosaic of age classes providing older forest for nesting and dense young forest for foraging. Leadbeater's possum can use regeneration from timber harvesting as foraging habitat after approximately 10-15 years (Smith and Lindenmayer 1992; Nelson *et al.* 2015), if there are suitable nesting sites nearby.

Salvage harvesting of trees killed or damaged in high-intensity bushfires is conducted to recover timber after fires. Salvage harvesting impacts Leadbeater's possum habitat by reducing the number of hollow-bearing trees and the prevalence of multi-aged forest (Lindenmayer and Ough 2006; Lindenmayer *et al.* 2008). In the Central Highlands, salvage harvesting took place after bushfires in 1926, 1932, 1939, 1983 and 2009. Salvage harvesting is subject to prescriptions that aim to protect large, live hollow-bearing trees (Department of Sustainability and Environment 2008a), and areas are protected where these large trees occur in densities that would have met the criteria for Zone 1A habitat prior to the fire. Unburnt patches within fire-affected areas are also retained until the surrounding area regenerates.

In addition to the direct impacts of timber harvesting on habitat availability for Leadbeater's possum, harvesting may have some indirect impacts, although the severity of such impact is not well resolved. Proliferation of the track network associated with harvesting may isolate some Leadbeater's possum subpopulations and reduce dispersal. Fires purposefully lit to facilitate germination following harvesting may also pose some risks of spreading beyond the harvested area.

4.2.3. Reduction in the abundance of hollow-bearing trees

This factor can be considered to be a consequence of other threats or as a threat itself, but it is included specifically here as a threat as it is such an important consideration for the future of this species. The quality of the montane ash habitat for Leadbeater's Possum has declined in recent decades due to a significant loss of hollow-bearing trees. Long-term monitoring over the last 30 years in the Central Highlands has shown that within unburnt areas, approximately 3.5% of dead trees collapsed per year during that period and approximately 1.5% of large, live hollow-bearing trees died per year (Lindenmayer *et al.* 2012). This loss of hollow-bearing trees is predicted to continue into the future, with most of the remaining dead trees from the 1939 fires predicted to collapse within 50 years. There is currently negligible development of new hollow-bearing trees, as 1939 regrowth is yet to form hollows. The combination of the loss of existing hollow-bearing trees and a current lack of development of new hollow-bearing trees is predicted to lead to an increasingly severe shortage of these trees in the next 30-70 years (Lindenmayer *et al.* 1990b; Lindenmayer *et al.* 2012).

4.2.4. Eucalypt dieback and altered hydrology (for lowland subpopulation)

Lowland swamp forest habitat at Yellingbo and in nearby areas is experiencing ongoing decline in habitat quality due to eucalypt dieback and reduced regeneration, resulting in an altered, more open forest structure. Largely due to such ongoing habitat deterioration, only about 15% of the 180 ha of lowland swamp forest in the Cockatoo Creek section of Yellingbo Nature Conservation Reserve now supports high quality habitat, and the population of Leadbeater's possum in the reserve has declined severely across the monitored period of 2001-2015 (Harley 2016). This reduction in habitat quality is due to severe eucalypt dieback caused by altered hydrology of the Cockatoo Creek floodplain and lack of appropriate disturbance regime to promote natural regeneration of eucalypts and *Melaleuca* and *Leptospermum* understorey (Harley 2016).

4.2.5. Population fragmentation

An ongoing reduction in the extent of suitable habitat is likely to lead to increased fragmentation of the population into a series of variably-sized subpopulations. Isolated subpopulations may experience high risks of loss through stochastic events (notably bushfire) and loss of genetic heterogeneity, and consequently have a high likelihood of extirpation. The fate of such subpopulations (i.e. their probability of extinction) is influenced by habitat quality and extent, the initial population size and its genetic variability, the possum's capability and extent of dispersal, the disturbance (i.e. fire and timber harvesting) regime, and characteristics of the landscape (Lindenmayer and Possingham 1995a, 1995c, 1995b, 1996b, 1996a). Very small isolated subpopulations have a high probability of extinction within 20-50 year periods (Lindenmayer and Possingham 1995c), but the relationship between initial population size and extinction risk is gradational (rather than characterised by a particular threshold in initial population size), and extinction risk in a subpopulation is also much influenced by disturbance regime and other factors.

The factors contributing to isolation of subpopulations are not well resolved. Given Leadbeater's possum's reliance on continuous vegetation cover, roads may be barriers to dispersal and hence may serve to fragment populations (Lindenmayer *et al.* 2015b). Molecular analyses for the Yellingbo subpopulation indicate that population fragmentation can occur over very small spatial scales, even where continuous vegetation cover exists, suggesting the species is highly sensitive to habitat quality (Hansen 2008; Hansen and Taylor 2008).

4.2.6. Climate change

The climate of the Central Highlands is likely to change significantly in future decades, with high-confidence predictions of higher temperatures (mean annual temperature is expected to rise by 2030 to 0.4 to 1.1°C above that of the 1986-2005 period), a higher frequency of days of extreme heat, increased incidence and longevity of meteorological drought, and harsher fire-weather climate (Grose *et al.* 2015). These projections largely maintain or accelerate climate trends evident over recent decades, which have contributed to ongoing reduction in the quality and extent of habitat suitable for Leadbeater's possum, and can be expected to continue to exacerbate these trends.

Ongoing increases in the incidence of drought and high temperatures are likely to lead to further marked increase in the frequency and intensity of bushfires (Williams *et al.* 2009; Dutta *et al.* 2016), and hence to more frequent acute episodes of high mortality of possums, and chronic marked reductions in the landscape-scale abundance of hollow-bearing trees.

Regardless of the associated increased risks of severe bushfire, a higher incidence of drought and of extremely hot days is also likely to lead to high rates of mortality of large trees. For example, elevated rates of tree mortality were reported for the period 2004 to 2011 (during which 23% of large living trees died on unburned sites), associated with drought conditions (Lindenmayer *et al.* 2012; Lindenmayer *et al.* 2013a). While such drought-killed trees may stand as stags in the landscape, they are more susceptible to collapse during and after severe bushfire than are large living trees (Lindenmayer *et al.* 2012), so an increased incidence of severe drought in the future will result in further reductions in the abundance of hollow-bearing trees, and hence to decline in the extent and quality of habitat suitable for Leadbeater's possum.

Furthermore, because mountain ash and alpine ash have relatively narrow constraints of climatic suitability (Lindenmayer *et al.* 1996), climate change may lead to a reduction in the distributional extent of these two species. It may also lead to distributional contraction indirectly because an increased incidence of severe fire due at least in part to climate change may reduce the area occupied by ash species, where fires recur at intervals shorter than their time to maturity.

Climate change may also affect food availability for Leadbeater's possum, through changes in the abundance and diversity of invertebrates, the production and persistence of exudates, and the frequency and productivity of flowering events. There is only limited information to specifically link these factors to climate characteristics in montane ash systems or to predict the impacts of climate change on food resource availability, however climate conditions have been shown to cause a major reduction in the availability of some types of food for Leadbeater's possum (Smith 1980; Smith 1984a; Lindenmayer and Possingham 1995c), and breeding success in Leadbeater's possum is 'closely related' to the abundance of some food resources (Smith 1980; Lindenmayer and Possingham 1995c). More generally, for some Victorian forest systems, drought has been shown to cause a reduced incidence of eucalypt flowering and also a decline in bird species for which invertebrates comprise a high proportion of diet (Mac Nally *et al.* 2009).

It is possible that an increased incidence of days of extreme heat may narrow the range of hollows that are suitable as den and breeding sites for Leadbeater's possum, but there is insufficient evidence to assess the likelihood of such change.

5. LEGISLATIVE, POLICY AND PLANNING CONTEXT

5.1. The legislative and the policy environment

This Recovery Plan is informed and guided by relevant Commonwealth and State legislation and policies as well as Australia's obligations under various international agreements.

5.2. National threatened species policy

In 2015, the Australian Government released the Threatened Species Strategy, which committed to a new actions-based approach to protecting and recovering Australia's threatened plants and animals. The Leadbeater's possum was identified in the Strategy as a species requiring emergency intervention to avert extinction. Targets to measure success included 20 threatened mammals with improved trajectories by 2020, including the Leadbeater's possum.

The Australian Government Environment Minister also approved an 'Action Plan' for the Leadbeater's possum in August 2015 (https://www.environment.gov.au/biodiversity/threatened/publications/leadbeaters-possum-action-plan), which provided additional advice on conservation management for this species, including commitments of on-ground funding to improve habitat, research initiatives, and the development of a new Recovery Plan.

5.3. Victorian state policy and planning

The Leadbeater's possum is protected under Victoria's state policy and planning framework. Although protection applies to both public and private land, the possum is found almost exclusively on public land, with less than 1% of records on private land. As such, the planning effort is greater for public land. Outlined below are the key policy, planning and management elements relevant to the Leadbeater's Possum, with further information on existing and previous conservation measures provided in Section 6.1.

Land management agencies of the Victorian State Government use park and forest management plans to provide for the balanced use of the public land which the possum inhabits. Key current land planning documents include but are not limited to the *Central Highlands Forest Management Plan* 1998 under the *Forests Act 1958* (Department of Natural Resources and Environment 1998), the *Yarra Ranges National Park Management Plan 2002* and the *Baw Baw National Park Management Plan 2005* (both prepared by Parks Victoria under the *National Parks Act 1975*).

The forest management plan creates the Forest Management Zone system. These zones specify which areas are used as general management zones (GMZ) managed for a range of uses and values including timber harvesting, special management zones (SMZ) which are managed to retain specific features and in which modified harvesting is allowed, or special protection zones (SPZ), areas in state forest managed for conservation. SPZs are included in the CAR reserve system as 'informal reserves'. SPZs and SMZs can be altered during a zoning review.

Forest management zones are of particular importance to commercial timber harvesting operations which intersect with the Leadbeater's possum distribution in the Central Highlands. Timber harvesting is permitted in GMZs and SMZs of state forest, subject to the *Allocation Order 2013 (as amended*) and ensuring compliance with the regulatory framework outlined in the *Code of Practice for Timber Production 2014* (Department of Environment and Primary Industries 2014b) and the associated suite of management standards and procedures (Department of Environment and Primary Industries 2014c). These documents contain specific regulatory requirements that must be complied with when undertaking timber harvesting activities and include actions to protect species like the Leadbeater's possum and its habitat.

VicForests, the state-owned government enterprise responsible for the commercial sale of timber from state forests on behalf of the Victorian State Government must comply with these regulatory requirements. VicForests undertakes coupe planning and applies additional modified harvesting methods to further manage risks associated with potential impact to the Leadbeater's possum. Key initiatives include regrowth retention harvesting, pre-harvest surveys and research into improvements to silvicultural practices.

The Victorian Government has established an independent Forest Industry Taskforce to provide leadership and reach common ground on future issues facing the timber industry, job protection, economic activity, and the protection of native flora and fauna and threatened species, such as the Leadbeater's Possum. The primary area of focus for the taskforce will be on future use and management of state forests in eastern Victoria, including the Central Highlands. The taskforce will seek to jointly achieve broad community and cross-parliamentary support to adopt and implement the agreed outcomes. The taskforce is working to provide recommendations to government by 30 June 2016. Further information about the taskforce can be found at: http://www.dpc.vic.gov.au/.

5.4. National forest policy

The Native Forest Policy Statement (Anon 1992) described three complementary mechanisms required to achieve nature conservation objectives:

> "First, parts of the public native forest estate will continue to be set aside in dedicated nature conservation reserve systems to protect native forest communities, based on the principles of comprehensiveness, adequacy and representativeness. The reserve system will safeguard endangered and vulnerable species and communities. Other areas of forest will also be protected to safeguard special areas and to provide links where possible between reserves or other protected areas. Nature conservation reserves will be managed so as to protect their values. Second, there will be complementary management outside reserves, in public native forests that are available for wood production and other commercial uses and in forests on unallocated or leased Crown land. Third, the management of private forests in sympathy with nature conservation goals will be promoted" [p. 7].

The first (the establishment of a reserve system comprising dedicated conservation reserves that will safeguard threatened species) and second components are especially relevant for Leadbeater's possum conservation, whereas the third component is largely irrelevant in this case because little of the possum's distribution occurs on private lands.

The National Forest Policy Statement is implemented in part through Regional Forest Agreements (RFAs), which are 20-year agreements between the Australian Government and state governments with an objective to provide a balance of environmental, social and economic outcomes in the management of Australia's native forests. They facilitate development of an internationally competitive wood and wood products industry; develop and implement ecologically sustainable forest management and use; promote the conservation and management of privately owned forests, and establish a comprehensive, adequate and representative (CAR) forest reserve system consistent with the 'JANIS' criteria (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997). Within RFA areas, forestry operations carried out in accordance with the RFA are exempt from the provisions of the EPBC Act, except where they are likely to have significant impact on matters of national environmental significance associated with World Heritage or Ramsar wetland sites.

The Leadbeater's possum's range is entirely within the Victorian Central Highlands RFA area. The Central Highlands RFA is one of five RFAs in Victoria and was signed on 27 March 1998 following a comprehensive regional assessment of the social, economic, environmental and cultural and natural heritage values of the region's native forests.

The Central Highlands RFA recognised that the CAR reserve system and the application of management strategies and management prescriptions in the Central Highlands Forest Management Plan, developed under Victoria's Forest Management System, provides for the protection of threatened species and communities. Changes to the RFA occur through the written agreement of the Australian Government and the Victorian Government.

The biodiversity conservation aim of the Central Highlands Forest Management Plan is 'to ensure that all indigenous plant and animal species and communities survive and flourish throughout the Central Highlands' (Department of Natural Resources and Environment 1998). It included guidelines for threatened species generally and for Leadbeater's possum specifically, which are now outlined in Management Standards and Procedures for Timber Harvesting Operations (Department of Environment and Primary Industries (2014c).

The RFA notes that management guidelines and prescriptions in the Plan may be reviewed 'when new information on the impact of forest management or utilisation activities on biological or cultural values becomes available' and 'if the status of a threatened species changes'.

In relation to the CAR reserve system, the JANIS criteria noted that the forest reserve system should be considered in the context of the overall landscape (i.e. with consideration of the complementary conservation values and benefits derived from sympathetic management of unreserved lands). JANIS noted that "The CAR reserve system comprises areas of both public and private land that are reserved specifically for conservation purposes, and where the tenure of the reserved areas is secured by legislation or other methods appropriate for the area concerned" (p. 6) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

Although JANIS recognised that the forest CAR reserve system could comprise a mix of dedicated reserves (i.e. national parks and conservation reserves), informal reserves (SPZs) and prescriptions, it also indicated the primacy of dedicated reserves within this mixture:

> "All reasonable effort should be made to provide for biodiversity and old-growth forest conservation and wilderness in the Dedicated Reserve system on public land. However, where it is demonstrated that it is not possible or practicable to meet the criteria in the Dedicated Reserve system, other approaches will be required", and
>
> "In situations where it is not possible or practicable to include conservation values into Dedicated Reserves, it is appropriate for areas to be reserved under other secure tenure or management arrangements" (p. 6) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

JANIS provided guidelines on the interpretation of 'adequacy' for the extent of the required reserve system. It defined 'adequacy' as "the maintenance of ecological viability and integrity of populations, species and communities" (p. 5), indicating that an adequate reserve system should be of sufficient extent to maintain the long-term viability of species. This objective is also explicit in the JANIS statements that:

> "Reservation to conserve biodiversity needs to focus on the continued viability of species and ecosystems rather than the attainment of area targets" (p. 11) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997),

and

> "the reserve system should seek to maximise the area of high quality habitat for all known elements of biodiversity wherever practicable, but with particular reference to … the special needs of rare, vulnerable or endangered species" (p. 13) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997),

and

> "no precise basis exists for determining criteria that provide for adequacy. However, the general rule is that the chances of long-term survival increase with increased proportions of populations of forest ecosystems reserved and appropriately managed" (p. 5) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

JANIS also noted that individual reserves should be of sufficient size to provide for the viability of populations of species within them:

> "reserves should be large enough to sustain the viability, quality and integrity of populations" (p. 13) (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

Hence, for Leadbeater's possum, this policy should be interpreted as indicating that (i) the reserve system should wherever possible and practicable be based largely on dedicated reserves, (ii) the reserve system (the combined dedicated, informal and prescription components) should be sufficiently large to maintain the long-term population viability of the species; (iii) the reserve system should be appropriately managed, and (iv) populations and suitable habitat outside reserves are managed in a manner that complements the role of reserves, and contributes significantly to the overall conservation objectives and outcomes.

5.5. International agreements and obligations

Australia is a signatory to a number of international agreements relevant to the conservation of Leadbeater's possum. This plan is consistent with and is guided by Australia's international responsibilities under these agreements, and the plan's implementation will support meeting these obligations. These include:

- United Nations 2015 sustainable development goals which include to 'take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species' (Goal 15.5).

- Convention on Biological Diversity's Aichi Target 12 that states 'by 2020 the extinction of known threatened species has been prevented and their conservation status … has been improved and sustained''.

- The conservation of Leadbeater's possum relates to the sustainable management of its temperate forest habitat. Australia is a signatory of the Montreal Process (Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests). This notes that 'a key objective for the conservation of biological diversity is slowing down the rate of population decline, and species depletion and extinction due to human factors', and requires the Australian government to report regularly on the number and status of forest species at risk or in serious decline, and also on management actions taken to attempt to safeguard such species.

This Recovery Plan considers some *ex situ* and translocation management actions. Although not binding, it is appropriate that such actions for Leadbeater's possum should be consistent with international standards and protocols for *ex situ* conservation and translocation (IUCN/SSC 2013, 2014) as well as relevant Victorian government legislation and policy.

5.6. Implications for this Recovery Plan

The ongoing deterioration in the conservation status of the Leadbeater's possum, leading to its recent uplisting to Critically Endangered status, indicates that expectations and obligations under a range of international, national and state policies are not being met.

Conservation practice and policy has not yet 'maximised' the chances of the long term survival of the Leadbeater's possum as required for recovery planning under the EPBC Act.

6. CONSERVATION AND MANAGEMENT HISTORY

6.1. Existing conservation measures

Leadbeater's possum has been the subject of much conservation research and management activity extending for more than three decades. Much of this activity was framed by the previous Recovery Plan (Macfarlane *et al.* 1997), and overseen by a Leadbeater's possum recovery team. That conservation effort built a substantial legacy and foundation for current conservation activity. The recent review of that initial Recovery Plan (http://www.environment.gov.au/biodiversity/threatened/recovery-plans/comment/draft-recovery-plan-leadbeaters-possum) summarised that research and management effort, and the extent to which each action was implemented.

More recently, the Victorian Government has focused a major conservation management effort through the Leadbeater's Possum Advisory Group (LPAG), which was established in June 2013. LPAG was established to provide recommendations to government that aimed at 'supporting the recovery of the possum while maintaining a sustainable timber industry' in the Central Highlands. LPAG recommended a package of actions which aimed to slow the projected decline in population numbers in the Central Highlands, by providing protection to known colonies, protecting current high quality habitat, expanding future old-growth forest and possum habitat in the future, to proactively increase the availability of nest sites at selected locations (through provision of nest boxes and artificial hollows), and to support improving knowledge to more effectively implement management actions (Leadbeater's Possum Advisory Group 2014a). On 14 April 2014, the Victorian Government accepted all 13 recommendations and announced that it would invest $11 million to implement these over the following five years. While making important improvements to the conservation of Leadbeater's possum, due to the dual role of the terms of reference where the conservation measures needed to be within a sustainable timber industry, the package of actions recommended by LPAG did not extend as far as would have been possible if the focus was purely on the conservation of the species (Leadbeater's Possum Advisory Group 2014b). The effectiveness of the implementation of this package of actions is regularly assessed and will be formally evaluated in 2018 (Leadbeater's Possum Advisory Group 2014a).

The LPAG recommendations were incorporated into a revised Victorian Action Statement in 2014 which outlines the conservation measures that are currently in place for Leadbeater's possum (Department of Environment and Primary Industries 2014a). The aim of the Action Statement is to ensure that Leadbeater's possum can survive, flourish and retain its potential for evolutionary development in the wild. Further measures were introduced in 2015, including accelerating the LPAG targeted survey program to more quickly locate and protect an additional 200 Leadbeater's possum colonies, application of remote sensing techniques to map key habitat features, and the introduction of a risk-based pre-timber harvesting survey program deploying new survey methodologies.

Overall 34% of the potential habitat within the distribution of Leadbeater's possum is protected in dedicated Reserves (i.e. parks and reserves managed by Parks Victoria) (Leadbeater's Possum Advisory Group 2014b). The largest areas of reserved ash forest are in the Yarra Ranges National Park, which includes three extensive water catchments. The major sub-alpine (snow gum) woodland sites inhabited by Leadbeater's possum are protected within the Yarra Ranges National Park (Lake Mountain), Mount Bullfight Nature Conservation Reserve and Baw Baw National Park. The lowland swamp forest occupied by Leadbeater's possum is fully protected within the Yellingbo Nature Conservation Reserve (Department of Environment and Primary Industries 2014a).

A further 14% of the potential habitat of the species is protected in Special Protection Zones (SPZ) within state forest, resulting in 48% of the potential habitat area reserved in parks or SPZs. This includes a 'Leadbeater's possum reserve system' which was established in 2008 to protect priority areas of habitat, with the focus on old-growth forests as these were most likely to provide habitat into the future. This system comprises 30,500 ha of high quality habitat (Smith and Morey 2001), incorporating parts of the existing National Parks and with the areas in state forest incorporated into SPZs. All areas of mapped old-growth ash forest (> 5 ha) in the Central Highlands are protected in SPZs and are now buffered by 100 m to provide further protection (Leadbeater's Possum Advisory Group 2014b).

Within the remaining area of state forest that is available for timber harvesting, additional areas are excluded from harvesting due to biodiversity, regulatory, operational and prescriptive reasons (21% of the potential habitat of Leadbeater's Possum: Leadbeater's Possum Advisory Group (2014b)). Prescriptions for protecting high quality Leadbeater's possum habitat were first implemented in 1998 through the Central Highlands Forest Management Plan (Department of Natural Resources and Environment 1998) and updated through the Management Standards and Procedures for Timber Harvesting operations (Department of Environment and Primary Industries 2014c), established under the Code of Practice for Timber Production (Department of Environment and Primary Industries 2014b).

Mixed-aged forest with high densities of old trees are protected using Zone 1A prescriptions. Zone 1A habitat is defined as more than 10 live mature or senescent hollow-bearing ash trees per 3 ha, in patches greater than 3 ha. Zone 1B habitat is defined as more than 12 live or dead, hollow-bearing ash trees per 3 ha in patches greater than 10 ha and with wattle density exceeding 5 m^2/ha (Department of Environment and Primary Industries 2014a). Timber harvesting and associated roading is currently excluded from areas of forest meeting the criteria for Zone 1A or Zone 1B. The locations of SPZs are reviewed during periodic zoning reviews. Survey standards have been released to provide interpretation and guidance on the definition of Zone 1A and 1B (Department of Environment Land Water and Planning 2015b). Using these definitions there are only limited areas that now qualify as Zone 1 habitat in the Central Highlands.

To protect the species where it occurs in state forests outside these areas of high quality habitat, LPAG recommended a new measure to protect known colonies (Leadbeater's Possum Advisory Group 2014a). As a result, 200 m radius timber harvesting exclusion zones (12.6 ha in size), have now been established around the location of all Leadbeater's possum records since 1998, excluding those burnt with high fire severity in the 2009 fires. Exclusion zones are also being established around all new records, with LPAG recommending a review after 200 new records whose exclusion zones impacted General Management Zone or Special Management Zone in state forest, or after two years of intensive surveys, whichever came first. To facilitate the location of new records DELWP is conducting extensive targeted surveys and is working with the community and other organisations to obtain additional records. Within the first year of surveys in 2014-15, 116 new location records were obtained, 71 in state forest and 45 in national parks (Department of Environment Land Water and Planning 2015a).

DELWP's targeted surveys select sites based on areas where previous occupancy modelling (Lumsden *et al.* 2013) had predicted a high likelihood of the species occurring, and/or close to existing records of the species (Nelson *et al.* 2015). A two year timber harvesting moratorium (April 2014 to April 2016) was established for areas predicted to have a greater than 65% likelihood of the species occurring while surveys are undertaken, with harvesting deferred from 14,800 hectares of state forest. Of the 71 new records recorded in 2014-15 in state forest, 50 were from the DELWP targeted surveys, from sampling 113 sites (44%). There were records from all age classes sampled, including young regrowth from fires and timber harvesting (15 – 36 years old). Clusters of records and their associated timber harvesting exclusion zones are being developed to increase the size of the protected area to improve long term viability of these colonies (Nelson *et al.* 2015).

The establishment and regular checking of nest boxes has also progressed recently as a survey and monitoring tool, with particular applicability in sub-alpine woodland and lowland swamp forest habit and with varying success in montane forests (Harley 2016). Project Possum is a collaborative project between Parks Victoria, Zoos Victoria and the Friends of Leadbeater's Possum that aims to provide long-lasting nest boxes at strategic locations within Leadbeater's possum's range in the Central Highlands. As at January 2016, 414 nest boxes have been installed (245 in sub-alpine woodland and 169 in montane ash forest).

In implementing the LPAG recommendations (Leadbeater's Possum Advisory Group 2014a), VicForests is now undertaking regrowth retention harvesting on at least 50% of the area of ash harvested within the Leadbeater's possum range. Regrowth retention harvesting involves the retention of clusters of trees as habitat 'islands' or 'peninsulas' such that 50% of the coupe is close to retained forest. This design allows for some hollow-bearing trees to be preserved on coupes within the 60-80-year harvest rotation, and promotes a mosaic of old and young forest once the coupe has regenerated. This retained habitat can assist recolonisation of biodiversity to harvested areas over time. Trials are underway to test the effectiveness of alternative methods of regeneration after harvesting (Department of Environment Land Water and Planning 2015a), rather than the traditional 'regeneration' or 'slash burn' which can accelerate the decay and collapse of non-targeted hollow-bearing trees (Lindenmayer *et al.* 2013a; Lindenmayer *et al.* 2013b).

Intensive, widespread bushfires are a significant threat to the ongoing persistence of Leadbeater's possum. LPAG recommended actions aimed at increasing the protection of Leadbeater's possum colonies and habitat through intensified fire planning and management. Where possible and appropriate, active fire management activities will be used to protect identified colonies and high-quality habitat from bushfire, taking into consideration other threatened species requirements (Leadbeater's Possum Advisory Group 2014a). This includes suppression activities and fuel management in adjacent drier forest types. Strategic fuel breaks have been constructed to protect Melbourne's water supply from fire. To reduce the risk of these breaks fragmenting Leadbeater's possum habitat, bands of wattle and ash forest are retained at 100 m intervals in some areas, and removal of hollow-bearing trees is restricted (Department of Sustainability and Environment 2008b). Rope bridges are being trialled to investigate if these can reduce fragmentation impacts of fuel breaks and roads, with individuals observed using these to cross over roads (R. van der Ree *pers. comm.*).

Fire recovery protocols have been developed to assist in decision making and timely emergency management responses following bushfires. These protocols provide guidance on when intervention – such as providing additional nesting resources, supplementary food, artificial connectivity or translocation – is warranted. Following the severe impacts of the 2009 bushfires at Lake Mountain, additional nesting sites were provided and a supplementary feeding program undertaken over winter for three years following the fire. This was coordinated by Parks Victoria, with extensive volunteer participation from the Friends of Leadbeater's Possum group. The few remaining animals made extensive use of the supplementary food provided (J. Antrobus and D. Harley *pers. comm.*).

Long-term population monitoring and nest box provisioning has been underway for the last lowland population at Yellingbo since the mid-1990s, and in 2012 a captive-breeding program was established by Zoos Victoria to support the recovery of this genetic management unit (Harley 2012). The captive-breeding program is linked with a major habitat restoration program that is underway for both Leadbeater's possum and the helmeted honeyeater *Lichenostomus melanops cassidix*.

Since 2009, Parks Victoria and Greening Australia have undertaken targeted revegetation in active Leadbeater's possum territories at Yellingbo Nature Conservation Reserve to compensate for the loss of dense vegetation structure and lack of natural regeneration. During 2013-15, almost 400,000 stems were planted at Yellingbo by Greening Australia, Parks Victoria and the Friends of Helmeted Honeyeater. During 2015-18, a further 792,000 stems will be planted by Greening Australia, the Friends of Helmeted Honeyeater and

Healesville Sanctuary with funding from the Commonwealth Government's 20 Million Trees Programme.

Suitable floodplain forest is also being restored in the Coranderrk Bushland that adjoins Healesville Sanctuary, with future plans to release captive-bred Leadbeater's possums there so that the breeding program includes free-ranging individuals.

Parks Victoria is working with adjacent landowners to fence off stream frontages and phase out grazing from areas to be added to the Yellingbo Nature Conservation Reserve, to improve water quality and protect native vegetation (Department of Environment Land Water and Planning 2015a). A deer control program was introduced in 2014 to attempt to reduce browsing on the revegetation. In addition revegetation plots are being fenced to exclude deer and native browsers.

The earlier **Section 3. Background Information Informing Recovery Action** summarises a very substantial evidence base resulting from decades of intensive research on Leadbeater's possum and its environment. This research effort has been, and will continue to be, a crucial component of conservation management for this species. The historic and ongoing research effort is not reviewed here (see Harley (2016)), but this section briefly notes some recent and foreshadowed research activity that targets key knowledge gaps that, if filled, may substantially increase conservation management effectiveness.

- a radio-tracking study is being established to quantify den tree use, spatial habitat use and the habitat requirements of Leadbeater's possum in a regrowth dominated landscape, including how the use of regrowth habitat for foraging may depend upon the proximity of contrasting habitat that provides hollows (research undertaken by ANU);
- a study is being established to assess options for habitat manipulation, specifically the extent to which suitable understorey vegetation can be developed in areas with hollow-bearing trees but currently without a dense understorey layer (ANU);
- high resolution aerial photography and remote sensing technology (LiDAR) will be used for the fine-scale detection and mapping of particular critical habitat features, notably hollow-bearing trees and understorey density, across the Central Highlands range, to allow high resolution mapping of habitat suitability and improve spatial habitat models (DELWP with input from VicForests and University of Melbourne);
- studies are being undertaken on options for increasing hollow (nest site) availability in a range of environmental settings, and the effectiveness of such options (community groups, DELWP, University of Melbourne VicForests and Zoos Victoria).
- a project has been developed to investigate future genetic management options for the lowland population (Monash University, Zoos Victoria and DELWP);
- a study is investigating alternatives to high intensity regeneration burns after harvesting to protect retained habitat (VicForests);
- studies are being undertaken to understand the biodiversity response to the use of regrowth retention harvesting systems as an alternative to traditional clear fell techniques (VicForests and ANU);

- forest models are being developed to better understand the implications of management actions on spatial and temporal changes to forest structure (University of Melbourne, VicForests and DELWP).

6.2. Other previously proposed conservation initiatives

The conservation of Leadbeater's possum has attracted considerable interest from researchers, conservation organisations, and other non-government groups. Some conservation recommendations from these groups have been implemented, at least in part, through the recent Victorian Government initiatives (particularly through the Leadbeater's Possum Advisory Group process) described in section 6.1.

However, other conservation recommendations have not been implemented. As part of the LPAG process many recommended actions were evaluated for their likely contribution to the recovery of the species (Leadbeater's Possum Advisory Group 2014b). Some of these actions were subsequently excluded from their consideration because the LPAG process was predicated on the need to balance conservation and timber-harvesting objectives.

In this section, we provide a brief account of some recommendations proposed by non-government groups, in the context that these proposals have informed the objectives and actions described in section 7 of this plan.

A high profile recommendation from many conservation groups and some researchers has been for the establishment of a 'Great Forest National Park' that would very substantially increase the extent of the existing dedicated reserve system in the Central Highlands, and specifically include the vast majority of the distributional extent of the Leadbeater's possum (Lindenmayer (2013); http://www.greatforestnationalpark.com.au/park-plan.html). The most comprehensive of such proposals encompasses *and extends beyond* the distributional extent of the Leadbeater's possum, proposing the addition of ca. 355,000 ha of mostly montane ash forest to the existing ca. 180,000 ha of reserved area centred on the Central Highlands, with this addition including about 86% of the existing state forest extent (The Working Group for the Great Forest National Park 2015). The conservation status and needs of Leadbeater's possum form a principal basis of the rationale for this enhanced reserve system, although only part of this area is likely to contain Leadbeater's possum.

Another high-level conservation recommendation was that highlighted by the Threatened Species Scientific Committee in the Conservation Advice approved by the Australian Minister for the Environment:

> "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" (Threatened Species Scientific Committee 2015).

That Conservation Advice also noted that 'all populations of Leadbeater's possum are important' and recommended 'protecting all current and future Leadbeater's possum habitat'.

Additional to these broad recommendations, there have been some notable packages of specific recommendations aimed at enhancing the conservation outlook of Leadbeater's possum, mostly through seeking to further reduce the detrimental impacts of timber-harvesting upon its habitat (Lindenmayer *et al.* 2013a; Lindenmayer *et al.* 2013b; Lindenmayer *et al.* 2014a; Lindenmayer *et al.* 2015b). *Inter alia*, these include explicit guidelines to:

- provide greater protection to current and prospective old-growth forest;
- increase the rotation period for timber-harvesting;
- increase the size of the protective buffer area around known Leadbeater's possum colonies;
- be more inclusive in the definition of Leadbeater's possum Zone 1A habitat (i.e. to lower thresholds of density of hollow-bearing trees, and include dead hollow-bearing trees within the defining criteria);
- enhance protection and increase buffer areas around all large hollow-bearing trees;
- protect all existing old-growth ash forest and expand the future old-growth estate; and
- replace clear-felling with regrowth retention harvesting.

Consensus among experts has indicated that, if enacted, most of these recommendations would provide substantial benefits to Leadbeater's possum, including having a major impact in reducing the likelihood of their extinction (Leadbeater's Possum Advisory Group 2014b). For example, Leadbeater's Possum Advisory Group (2014b), concluded that a timber harvesting exclusion zone of 200 m radius around existing known colonies would have only a 'low to medium' impact on reducing extinction-risk, whereas increasing the exclusion zone to 500 m radius would have a 'medium' impact on reducing extinction-risk, and increasing it to 1 km would have a 'high' impact on reducing extinction-risk.

7. RECOVERY OBJECTIVES AND ACTIONS

7.1. Context

The recovery objectives and actions proposed here are informed by a set of general principles and requirements. These include:

(1) that the pre-eminent purpose of this Recovery Plan is to stop the decline and support the recovery of Leadbeater's possum so that its chances of long-term survival in nature are maximised, consistent with the stipulations of recovery planning under the *Environment Protection and Biodiversity Conservation Act 1999*;

(2) that decades of research and management activity have provided a robust evidence base for recovery, and such evidence has formed the basis of a considered assessment of the likely efficacy of possible recovery actions (Leadbeater's Possum Advisory Group 2014b). Recovery objectives and actions delineated here have been informed by this evidence base and will incorporate findings that arise from new and ongoing research;

(3) that while existing recovery actions have contributed to some conservation advances, they have been, and are likely to continue to be, insufficient to recover the species, hence a substantially new or more committed management response is required;

(4) that the overwhelming majority of the known population of Leadbeater's possum is confined to the Central Highlands montane ash forest, and that the development of effective conservation management actions – including reducing the risk of landscape-scale fire – for this species in this region is most critical to the species' likelihood of recovery;

(5) but that, on current trends, there is an unacceptably high risk of extinction for the species in this region, especially through extensive bushfire, and hence there is a need to try to spread this risk through attempts to establish subpopulations of the species in the most suitable habitat outside this region;

(6) that conservation effort needs to attempt to secure both the Central Highlands (montane ash and snow gum) subpopulations and the lowland swamp forest subpopulation (an Evolutionarily Significant Unit), with this latter one particularly at risk of imminent extinction;

(7) that conservation success will not be achieved by management actions alone, but will depend also upon refinement and complementarity of existing and future planning and policy settings, such that these contribute appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature; and

(8) that there remain important uncertainties about some candidate conservation management actions (such as translocation, effective fire mitigation options, accelerated hollow development), so this Recovery Plan should address these knowledge gaps and be flexible, responsive to new information, and capable of adaptive management.

7.2. Recovery objectives, actions and performance measures

7.2.1. <u>Long-term</u> recovery objective

To increase the extent, quality and connectivity of currently and prospectively suitable habitat, and its occupancy by Leadbeater's possum, in order to maximise the probability of persistence of the species.

Rationale: Conservation planning for Leadbeater's possum is a long-term proposition and commitment. Actions taken now to enhance its conservation status are unlikely to reverse the current decline in the extent of its suitable habitat or of its population over the 10-year period of this plan, but they will help to slow this rate of decline. These actions will provide a basis for promoting recovery and managing the species over the medium to long-term. And importantly, actions taken or not taken now will affect its likelihood of extinction over a 50 to 100 year timeframe.

Given some still existing substantial uncertainties about population size, the scale and impact of future threats and the likely benefits and practicality of potential actions, it is challenging at this stage to prescribe 'acceptable' and plausible target levels for the probability of long-term persistence of Leadbeater's possum. No matter what set of conservation actions are taken, it is unlikely that its long-term fate can be guaranteed (i.e. that those actions would result in a 0% probability of functional extinction over the next 100 years). A reasonable and realistic long-term target to help frame the short-term objectives in this Plan is that those actions should collectively so benefit this species that its probability of extinction over a 100-year period becomes less than 0.01 (i.e. 1%). Note that this target is less ambitious (but probably more realistic) than that described in the previous Recovery Plan, which was to downlist the species from endangered to vulnerable within 10 years, and for the species to have 'no more than a 1% probability of extinction over 250 years' (Macfarlane et al. 1997).

Performance criteria are listed in the section below for a set of objectives operating over the lifetime of this Plan. It is less meaningful to attempt to provide comparable criteria for the period beyond this plan, but the long-term objective described above would require the following outcomes:

- the total population size of Leadbeater's possum stabilises and then increases over a 20-50 year period from now;
- risks to Leadbeater's possum from catastrophe (notably extensive, severe bushfire) are managed effectively through securing viable subpopulations across an area that is at least as extensive as its distribution immediately prior to the 2009 bushfires;
- the extent and continuity of high quality habitat and old-growth forest is substantially increased;
- there is an ongoing commitment, with appropriate resourcing, to effective and enduring management of threats to this species, including effective management that results in a pattern of bushfire frequency and severity that is less detrimental to this species (and its forest environment) than that presently prevailing;
- the distinctive subpopulation in the lowland swamp forest is retained and its population size and the extent and suitability of its habitat are substantially greater than at present.

7.2.2. Recovery objectives, actions, outcomes and performance criteria <u>for the lifetime of this Plan</u>

The sections below describe a set of objectives, each with associated actions, performance criteria and timeframes for key deliverables. Note that not all deliverables are necessarily listed for each action.

The objectives and actions proposed in this section should be considered as an integrated and coherent package. These objectives and actions span a broad gamut of policy, management, research and other components, recognising the high profile but complex conservation context for this species. The set of objectives and actions described here includes all or components of conservation actions developed through the recent LPAG process and implemented through the Victorian Action Statement for this species (Department of Environment and Primary Industries 2014a), but the set described here also significantly extends these actions and includes new actions. This set of actions does not necessarily include all actions recommended outside the LPAG process (i.e. those described in section 6.2), but includes components of these and encompasses those components within a broader package that should collectively secure the conservation future for this species.

All of the actions and objectives in this plan will contribute significantly to the conservation of Leadbeater's possum, and all individual actions are of high priority and need to be implemented. However, to assist in the orderliness of this implementation, actions are labelled (see section 8.1) as either 'urgent' (i.e. the conservation future of the species depends upon this action being implemented), 'essential' (i.e. the conservation future of the species will be jeopardised if this action is not implemented), or 'highly beneficial' (i.e. this action will contribute to the conservation future of this species).

<u>Objective 1</u>: All relevant existing and future planning and policy settings are reviewed and where required, refined and implemented in a manner that contributes appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature.

Rationale: Management actions alone will not be sufficient to recover the Leadbeater's possum: that objective also needs harmonisation of existing and future planning and policy settings such that they collectively and coherently contribute appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature.

> *Action 1.1. Review and, where required, revise existing relevant planning and policy settings to ensure that they provide for maximising the chances of long-term survival of Leadbeater's possum.*
>
> *Action 1.2. Ensure that future relevant planning and policy settings provide for maximising the chances of long-term survival of Leadbeater's possum.*
>
> *Action 1.3. Ensure coordination between relevant planning and policy settings to maximise the chances of long-term survival of Leadbeater's possum.*

Performance criteria

1. All relevant plans and policy are compatible with, coordinated and contribute effectively to, the objective of maximising the likelihood of long-term survival of Leadbeater's possum.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	All key relevant policies and plans are assessed to identify settings or practice that may contribute significantly to, or may be inconsistent with, the successful implementation of this Recovery Plan (*Action 1.1*). Any new key relevant policies and plans take accord of, are consistent with, and contribute significantly to the implementation of this Recovery Plan (*Action 1.2*) **
By end of 2nd year of this Plan	Settings in all key relevant policies and plans are refined to ensure alignment with this Recovery Plan, and effective coordination across plans and policies to achieve the Recovery Plan's objectives (*Actions 1.1 and 1.3*) **
By end of 5th year of this Plan	
By end of 10th year of this Plan	

** Action is ongoing thereafter

<u>Objective 2</u>: 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.

Rationale: The key conservation concern for Leadbeater's possum is ongoing decline in the extent, quality and connectivity of suitable habitat. This objective seeks to focus explicitly on the maintenance and management of habitat that is currently suitable, and habitat that will become suitable in the future. Where appropriate, retention of habitat should be through an increase in the dedicated reserve system to improve that system's adequacy, supported by complementary state forest informal reserves and values protected by prescriptions. A whole of landscape management planning approach is needed to identify, secure and effectively manage habitat as well as mitigating landscape and other threats, including capacity to respond to emergency events such as severe extensive fire.

This objective relates to the nub of the conservation challenge for Leadbeater's possum: in a highly dynamic landscape and with some substantial uncertainties, how to define, retain and manage sufficient areas of suitable habitat over periods of many decades to provide for the conservation security for the species. The approach adopted here to address this problem is to maintain or enhance existing protective mechanisms at least until a dynamic land-use planning exercise is implemented that pivots explicitly on the requirement that sufficient habitat is retained and managed to provide a high level (99%) of confidence that the species will persist in nature over at least a 100 year period.

Note that, except where stipulated, all actions contributing to this objective relate to the Central Highlands.

> *Action 2.1. Enhance existing levels of protection for areas in which colonies are not known but may be present, by undertaking pre-harvest surveys in all coupes prior to proposed timber harvesting. If these surveys detect Leadbeater's possum, the colonies must be protected from harvesting.*
>
> Under the implementation of the Leadbeater's Possum Advisory Group recommendations, a 2 year timber harvesting moratorium (which commenced April 2014) was placed on areas predicted to have greater than a 65% likelihood of the species occurring (from ARI occupancy modelling), to enable targeted surveys to be undertaken. At the end of 2015, a broader risk-based approach commenced whereby VicForests would undertake pre-logging surveys at coupes considered to have a high probability of the species being present, based on a range of criteria including proximity to existing records. Given (i) that a large proportion of the species' range occurs in state forests; (ii) much of the species' total population probably occurs in state forests; (iii) that recent surveys have found previously unknown Leadbeater's possum colonies in areas proposed for harvesting (Nelson *et al.* (2015), and (iv) the critically endangered status of this species means that all (not just those considered high priority) proposed timber harvesting coupes within ash forest in the Central Highlands should be surveyed before any harvesting activity. No harvesting should be allowed at any site unless comprehensive pre-logging surveys – using guidelines in the Leadbeater's possum survey standards (Department of Environment Land Water and Planning 2015b) – demonstrate, with a high level of confidence, the absence of Leadbeater's possum.

Action 2.2. Assess the feasibility, risks and cost-effectiveness of fire management options that seek to deliver long-term, strategic and landscape scale enhancement of the extent and quality of current and prospective suitable habitat. Develop and implement fire management that effectively secures and promotes long-term, strategic and effective protection of known colonies and suitable habitat.

This Action relates to populations across the entire range, including the sub-alpine (snow gum) woodlands and lowland swamp gum forest habitats. It addresses the primary threat to the possum and its habitat. This action will build on the East Central Bushfire Risk Landscape management plan (Department of Environment and Primary Industries 2014d), which encompasses all of the Leadbeater's possum range. This plan assessed the bushfire risk to known Leadbeater's possum colonies and high quality habitat, and modelled the extent to which fuel management in adjacent areas reduced this risk.

In implementing this action, management needs to evaluate options relating to short- and long-term planning, local and landscape scales, cost-effectiveness, and risks. It needs to consider pre-emptive fire management actions, responses to bushfires, and post-fire remediation, within the context of the objectives of the Code of Practice for Bushfire Management on Public Land (Department of Sustainability and Environment 2012).

Action 2.3. Enhance existing levels of protection for important habitat features by protecting and buffering all live and dead hollow-bearing trees in montane ash forests within the distribution of Leadbeater's possum.

Large hollow-bearing trees (dead or alive) are a fundamental defining feature of suitable habitat for Leadbeater’s possum, but are a rapidly declining resource. At present, these are offered some, but not necessarily effective, protection under timber harvesting prescriptions. All large, live and dead hollow-bearing trees in montane ash forests within the distributional range of Leadbeater’s possum should be protected using in-field prescriptions, with adequate buffers of uncleared vegetation around them. A set of tractable, explicit and operational, definitions of large, live and dead hollow-bearing trees need to be determined (based on appropriateness for Leadbeater’s possum and other hollow-dependent fauna), as does the most appropriate size for their protective buffer.

Action 2.4. Review the conservation effectiveness of timber harvesting regulatory prescriptions and related guidelines relevant to the protection of known Leadbeater’s possum colonies and habitat, and refine these prescriptions and guidelines to provide more effective conservation outcomes.

Under existing management processes, all known colonies and high quality habitat in the form of Zone 1A and 1B are currently afforded some protection in state forest through timber harvesting zoning and prescriptions using a detection-based approach to locate these areas. However, the current levels of protection do not provide the maximum possible conservation security for Leadbeater’s possum (Leadbeater’s Possum Advisory Group 2014b). Therefore, all timber harvesting regulatory prescriptions and related guidelines relevant to Leadbeater's possum and its habitat need to be reviewed, to reduce the impacts of timber harvesting activities on the viability of Leadbeater’s possum colonies and high quality habitat. Such enhancement should involve increase in the buffer size and other protective mechanisms around known colonies and high-quality habitat.

This Action seeks to ensure state forest continue to play an integral role in the long-term conservation of the species by protecting known colonies. While this review and the landscape scale modelling approach for protecting broader areas of habitat (Action 2.6 and 2.7) are being undertaken, at least the existing levels of protection for all known colonies and high quality habitat should be maintained.

Action 2.5. Refine and update occupancy and other relevant distributional and population viability modelling across the full range of the species (incorporating finer-scale mapping of key habitat attributes, such as large hollow-bearing trees and understorey density).

This is the foundation for a land-use (conservation) planning exercise at a landscape scale (rather than based on the detection of individual colonies or Zone 1 habitat). It will require (i) an updating of spatial habitat models across the full range of the species (including the occupancy model developed in Lumsden *et al.* (2013) and broader habitat distribution models, to incorporate new information arising from the substantial survey effort since then (e.g. Nelson *et al.* (2015)); (ii) complementing that modelling with non-spatial habitat modelling developed by Lindenmayer and colleagues; and (iii) testing these models through additional structured surveys.

Following refinement (and testing) of these distributional models, they then need to be linked to population viability and other dynamic modelling, to project, predict and map the distributional extent of suitable habitat under a range of disturbance regimes over at least a 100 year period.

Action 2.6. Based on models developed in Action 2.5, undertake landscape scale land-use planning that provides options for conservation of suitable habitat now and in the future to ensure an acceptably high likelihood of persistence (i.e. at least 99% over 100 year period) for Leadbeater's possum.

This action will enable a landscape-scale approach to determine appropriate protection, in addition to the location and protection of known Leadbeater's possum colonies. Given the distributional and viability models developed in Action 2.5, this Action seeks to determine options to achieve the appropriate mix of additional dedicated reserves, informal reserves and values protected through prescriptions in the remaining areas of state forest that will be required to meet the long-term objective of being at least 99% confident that the species will persist in the wild for at least 100 years. That objective should be the numerical target of this planning, but a subsidiary objective is to strategically develop and maintain a substantial increase in the extent of old-growth forest.

Action 2.7. Expand the dedicated 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.

The conservation future of Leadbeater's possum will depend upon a complementary mix of dedicated reserves, informal reserves and protection of values through prescriptions. However, all else being equal, dedicated reserves are likely to provide greater conservation security and more confidence in conservation outcomes than unreserved lands that may be subject to timber harvesting with variably effective management prescriptions. Lumsden *et al.* (2013) used projective population modelling to demonstrate that the current reserve system alone is inadequate for the long-term conservation of Leadbeater's possum, and especially so when incorporating the likelihood of future extensive bushfires. Accordingly, there is scope and need for substantial enhancement of the existing dedicated reserve system, to recognise its primary role in providing for the long-term persistence of the species. Substantial expansion of the current reserve system informed by Actions 2.5 and 2.6 should seek to encompass all areas of high likelihood of occurrence of the species (currently and prospectively). It should also include areas of current and projected old-growth forests; and such expansion should increase the connectivity of the reserve system, as well as protecting a range of other values.

Action 2.8. Assess the practicality and effectiveness of habitat augmentation including the provision of nest boxes, artificially excavated hollows, or manipulation of understorey. Where benefits can be obtained effectively, strategically implement these to enhance the current and projected extent of suitable habitat in the Central Highlands.

This Action relates to all land tenures in the Central Highlands and is based on the premise that the current and projected extent and quality of suitable habitat is a major limiting factor, and that active management may be able to support the persistence of colonies where den sites are declining and provide some increase in the extent of suitable habitat.

Note that this Action links also to research Action 5.3, that seeks to assess the benefit, practicality and cost-effectiveness of such habitat augmentation measures.

Action 2.9. Enhance habitat suitability and extent for lowland swamp forest habitat.

Currently, there is a lack of eucalypt regeneration in the floodplain at Yellingbo, and habitat management and restoration is required to increase the amount of structurally dense forest to provide additional foraging habitat and connectivity. This includes hydrological restoration in the floodplains of the Cockatoo and Macclesfield Creeks and the development and application of a disturbance regime to promote the regeneration of dense stands of canopy and middle-storey species on the floodplain and terraces immediately adjacent to the floodplain. Until appropriate broad-scale disturbance mechanisms are developed, manual revegetation should be undertaken in priority sites, notably those currently supporting Leadbeater's possum colonies, at Yellingbo (and in similar suitable sites in the vicinity). The long-term target is to provide at least 80 hectares of suitable foraging habitat for Leadbeater's possum in the reserve, and hence to reverse the current decline of the subpopulation in lowland swamp forest.

Performance criteria:

1. Timber harvesting occurs only in sites known not to contain Leadbeater's possum.

2. Options for fire management are better evaluated for impacts on Leadbeater's possum, and fire management policy, planning and actions are implemented in a manner that minimises risks to the viability of Leadbeater's possum, and reduces the likelihood of extensive and severe bushfires.

3. All large, live and dead hollow-bearing trees are adequately protected from timber harvesting.

4. Timber harvesting prescriptions and guidelines are reviewed and refined appropriately to provide more effective protection for high quality habitat and known colonies.

5. An enhanced spatial distribution model, and a spatially-explicit population viability model, are developed and form a robust basis for current and future conservation planning.

6. Areas that can provide suitable habitat now, and over the next 50 years are modelled, mapped, and excluded from timber harvesting.

7. Sufficient additional areas of current and prospective suitable habitat are incorporated in an expanded dedicated and informal reserve system to ensure that the system maximises the likelihood of persistence of Leadbeater's possum, over at least a 100-year period.

8. The effectiveness of nest boxes, artificially excavated hollows and manipulation of understory is understood and these management actions are implemented where appropriate.

9. Active habitat management and restoration at Yellingbo (and similar nearby areas) provides increased habitat extent and suitability.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	Guidelines and regulatory processes are established to ensure that adequate surveys are undertaken in all areas of ash forest within the range of the species prior to timber harvesting so that harvesting only occurs in sites known not to support Leadbeater's possum (*Action 2.1*). The risks, consequences and effectiveness for Leadbeater's possum viability of fire management options are evaluated (*Action 2.2*). New prescriptions are developed to ensure that all large, live and dead hollow-bearing trees are effectively protected from timber harvesting operations (*Action 2.3*). Existing timber harvesting prescriptions and guidelines are reviewed and resulting changes are implemented through changes to guidelines and regulatory processes (*Action 2.4*). Improved distributional models are developed that combine distribution and habitat models developed by Victorian government

	and ANU researchers, and incorporates substantial new data from recent surveys and mapping of additional habitat features (*Action 2.5*).
By end of 2nd year of this Plan	A long-term strategic fire management plan for the Central Highlands is developed or refined that identifies key risks, key biodiversity assets for protection, effective management to reduce likelihood of extensive high intensity fire, effective responses to asset protection during high intensity fire, and effective emergency recovery post-fire (*Action 2.2*). Dynamic population viability modelling is refined such that likelihood of extinction can be calculated robustly across a range of reservation and management options, and across a range of plausible future disturbance episodes. This modelling is then linked to distributional modelling to identify reservation and management scenarios that provide an acceptably low risk of extinction (<1% probability) over a 100-year period (*Action 2.5*). The reserve system is expanded consistent with distribution and population viability models, and land-use planning to a level that provides confidence that long-term risks of extinction are acceptably low (*Action 2.6 and 2.7*). Based on evidence from research (i) the effectiveness of habitat augmentation measures is assessed, (ii) sites are identified where augmentation can contribute most significantly to the long-term persistence of Leadbeater's possum, and (iii) a long-term strategic program of habitat augmentation is implemented, such that this contributes most effectively to persistence (*Action 2.8*).
By end of 5th year of this Plan	Active restoration and related activities provide the basis for long-term increase in the extent of suitable habitat for Leadbeater's possum in the Yellingbo reserve and similar nearby areas (*Action 2.9*).
By end of 10th year of this Plan	Enhanced reservation and effective management of adequate areas of unreserved habitat provides an acceptably low risk of extinction (e.g. <1% probability) over a 100-year period (*Multiple actions*).

<u>Objective 3</u>: Where there is net long-term benefit (i.e. likelihood of increase in overall population viability), translocate individuals or colonies *within* and adjacent to the known range.

Rationale: The distribution of Leadbeater's possum is fragmented, and probably increasingly so. Some small isolated subpopulations are likely to have especially low viability. There is probably little effective natural dispersal of individuals of this species over distances of more than 10 km. In addition, because of past events, some currently suitable habitat may now be unoccupied, or areas will become suitable in the near future (e.g. parts of the area burnt in the 2009 fires). Strategic translocations within the known range may decrease population fragmentation, and increase subpopulation viability and occupancy of suitable habitat. It is prudent to carefully trial such translocations early in the plan, given the likelihood of greater need for such actions in the future as the population size declines and becomes increasingly fragmented.

> *Action 3.1. Identify priority areas within and adjacent to the known range to which translocations may provide benefit to the possum's population viability. Assess the risks, potential impacts upon existing subpopulations, benefits, likelihood of success, and cost-effectiveness of translocation options. Develop appropriate protocols for use and implementation of translocation (most likely 'wild-to-wild' introductions).*

> *Action 3.2. Assess the risks, benefits, practicality, cost-effectiveness and consequences of 'gene pool mixing' to increase the viability of the lowland sub-population.*

> *Action 3.3. Where Actions 3.1 and 3.2 indicate likelihood of net benefit, undertake carefully monitored trial translocations, and – if successful – extend translocations to other priority areas.*

Performance criteria:

1. Assessment is completed that identifies where translocation may be valuable within the known range, and evaluates risks, costs, and benefits of translocation options.

2. Translocation protocols are developed and trialled.

3. 'New' colonies or subpopulations within the known range are established through translocation.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	Protocols and guidelines (that describe the feasibility, risk assessments, evaluation of costs and benefits, and recommended procedures) for translocation are developed (*Action 3.1)*.
By end of 2nd year of this Plan	Where net benefit is expected, priority sites for translocation within and adjacent to the Central Highlands are identified (*Action 3.1)*. The use of gene pool mixing as a management option for the lowland population is carefully evaluated (with consideration of risks, costs and benefits, and with appropriate community consultation); and explicit guidelines are established for if, when and how it should be used to contribute to enhancement of the long-term viability of the lowland population (*Action 3.2)*.
By end of 5th year of this Plan	Where net benefit is expected, at least three trial translocation projects are undertaken (*Action 3.3*).
By end of 10th year of this Plan	Translocated populations are effectively established and contribute significantly to overall long-term population viability (*Action 3.3*).

<u>Objective 4</u>: Seek to locate, or establish, additional populations outside the core range of the Central Highlands.

Rationale: The conservation future of Leadbeater's possum within its known range in the Central Highlands is precarious. Its overall conservation outlook is likely to be improved by seeking to spread extinction risks by establishing additional populations outside this known range, while the current population size may still allow for such translocation.

> *Action 4.1. Using recently developed survey approaches, survey potentially suitable areas (in Victoria) – including the areas predicted by habitat modelling to provide suitable habitat and/or where there are previous unverified records – outside the known range.*
>
> *Action 4.2. If such surveys locate 'new' existing populations (beyond the Central Highlands), assess their status, population size, genetic affinities, habitat relationships, extent of suitable and prospective habitat and management requirements; and implement such management.*
>
> *Action 4.3. If such surveys fail to locate existing populations, identify the most suitable candidate areas for translocation.*
>
> *Action 4.4. Assess the welfare risks, likelihood of success, cost-effectiveness, and potential impacts upon existing populations of translocations to those areas outside the current range considered most practical and likely to result in the establishment of new viable subpopulations. If considered to have significant benefits, implement such translocations.*
>
> Note that this Action links to Actions 3.1 and 3.3. Any translocation should be consistent with relevant legislation and IUCN guidelines, and consistent with trial translocation protocols developed under Action 3.1 above.

Performance criteria:

1. Areas of highest prospectivity for Leadbeater's possum outside the Central Highlands are identified and surveyed with appropriate methods.

2. Assessment of the likely benefits, risks and feasibility of translocation to new areas assists with decision-making processes.

3. 'New' subpopulations are established through translocation to suitable habitat.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	At least 10 priority areas considered most likely to contain populations of Leadbeater's possum outside the current known range are identified, and surveyed adequately using appropriate protocols (*Action 4.1*).
By end of 2nd year of this Plan	A further 10+ priority areas considered most likely to harbour populations of Leadbeater's possum outside the current known range are identified, and surveyed adequately using appropriate protocols (*Action 4.1*).

	If Action 4.1 results in location of new populations outside known range the status (including abundance, habitat requirements, range extent, threats) is assessed, and appropriate conservation management responses are developed and implemented (*Action 4.2*). If Action 4.1 fails to locate new populations outside known range, using habitat suitability modelling, preliminary survey and risk spreading principles, at least five sites (outside the current known range) with highest potential for translocation are identified; and translocations options for these sites are assessed. (*Action 4.3*).
By end of 5th year of this Plan	At least three trial translocation projects are undertaken (*Action 4.4*).
By end of 10th year of this Plan	Translocated populations are effectively established, and contribute significantly to overall long-term population viability (*Action 4.4*).

<u>Objective 5</u>: Targeted research addresses key knowledge gaps such that management options are better informed and management actions more effective.

Rationale: Notwithstanding several decades of intensive research, there remain some key knowledge gaps that constrain conservation management effectiveness. In some cases, where that research closely relates to other management objectives, the research actions are described within those objectives (e.g. Actions 2.2, 2.5, 2.8, 3.1, 3.2, and 4.1). Note that the actions described here should not be seen to limit research options. Other currently established or proposed research actions will also contribute to the objectives of this Plan.

Action 5.1. Establish an ongoing research forum to enhance existing collaboration among researchers, and between researchers, managers and other interested parties, to make the most effective use of research actions and to identify and address any further key knowledge gaps.

Action 5.2. Undertake research that provides more robust knowledge of key demographic and other ecological characteristics relevant to conservation management, specifically including dispersal characteristics and population size.

Action 5.3. Investigate key aspects of the post-fire ecology of Leadbeater's possum. This research should include at least: (i) assessing current hollow availability and the importance of large dead and any live hollow-bearing trees in the burnt landscape; (ii) investigating hollow development within trees that were 1939 regrowth before being burnt to determine their potential to provide nesting sites into the future; and (iii) investigate persistence of colonies within fire refuges surrounded by burnt areas , to determine if they will be effective sources for natural recolonisation or if translocations will be required to accelerate recolonisation of the regenerated burnt areas.

Action 5.4. Design and implement experimental trials that rigorously assess the relative benefits of prescriptions, actions and other management options, in a manner that allows results to inform ongoing refinement of those prescriptions and actions and the Plan itself.

Performance criteria:

1. Critical knowledge gaps are identified and filled, and management applies this knowledge and is demonstrably more effective.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	A regular research forum is established for all key researchers and stakeholders to (i) help coordinate research; (ii) identify key knowledge gaps; (iii) effectively disseminate new information from research; (iv) guide effective uptake of knowledge to management; and (v) help resolve contested research findings or implications (*Action 5.1*).
By end of 2nd year of this Plan	The status of subpopulations within fire refuges has been assessed to determine their short-term persistence prior to the surrounding areas becoming suitable habitat (*Action 5.3*).
By end of 5th year of this Plan	The size of the total population and individual subpopulations is reliably estimated, and used with population viability analysis to help guide management responses (*Action 5.2*). Using an adaptive management framework, the effectiveness of key actions within this plan has been experimentally tested and the actions revised where appropriate (*Action 5.4*).
By end of 10th year of this Plan	The status of subpopulations within fire refuges has been assessed to investigate longer term persistence and the extent to which animals have recolonised the surrounding regenerating forest (*Action 5.3*).

Objective 6: An integrated monitoring program is effectively implemented (and maintained) that publicly reports in a timely manner on possum status, existing and prospective habitat extent, quality and connectivity, and effectiveness of management actions.

Action 6.1. Collate existing monitoring data and programs (for population trajectories, extent and suitability of habitat, and management effectiveness). Maintain, enhance or develop new monitoring programs to ensure an integrated monitoring and survey program across all tenures and management zones and develop an effective public reporting of monitoring results.

Action 6.2. Identify key trigger points or thresholds in monitoring results that would catalyse priority emergency response (and identify such emergency response options).

Action 6.3. Where translocations are proposed (see Actions 3.3 and 4.4 above), design translocation trials in a manner that allows for reporting on success or failure, and those factors that contribute to this fate. Monitor those trials, and use results to refine the efficacy of translocation protocols, or to assess critically whether they are of net benefit.

Action 6.4. Monitor the extent of success (including cost-effectiveness and collateral benefits) of management actions individually and collectively, and use such information as appropriate to refine actions.

Performance criteria

1. An integrated monitoring program reports effectively, regularly and publicly on key measures, including relative abundance population trends, extent of suitable habitat, and management effectiveness.

2. Management actions are reviewed in response to evidence from monitoring, and revised accordingly.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	An integrated monitoring program is developed (based on coordination or complementarity of existing, enhanced and new monitoring components), with such program including (i) timely public reporting on trends in possum abundance, key habitat features (e.g. extent of old-growth forest, abundance of large hollow-bearing trees) and extent of success of management actions, (ii) explicit trigger points for defined emergency responses; and (iii) secure commitment over at least the lifetime of this Plan (*Actions 6.1, 6.2*) A process is developed and implemented (e.g. a website) to regularly provide updates to the public on progress of implementing the actions in this Recovery Plan (*Action 6.1*)
By end of 2nd year of this Plan	Integrated monitoring program implemented, with appropriate and timely public reporting on trends in possum abundance, key habitat features and extent of success of management actions (ongoing) (*Actions 6.1, 6.2, 6.4*). Design completed for experimental translocation and associated monitoring options (*Action 6.3*).
By end of 5th year of this Plan	Monitoring associated with experimental translocation is implemented with appropriate and timely public reporting on success or failure (*Action 6.3*). Translocation trials are reviewed for effectiveness (*Action 6.3*).
By end of 10th year of this Plan	The package of actions presented in this plan is evaluated collectively to determine their overall effectiveness (*Action 6.4*).

<u>Objective 7</u>: All stakeholders support and where relevant are involved in the implementation of the Plan.

Action 7.1. Establish (or build from existing mechanisms) and maintain an effective recovery team or similar governance model to oversee implementation of the Recovery Plan, and ensure effective and timely operation of such a team.

Action 7.2. Involve the community in Leadbeater's possum recovery.

Action 7.3. Provide enhanced opportunities for the participation of Indigenous groups in research, monitoring, management and other components of this Plan.

Action 7.4. Promote and publicise the Recovery Plan and recovery effort.

Performance criteria:

1. Effective governance is established and there is clarity around roles and responsibilities.

2. Community awareness of, support for, and participation in Leadbeater's possum recovery is increased.

3. Indigenous groups have the opportunity to play a substantial role in the implementation and oversight of conservation management for Leadbeater's possum.

4. Public information and education materials and programs are developed and implemented, to the satisfaction of all relevant interest groups.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	Key stakeholders identify and implement the most effective ongoing governance operation of this plan (*Action 7.1*). Indigenous groups scope their involvement in implementation of this plan (*Action 7.3*). *Multiple actions*. A stakeholder forum is established to support community engagement in the plan's implementation; particularly to (i) identify, establish and coordinate engagement opportunities; (ii) coordinate and disseminate information more broadly; (iii) monitor and measure success of engagement action; (iv) establish on-going reporting to governance model established (under *Action 7.1*)
By end of 2nd year of this Plan	The implementation of this plan appropriately involves Indigenous groups in a manner and to the extent sought by them (*Action 7.3*).
By end of 5th year of this Plan	A stakeholder forum reviews, quantifies and evaluates the extent to which community awareness of, support for, and participation in Leadbeater's possum recovery has increased. This will inform the 5 year Recovery Plan review (Action 8.4) (*Multiple actions.*)
By end of 10th year of this Plan	

<u>Objective 8:</u> Ensure effective and adaptive implementation and management oversight of the Plan including adequate resourcing.

Action 8.1. All partners in the Plan coordinate and adequately resource implementation to achieve objectives through adaptive management and cost-effective delivery.

Action 8.2. Establish appropriate governance and protocols to be able to respond to emergency events.

Action 8.3. Monitor the extent of implementation of management actions.

Action 8.4. Report regularly on performance effectiveness of this Recovery Plan, including a formal review at 5 years, and adapt as required.

Performance criteria:

1. The plan's progress and success is regularly assessed and reported, explicitly including a five-year review of the Recovery Plan.

2. Resources are adequate to implement the Plan.

3. Managers, researchers and others respond capably and in a timely manner to unforeseen events.

Deliverables

Timing	Outcome
By end of 1st year of this Plan	Resourcing secured for Plan implementation (*Action 8.1*).
By end of 2nd year of this Plan	
By end of 5th year of this Plan	Comprehensive interim review completed of the implementation and success of this Recovery Plan, with recommendations for adaptive changes (*Action 8.4*).
By end of 10th year of this Plan	Comprehensive review completed of the implementation and success of this Recovery Plan, with this review informing the development and implementation of a new Plan (*Action 8.4*).

8. PLAN IMPLEMENTATION

8.1. Implementation schedule and costs

Implementation of this Plan will require commitment and effective coordination and collaboration between key stakeholders and partners. A recovery team or similar governance model (Actions 7.1 and 8.1) will be the key mechanism to facilitate recovery coordination and identify funding opportunities. Implementation partners are identified for each action (Table 4) and broadly include government agencies with statutory responsibilities to protect and manage Leadbeater's possum and its habitat, zoos, forest-based industry groups, community organisations, Indigenous communities and research institutions.

Implementation partners will ensure that any risks associated with implementing actions are identified and managed, and that adaptive management underpins all actions. Adaptive management and prioritisation decisions will be made by the responsible organisations, in consultation with key partners and the recovery team to ensure any changes are consistent with and progress the Recovery Plan objectives. It is the responsibility of organisations implementing actions to report on implementation through the proposed governance and reporting structure.

Implementing this Plan is subject to budgetary and other resource constraints affecting the key stakeholders. The cost of implementing this Plan should where possible be incorporated into the core business expenditure of the affected organisations and through additional funds obtained for the explicit purpose of implementing this Recovery Plan. Some actions, or parts of actions, are being implemented through other Leadbeater's possum conservation efforts (see Section 6.1). Additional investment in this Recovery Plan will augment these and ensure coordination of effort to meet plan objectives. Other proposed actions are new and funding opportunities are yet to be secured. It is expected that the responsible Victorian and Commonwealth agencies will use this plan to collaborate in prioritising action and investment to protect Leadbeater's possum and enhance its recovery.

The implementation costs in Table 4 are indicative only and are based on estimates from comparable actions undertaken or underway as part of the ongoing Leadbeater's possum conservation effort. Costs also draw upon the relative indicative costs identified by the Leadbeater's Possum Advisory Group (2014a). It is not practical at this point to provide meaningful costing figures for actions beyond year five. Significant investment in actions, particularly in the first three years is required to establish the foundation for ongoing conservation effort and will provide more realistic indications of ongoing implementation costs. Indicative costs for actions beyond the fifth year will therefore be developed as these initial actions are implemented and will inform the five year review.

Once the Recovery Plan is in place, a detailed implementation plan is to be negotiated by implementation partners through which agreement is reached on partner contributions to the implementation of actions. Annual and where possible ongoing budgets should be identified, coordinated and secured by the implementation partners with timing and reporting processes consistent with the proposed timeframes and the priorities identified in Table 4. This implementation plan will identify and commit responsible partners to agreed actions and be facilitated by the recovery team or other governance model. Because actions are to be implemented adaptively, priority, timing and cost estimates may change during implementation.

Priorities:
All proposed actions will collectively contribute to the ongoing recovery needs of Leadbeater's possum and all individual actions are considered priorities for implementation. However, the extent of implementation will be subject to budgetary and other resource constraints. To guide implementation decisions and adaptive responses to any such resource constraints, actions are assigned priorities:

> **urgent** – the conservation future of the species depends upon this action being implemented;
> **essential** – the conservation future of the species will be jeopardised if this action is not implemented;
> **highly beneficial** – this action will contribute to the conservation future of this species.

Table 4: Indicative time frames, priorities and estimated costs ($000's) of recovery actions over the first five years of implementation .

Actions[#]	Priority	Implementation partners	Indicative cost and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
1.1 Review and, where required, revise existing planning and policy settings	Urgent	DELWP, AG	$700	$700	$200			$1600
1.2 Ensure that future relevant planning and policy settings maximise the chances of long-term survival	Urgent	DELWP, AG	$50	$50	$50	$50	$50	$250
1.3 Ensure coordination between relevant planning and policy settings	Essential	DELWP, AG	$20	$20	$20	$20	$20	$100
2.1 Enhance protection for colonies by undertaking surveys in all coupes prior to timber harvesting.	Urgent	DELWP, VF	$1000	$1000	$1000	$1000	$1000	$5000
2.2 Assess the feasibility, risks and cost-effectiveness of fire management options and implement fire management to protect known colonies and suitable habitat	Urgent	DELWP, VF, PV	$200	$200	$50	$50	$50	$550
2.3 Enhance existing level of protection for hollow-bearing trees	Urgent	DELWP, VF	$400					$400
2.4 Review timber harvesting regulatory prescriptions and guidelines, and refine these to provide more effective conservation outcomes	Urgent	DELWP	$50	$50	$50			$150
2.5 Refine and update occupancy and other relevant distributional and population viability models	Urgent	DELWP, Uni	$700	$700				$1400
2.6 Undertake landscape scale land-use planning that provides options for conservation of suitable habitat	Urgent	DELWP, AG		$50	$50			$100
2.7 Expand the dedicated reserve system to incorporate sufficient areas of current and prospective suitable habitat	Urgent	DELWP, AG, PV,		TBD	TBD	TBD		
2.8 Assess the practicality and effectiveness of habitat augmentation (nest boxes, artificially excavated hollows, manipulation of understorey), and strategically implement	Urgent	DELWP, AG, Uni, VF, PV, Zoos, CC	$300	$300	$300			$900
2.9 Enhance habitat suitability and extent for lowland swamp forest habitat	Essential	DELWP, AG, PV, Zoos, CC	2000	1100	100	100	100	$3400

Actions#	Priority	Implementation partners	Indicative cost and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
3.1 Identify priority areas within and adjacent to the known range to which translocations may provide benefit and develop translocation protocols	Highly beneficial	DELWP, PV, Zoos	$100	$100				$200
3.2 Assess the risks, benefits, practicality, cost-effectiveness and consequences of 'gene pool mixing' to increase the viability of the lowland subpopulation	Highly beneficial	DELWP, Uni, PV, Zoos		$50				$50
3.3 Where likely benefit, undertake carefully monitored trial translocations	Highly beneficial	DELWP, PV, Zoos			$1000	$1000	$1000	$3000
4.1 Using recently developed survey approaches, survey potentially suitable areas outside the known range	Essential	DELWP, PV, Zoos	$1000	$1000				$2000
4.2 If such surveys locate 'new' populations, assess their status and management requirements and implement management	Essential	DELWP, Uni, PV, Zoos			$700**	$700**	$700**	$2100**
4.3 If such surveys fail to locate existing populations, identify the most suitable candidate areas for translocation	Highly beneficial	DELWP, Uni, PV, Zoos			$50			$50
4.4 If significant benefits, implement translocations to areas considered most likely to result in the establishment of new viable subpopulations	Highly beneficial	DELWP, Uni, PV, Zoos			$1000	$1000	$1000	$3000
5.1 Establish an ongoing research forum	Urgent	DELWP, AG, Uni, VF, PV, Zoos, CC	$10	$10	$10	$10	$10	$50
5.2 Undertake research that provides more robust knowledge of key demographic and other ecological characteristics	Essential	DELWP, Uni, Zoos			$500	$500	$500	$1500
5.3 Investigate key aspects of the post-fire ecology of Leadbeater's possum	Essential	DELWP, Uni, PV, Zoos	$200	$200	$200	$200	$200	$1000
5.4 Design and implement experimental trials that rigorously assess the relative benefits of management options	Essential	DELWP, Uni, VF, PV, Zoos	$500	$500	$500	$500	$500	$2500

Actions#	Priority	Implementation partners	Indicative cost and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
6.1 Collate existing monitoring data and maintain, enhance or develop new monitoring programs	Urgent	DELWP, AG, Uni, VF, PV, Zoos, CC	$100	$100	$100	$100	$100	$500
6.2 Identify key trigger points or thresholds in monitoring results that would catalyse priority emergency response	Essential	DELWP, AG, Uni, VF, PV, Zoos, CC	$10	$10	$10	$10	$10	$50
6.3 Where translocations are proposed, design translocation trials in a manner that allows for reporting on success or failure	Highly beneficial	DELWP, Uni, Zoos, PV			$20	$20	$20	$60
6.4 Monitor the extent of success of management actions individually and collectively	Essential	DELWP, AG, Uni, VF, PV	$100	$100	$100	$100	$100	$500
7.1 Establish and maintain an effective recovery team or similar governance model	Urgent	DELWP, AG, Uni, VF, PV, Zoos, CC	$10	$10	$10	$10	$10	$50
7.2 Involve the community in Leadbeater's possum recovery	Essential	DELWP, AG, Uni, VF, PV, Zoos, CC	$50	$50	$50	$50	$50	$250
7.3 Provide enhanced opportunities for the participation of Indigenous groups in research, monitoring and management	Highly beneficial	DELWP,CC	TBD	TBD	TBD	TBD	TBD	
7.4 Promote and publicise the Recovery Plan and recovery effort	Highly beneficial	DELWP, AG, Uni, VF, PV, Zoos, CC	$20	$20	$20	$20	$20	$100
8.1 All partners in the Plan coordinate and adequately resource implementation	Essential	DELWP, AG, Uni, VF, PV, Zoos, CC	$20	$20	$20	$20	$20	$100
8.2 Establish appropriate governance and protocols to be able to respond to emergency events	Highly beneficial	DELWP, AG, Uni, VF, PV, Zoos, CC	$20					$20
8.3 Monitor the extent of implementation of management actions	Essential	DELWP, AG		$20		$20		$20
8.4 Report regularly on performance effectiveness of this Plan, including a formal review at 5 years	Essential	DELWP, AG,	$20	$20	$20	$20	$50	$130
Total			$7580	$6380	$6130	$5500	$5510	$31,100

See section 7.2.2 for full description of Actions; **Action (and costing) contingent on outcome of other Action

TBD = Indicative costs yet to be determined;

AG = Australian Government; **CC** = community conservation groups; **DELWP** = Department of Environment, Land, Water and Planning; **PV** = Parks Victoria; **Uni** = universities; **VF** = VicForests; **Zoos** = Zoos Victoria

8.2. Monitoring, evaluation and adaptation of the Recovery Plan

8.2.1. Monitoring and review

Monitoring of the plan itself will require ongoing assessment of the implementation and success of all actions, with regular reporting to the recovery team or other coordinating group.

A mid-term review (5 years) of the plan will be conducted using a 'Measure of Success' for every action and assessment of progress towards every objective and deliverable. This review will be used to help inform the need for any adaptation required within the plan, to identify and resolve any unexpected impediments, and to re-assess priorities for actions.

The review will be coordinated by relevant Australian and state government agencies, with input sought from key stakeholder groups such as non-governmental organisations, local community groups and research organisations. As per s.279(2) of the *Environment Protection and Biodiversity Conservation Act*, this 5-year assessment of progress will be reviewed by the Australian Minister for the Environment.

A comprehensive review of the implementation and success of the plan will be undertaken in Year 10 of the Plan as a foundation for the development of a revised 10-year plan. This review will consider, *inter alia*, trends in the status of the species and its habitat, effectiveness of actions described in this plan, new research findings and emerging issues, policy context, management capability and resourcing, and stakeholder satisfaction with governance and other matters.

8.2.2. Variation and adaptation

This plan recognises a need for some flexibility and adaptation, due to some substantial uncertainties in knowledge of aspects of the species' biology, and about the likelihood of success of some management actions, as well as the likelihood of somewhat unpredictable episodes of acute and severe threat. The 2009 bushfires had a severe impact on the conservation outlook for Leadbeater's possum. Should a comparable extensive bushfire occur over the life of this plan, there may be need for rapid responses in the conservation management of this species. Such response may include adaptation within this Recovery Plan, to re-prioritise some actions, or to establish new actions. Adaptation within the plan should be guided by the regular reporting described above, and should generally fit within the broad framework described in this plan. Any such needed adaptation in this plan should be overseen by the recovery team or other coordinating group.

If there is need to vary the plan beyond its current framework, such variation will require the approval of the Minister, informed by advice from the Threatened Species Scientific Committee (*Environment Protection and Biodiversity Conservation Act* s.279(3,5)).

8.3. Potential benefits and impacts associated with implementation

8.3.1. Broader biodiversity benefits

Actions taken for the recovery of Leadbeater's possum are likely to provide substantial benefits to many other native species and to the ecological communities with which it is associated – montane ash forests, snow gum woodlands and lowland swamp forests.

Management actions, plans and policies that seek to reduce the decline in (and eventually increase) the abundance of hollow-bearing trees across the range of Leadbeater's possum are likely to provide benefits to many other hollow-nesting species, including other possums, gliders, bats, owls, parrots, cockatoos, treecreepers, owlet-nightjars and kookaburras, for which available hollows may be limiting.

Management actions, plans and policies that seek to reduce the incidence of extensive, high intensity bushfires in montane ash forests, and other habitats used by Leadbeater's possum, will benefit many species that are associated with older-aged forest stands and/or are likely to suffer substantial mortality due to severe fire and its associated factors (e.g. increased predation impacts post-fire). Examples include superb lyrebird *Menura novaehollandiae*, Bassian thrush *Zoothera lunulata*, sooty owl, yellow-bellied glider *Petaurus australis* and southern greater glider (Loyn 1985; Macfarlane 1988; Milledge *et al.* 1991). Two threatened plants (the shiny nematolepis *Nematolepis wilsonii* and the tall astelia *Astelia australiana*), largely endemic to the Leadbeater's possum Central Highlands range, are highly likely to benefit from improved and strategic management responses to high intensity bushfire.

Enhanced fire management for Leadbeater's possum habitat may also lead to some broader-scale (regional) improved fire regimes for other habitats (i.e. those not used by Leadbeater's possum) within and adjacent to the Leadbeater's possum range. The conservation of some threatened aquatic species, such as the barred galaxias *Galaxias fuscus* and the Baw Baw frog *Philoria frosti,* largely restricted to habitat within the range of Leadbeater's possum, will benefit from improved fire management responses within their supporting catchments.

Management actions, plans and policies that seek to increase the extent and connectivity of the conservation reserve estate in montane ash forests for Leadbeater's possum will also provide benefit to other species that may be disadvantaged by timber harvesting or other disturbance activities that may occur outside but not within reserves. Examples of such species that may benefit from an enhanced reserve system supported by enhanced forest management prescriptions include southern greater glider, tall astelia, shiny nematolepis, and barred galaxias.

Management actions, plans and policies that seek to restore the extent, quality and connectivity of lowland swamp forest habitat for Leadbeater's possum will also provide benefit to other species that are associated with this habitat, notably the Critically Endangered helmeted honeyeater, which is now largely restricted to the Yellingbo Nature Conservation Reserve. Such actions will also benefit the habitat itself, including the threatened 'Sedge-rich *Eucalyptus camphora* Swamp Community'.

Research actions (including survey, monitoring, fine-scale mapping of habitat features and distributional modelling) for Leadbeater's possum are likely to provide increased information on the distribution of other co-occurring species, particularly other possums and gliders. A broad suite of arboreal mammals are monitored concurrently with Leadbeater's possum in ANU's long-standing monitoring program (Lindenmayer *et al.* 1991c; Lindenmayer *et al.* 1994b; Lindenmayer *et al.* 2003; Lindenmayer *et al.* 2011b; Lindenmayer *et al.* 2013c; Lindenmayer *et al.* 2014b) and recorded during DELWP's targeted surveys, and such information will help assess population trends for these species. Identifying areas of suitable habitat for other species will benefit from the mapping of Leadbeater's possum habitat features, such as large old trees.

Enhanced reservation and fire management across the core Leadbeater's possum range is likely to benefit the mountain ash forest ecological community generally, for which a recent assessment using IUCN criteria concluded that its conservation status was critically endangered (Burns *et al.* 2015).

The plan seeks to reduce the incidence of extensive fire, increase the area of montane ash forest in reserves and increase the extent of older-aged ash forest (and older-aged trees). Such outcomes would provide benefits for abatement of greenhouse gas emissions, especially given the very high reported carbon storage in older-aged ash forest (Keith *et al.* 2009; Keith *et al.* 2014a; Keith *et al.* 2014b). In turn, such reduction in greenhouse gas emissions would contribute to global climate change mitigation, and hence provide benefits to biodiversity far more broadly.

It is unlikely that there will be significant detriment to other native species arising from the implementation of this plan. Some plant and animal species associated with drier forests adjacent to known Leadbeater's possum colonies or habitat may be disadvantaged if such habitat is used extensively for pre-emptive management to reduce the likelihood of bushfire in Leadbeater's possum habitat. Some disturbance-favoured species (e.g. bush rat *Rattus fuscipes*, swamp wallaby *Wallabia bicolor*, agile antechinus *Antechinus agilis*, superb fairy-wren *Malurus cyaneus*, flame robin *Petroica phoenicea*, Australian magpie *Gymnorhina tibicen*: Loyn (1985); Macfarlane (1988)), may be disadvantaged by the enhanced fire management sought in this plan, but these are generally widespread and non-threatened species and any such detriment is likely to be minor relative to the benefits of this plan for threatened and other species.

Importantly, implementation of this plan will necessitate consideration of conservation and management needs of other threatened species, in particular those identified in Table 5 and for which approved conservation plans are in place, to ensure complementarity of actions. Engagement with these other recovery programs should seek to not only resolve any potential conflicts, particularly as they relate to fire management, but also to identify and realise opportunities for collaboration and any appropriate joint management responses. Examples of this are already occurring through habitat restoration projects at Yellingbo to benefit both the Leadbeater's possum and the helmeted honeyeater.

Table 5. Listed threatened species and ecological communities that occur in areas likely to be affected by this plan.

Threatened species or ecological community	EPBC Act status	Victorian FFA Act status (advisory list status)	Conservation plan	Likely impact of this plan
Tall astelia *Astelia australiana*	Vulnerable	Threatened (Vulnerable)	Recovery Plan; Action Statement	Consideration of and improved responses to risk of frequent large fires; protection of habitat; improved forest management prescriptions.
Shiny nematolepis *Nematolepis wilsonii*	Vulnerable	Threatened (Vulnerable)	Recovery Plan; Action Statement	Protection of habitat; improved consideration of and responses to risk of frequent large fires.
Barred galaxias *Galaxias fuscus*	Endangered	Threatened (Endangered)	Recovery Plan; Action Statement	Habitat protection; improved habitat management – fire management and forest management prescriptions – within supporting catchment.
Baw Baw frog	Endangered	Threatened (Critically	Recovery Plan; Action	Improved habitat management – fire

Threatened species or ecological community	EPBC Act status	Victorian FFA Act status (advisory list status)	Conservation plan	Likely impact of this plan
Philoria frosti		Endangered)	Statement	management.
Spotted tree frog *Litoria spenceri*	Endangered	Threatened (Critically Endangered)	Recovery Plan; Action Statement	Improved habitat management – fire management and forest management prescriptions – within supporting catchment.
Alpine tree frog *Litoria verreauxii alpina*	Vulnerable	Threatened (Critically Endangered)		Improved habitat management – fire management.
Sooty owl *Tyto tenebricosa*		Threatened (Vulnerable)		Habitat protection; increase in abundance of hollow-bearing trees; improved fire management.
Masked owl *Tyto novaehollandiae*		Threatened (Endangered)	Action Statement	Habitat protection; increase in abundance of hollow-bearing trees; improved fire management.
Powerful owl *Ninox strenua*		Threatened (Vulnerable)	Action Statement	Habitat protection; increase in abundance of hollow-bearing trees; improved fire management.
Helmeted honeyeater *Lichenostomus melanops cassidix*	Critically Endangered	Threatened (Critically Endangered)	Recovery plan; Conservation advice	Habitat restoration at Yellingbo; consideration of and improved fire management responses.
Broad-toothed rat *Mastacomys fuscus*		Threatened (Endangered)		Improved fire management; habitat protection.
Spot-tailed quoll *Dasyurus maculatus maculatus*	Endangered	Threatened (Endangered)	Recovery Plan; Action Statement	Habitat protection; increase in abundance of hollow-bearing trees; improved fire management.
Greater glider *Petauroides volans*	Nominated for listing	(Vulnerable)		Habitat protection; increase in abundance of hollow-bearing trees; improved fire management.
Sedge-rich *Eucalyptus camphora* Swamp Community		Threatened		Habitat restoration at Yellingbo; consideration of and improved fire management responses.

8.3.2. Social and economic considerations

The implementation of this Recovery Plan will have substantial social and economic benefits and costs. The benefits relate mainly to carbon storage and greenhouse gas abatement, water yields and quality, tourism, recreation, inspiration, and reduction in the likelihood of destructive fire. The costs relate mainly to reduced access to timber resources. In turn, these costs and benefits may have broader flow-on impacts on communities in the Central Highlands.

The pre-eminent purpose of this Recovery Plan is to stop the decline and support the recovery of the Leadbeater's possum so that its chances of long-term survival in nature are maximised. Actions to achieve this largely centre on protecting and enhancing known and prospective suitable habitat. Almost all of the known distribution of Leadbeater's possum is on public land managed as state forest or as conservation reserves and therefore subject to various public policy, regulatory and management action with associated costs and benefits to the community.

The management of state forests in Victoria aims to balance uses and values, including sustainable timber production, water production, tourism, recreation, carbon sequestration and biodiversity conservation. These forests provide a range of economic benefits including those derived through income, employment, and various goods and services.

Ash forests are highly valued for timber harvesting in Victoria. Approximately 70% of VicForests' annual ash timber supply is sourced from within the range of the Leadbeater's Possum (Leadbeater's Possum Advisory Group 2014a). In 2013-14, the native timber industry in the Central Highlands RFA area of Victoria generated $573 million in revenue, with $76 million in direct income, and $497 million in the community whose economy is reliant on the timber industry from this region (Deloitte Access Economics 2015).Native timber harvesting supported 405 full time equivalent jobs within the Central Highlands RFA area community and a further 1,712 full time equivalent jobs within the wider community.

Approximately 62,600 ha (31 per cent) of the ash forests within the Leadbeater's Possum range are potentially available for timber harvesting (Leadbeater's Possum Advisory Group 2014a). The implementation of Recovery Plan actions to enhance habitat protection through the expansion of the reserve system together with improved forest management prescriptions is highly likely to reduce the area of forest available for timber harvesting (Lindenmayer *et al.* 2016). This has economic implications for the timber industry and the communities that in part depend on it.

Enhanced habitat protection and augmentation, and improved fire management across the core Leadbeater's possum range is likely to benefit the mountain ash forest ecological community. Apart from the wider biodiversity benefits this will bring, it will also have positive impacts on the quality and yield of water. Forests provide vital hydrological service in Victoria in supplying drinking water to many communities (Department of Environment and Primary Industries 2014e).The mountain ash forests are significant catchment areas for Melbourne's water supply. Ash forests cover just under half this area, but yield 80% of the streamflow because they grow on the higher rainfall sites (Benyon *et al.* 1996). Approximately 20% of the mountain ash forest of this area is in closed water catchments, parts of which are also managed as the Yarra Ranges National Park (Viggers *et al.* 2013).

There is a well-documented empirical relationship between stand age and water yield for mountain ash forested catchments in the Central Highlands: catchments dominated by large old trees and old-growth forests yield significantly more water than catchments comprising primarily young forest (Vertessey *et al.* 2001; Viggers *et al.* 2013). Climatic conditions, natural disturbances (bushfires) and human activities (timber harvesting) in these forests all contribute to variation in water yields including reduced streamflow (Benyon *et al.* 1996; Creedy and Wurzbacher 2001; Feikema *et al.* 2010).

Large intense bushfires can have serious, long lasting effects on water yield from ash forests (Lane *et al.* 2010; Feikema *et al.* 2013; Department of Environment and Primary Industries 2014e). Immediately following bushfires, water yields from rain events may increase due to reductions in vegetative cover and increased runoff. As vegetative cover returns, its use of available water increases, lowering water inputs into streams. Regrowth ash forests use a greater amount of water than mature ash forests, and reduced water yield characteristics from these forests after bushfires persist for many decades (Benyon *et al.* 1996). Projected changes in rainfall runoff and fire frequency due to climate change are likely to have important implications for the management of forested catchments. Multiple fire events can result in a perpetually regenerating, high water using forest (Springa *et al.* 2005; Feikema *et al.* 2013).

Forests are an important component of the global carbon cycle, and maintaining or increasing forest carbon stocks is a key indicator of sustainable forest management (Department of Environment and Primary Industries 2014e). Management of native forests offers opportunities to store more carbon in the land sector and in contributing to global climate change mitigation.

However, the circumstances under which forest management provides mitigation benefits varies and is not universal and the relative benefits for carbon storage of managing native forests for wood production versus protection are contested (Keith *et al.* 2015; Ximenes *et al.* 2016). Different conclusions about mitigation benefits of forest management strategies have been reported which in part reflect site specific conditions as well as differing methodologies and underlying assumptions used in the models. A number of studies have attempted to quantify the overall mitigation implications of native forest harvesting for Australian forests – for example in New South Wales (Ximenes *et al.* 2012), Tasmania (Dean *et al.* 2012) and in the mountain ash forests in Victoria (Keith *et al.* 2014a; Keith *et al.* 2014b) – with different authors arriving at opposing conclusions regarding the net emissions costs and/or benefits of harvesting compared with non-harvesting.

Consistent with the implementation of many threatened species recovery programs, there are also potential social benefits for communities engaged in such programs. Leadbeater's possum in particular has high social value as one of Victoria's two state terrestrial faunal emblems and has substantial community profile and interest and is the focus of community conservation action. A long term collaborative effort by the community in working towards the successful recovery of an iconic critically endangered species, could have significant positive social benefit and serve as a model to engage communities more broadly in threatened species conservation.

Economic benefits can potentially be derived from the implementation of a more coordinated policy and management response to Leadbeater's possum recovery through an improved whole of landscape approach. This approach, with a proposed mix of initiatives in dedicated reserves and in state forest, supported by enhanced fire management and habitat augmentation, is a mechanism to improve coordination and enhance collaboration between stakeholders. There is potential that this will lead to efficiencies in coordinated action and more targeted investment across the landscape.

8.4. Affected interests

Listed below are key interested parties that may be involved in the development, implementation and review of the Leadbeater's possum Recovery Plan, and/or organisations likely to be affected by implementation of the actions proposed in this plan.

Government Agencies

- Department of Agriculture, Commonwealth
- Department of Economic Development, Jobs, Transport and Resources, VIC
- Department of the Environment, Commonwealth
- Department of Environment, Land, Water and Planning, VIC (including the Arthur Rylah Institute for Environmental Research)
- Melbourne Water
- Office of the Threatened Species Commissioner, Commonwealth
- Parks Victoria
- VicForests
- Zoos Victoria

Indigenous Groups

- Gunaikurnai Land and Waters Aboriginal Corporation
- Taungurung Clans Aboriginal Corporation
- Wurundjeri Tribe Land and Compensation Cultural Heritage Council Inc.

Industry Groups

- Australian Forest Products Association
- Victorian Association of Forest Industries

Non-government organisations and community groups

- Australian Conservation Foundation
- Field Naturalists' Club of Victoria
- Friends of the Helmeted Honeyeater
- Friends of the Leadbeater's Possum
- MyEnvironment
- Regional tourism businesses
- The Wilderness Society
- Victorian National Parks Association

Universities

- Australian National University
- Monash University
- University of Melbourne

8.4.1. Role and interest of Indigenous groups

Consultation on the development and implementation of the Leadbeater's Possum Recovery Plan is being undertaken with the Gunaikurnai, Taungurung and Wurundjeri Indigenous communities whose traditional lands overlap with the range of the Leadbeater's possum.

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10. ACRONYMS AND DEFINITIONS

10.1. Acronyms

ARI	Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning
ANU	Australian National University
CAR	Comprehensive, Adequate and Representative (for the reserve system)
DotE	Department of the Environment
DELWP	Department of Environment, Land, Water and Planning (Vic)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESU	Evolutionarily Significant Unit
GMZ	General Management Zone
IUCN	International Union for Conservation of Nature
LiDAR	Remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light
LPAG	Leadbeater's Possum Advisory Group
MNES	Matters of National Environmental Significance
NGO	Non-government organisation
PV	Parks Victoria
PVA	Population viability analysis
RFA	Regional Forest Agreement
SMZ	Special Management Zone
SPZ	Special Protection Zone
TSSC	Threatened Species Scientific Committee

10.2. Definitions

The following definitions help explain or clarify some technical terms used in the body of this plan. Where appropriate, definition of some of these terms have been sourced from the Leadbeater's Possum Advisory Group Technical Report 2014 (Leadbeater's Possum Advisory Group 2014b).

Buffer area – a circumscribed distance or area around a particular feature, whose protection from a designated threat helps to protect the feature itself.

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

CAR reserve system – **"**The CAR (comprehensive, adequate and representative) reserve system comprises areas of both public and private land that are reserved specifically for conservation purposes, and where the tenure of the reserved areas is secured by legislation or other methods appropriate for the area concerned…… All reasonable effort should be made to provide for biodiversity and old-growth forest conservation and wilderness in the Dedicated Reserve system on public land. However, where it is demonstrated that it is not possible or practicable to meet the criteria in the Dedicated Reserve system, other approaches will be required" (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

Central Highlands – the higher elevation forested area to the north-east of Melbourne broadly encapsulated by the Central Highlands Regional Forest Agreement Area. In this plan the Central Highlands population of Leadbeater's possum represents the montane ash and snow gum habitat and does not include the lowland population at Yellingbo.

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

Colony – for Leadbeater's possum, a social group that dens together, comprising a breeding pair and associated non-breeding individuals.

Coupe – as defined in the Victorian *Sustainable Forests (Timber) Act 2004* means a specific area of state forest identified for the purposes of a timber harvesting operation in a timber release plan from which timber is harvested in one operation.

Dedicated reserves – **"**Reserves where the management regime equates to specific protected area management categories defined by the IUCN Commission for National Parks and Protected areas (1994). [Categories I, II, III and IV]. Security of tenure, as demonstrated if Parliamentary action by Commonwealth, State or Territory Governments is required for revocation of the reserve, is fundamental to the establishment and management of formal reserves" (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

Dynamic modelling – modelling that includes consideration of changes over time in, for example, habitat availability and suitability, population size and dispersion, and viability, with such changes driven by fire and other disturbance events.

Evolutionarily Significant Unit – is a set of populations that are morphologically and genetically distinct from other similar populations, with such distinction arising from a distinct evolutionary history.

Exclusion zone – an area within the GMZ or SMZ where timber harvesting operations are excluded.

Exudate – a sugar-rich substance secreted by plants or by hemipteran insects feeding from plants, important in the diet of Leadbeater's possum.

Fire regimes – the characteristic pattern of frequency, intensity, extent and timing of fires in a given area or habitat.

Gene pool mixing - the mixing of genetically divergent lineages/populations of a species to rescue and restore genetic variation in populations that have undergone large reductions in genetic diversity and fitness.

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

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

In-field prescriptions – harvesting exclusion rules established to protect forest values found in proposed coupes during planning processes and field inspections, which may not result in a zoning amendment.

Informal Reserves – "Reserves that contain and are managed for conservation values which unequivocally contribute to the CAR system. Such reserves have a sound basis in legislation (e.g., management plans required under legislation) with provision of opportunity for public comment on changes to reserve boundaries, and where decisions on their establishment and alteration are politically accountable. In addition, they must be able to be accurately identified (on maps), and of sufficient area and adequate design to contribute to the continued viability of the values they seek to protect" (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997). Special Protection Zones (SPZs) are Informal Reserves.

Leadbeater's Possum Advisory Group – in 2013, the Victorian Government established the Leadbeater's Possum Advisory Group to provide recommendations aimed at supporting the recovery of the possum while maintaining a sustainable timber industry.

Leadbeater's Possum Reserve – an area in the Central Highlands of 30,500 hectares set aside in 2008 specifically for Leadbeater's possum conservation, of which 58% is within national parks and 42% reserved in SPZs in state forest. The reserve consists of 127 patches spread across the species' range. Each patch was greater than 50 ha in size and contained predominantly old-growth ash forest, as they were the areas most likely to provide habitat into the future.

Lowland swamp forests – forest dominated by mountain swamp gum *Eucalyptus camphora* with dense thickets of *Melaleuca* and *Leptospermum* species.

Montane ash forest – forest dominated by mountain ash *Eucalyptus regnans*, alpine ash *E. delegatensis* and/or shining gum *E. nitens*.

National Park – an area of permanently reserved land or water managed by Parks Victoria under the Victorian *National Parks Act 1975*. The objectives of the Act are the permanent preservation and protection of the natural environment and indigenous flora and fauna, as well as natural, cultural and other features.

Occupancy model – a modelling technique used to predict where a species is likely to occur based on environmental parameters and reflecting the impact of disturbances.

Old-growth forest – forest which contains significant amounts of its oldest growth stage – usually senescent trees – in the upper stratum and the effects of any previous disturbance is now negligible.

Phylogenetically distinctive species – a species that has few close relatives, for example a species that is the only (extant) species in a genus or family.

Population viability – the maintenance of a population in the wild that is sufficiently large to be resilient to disturbance and maintain its long-term evolutionary potential.

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

Potential habitat – all areas of montane ash forests or sub-alpine (snow gum) woodlands within the range of Leadbeater's possum in the Central Highlands. This includes approximately 200,000 ha of forest, not all of which will be occupied at any point in time.

Regional Forest Agreement (RFA) – In Victoria, an agreement between the Commonwealth and Victorian state government that establishes the framework for the conservation and sustainable management of forests within each of the five Victorian RFA regions. The main objectives of the Victorian RFAs are to identify a Comprehensive, Adequate and Representative (CAR) reserve system and provide for the conservation of those areas; to provide for the ecologically sustainable management and use of forests in each RFA region; and to provide for the long-term stability of forests and forest industries.

Regrowth retention harvesting or variable retention harvesting – the retention within a timber harvesting operation (or coupe) of clusters of trees as habitat 'islands' or 'peninsulas' such that 50% of the coupe is close to retained forest.

Relictual distribution – the current (remaining) range of a species that formerly had a substantially larger distribution.

Rotation – means the planned number of years between the regeneration of a forest stand and its subsequent harvesting.

Salvage harvesting – harvesting operations conducted to remove timber following wildfire or other major disturbance that has caused significant tree mortality or damage.

Special Management Zone (SMZ) – areas of state forest that cover a range of natural or cultural values and are managed to conserve specific features. The protection or enhancement of these values requires modification to timber harvesting or other land use practices rather than their exclusion. Timber and other forest produce may be harvested from this zone under certain conditions. Periodic zoning reviews are undertaken to ensure SMZs are in the most appropriate locations, including after significant disturbance events such as bushfires.

Special Protection Zone (SPZ) – areas of state forest managed for conservation designed to complement the dedicated reserve system and categorised as Informal reserves. Larger components of the zone are based on representative examples of vegetation communities and old-growth, as well as localities of key threatened and sensitive flora and fauna species. This zone is managed to minimise disturbances or processes that threaten their respective values, and timber harvesting is excluded. Periodic zoning reviews are undertaken to ensure SPZs are in the most appropriate locations, including after significant disturbance events such as bushfires.

Stag – large hollow-bearing tree killed by fire but remaining standing.

Stag-watching – a sampling and monitoring method which involves a set of observers positioned around large hollow-bearing trees and observing the emergence of animals from tree hollows at dusk.

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

Sub-alpine (snow gum) woodlands – higher elevation (ca. 1400 m) habitat dominated by snow gum *Eucalyptus pauciflora*. Leadbeater's possum occurs in this habitat mostly where there is a dense mid-storey (particularly of mountain tea tree *Leptospermum grandifolium*) along drainage lines.

Subpopulations – geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically 'one successful migrant individual or gamete per year or less') (IUCN Standards and Petitions Subcommittee 2013). Note that subpopulations may be in close proximity, but interchange of individuals between them may nonetheless be highly constrained because of barriers to dispersal or because dispersal capability is limited. If their isolation is relatively recent, subpopulations may not show substantial genetic distinctiveness.

Suitable habitat – areas of montane ash forests or snow gum woodlands in the Central Highlands considered to provide habitat that is currently suitable for the species to occupy.

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

Timber harvesting – any activities carried out for the purpose of removing timber for sale, including timber felling, regeneration and associated roading. Not including the collection of firewood for domestic use.

Translocation – the human-mediated movement of living organisms from one area, with release in another (IUCN/SSC 2013). In this Plan, translocation relates to moving of Leadbeater's possums to seek to establish a new subpopulation, or to bolster numbers (or genetic diversity) in an established subpopulation.

Values Protected by Prescription – "Where the nature of a forest value that is needed to contribute to the CAR reserve system makes inclusion in either Dedicated or Informal Reserves impractical (for example, very rare values, values with fragmented distributions, or values naturally occurring in linear form such as riparian vegetation), then protection may be prescribed in Codes of Practice or Management Plans and where appropriate, identified on maps. These prescriptions should meet the following principles: there is an opportunity for public comment on proposed changes; they have a sound scientific basis; and they are adequate to maintain the values they seek to protect" (Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee 1997).

11. REFERENCES

Anon (1992) 'National Forest Policy Statement: a new focus for Australia's forests.' (Commonwealth of Australia: Canberra)

Attiwill PM, Ryan MF, Burrows N, Cheney NP, McCaw L, Neyland M, Read S (2014) Timber harvesting does not increase fire risk and severity in wet eucalypt forests of southern Australia. *Conservation Letters* **7**, 341-354.

Baker SC, Read SM (2011) Variable retention silviculture in Tasmania's wet forests: ecological rationale, adaptive management and synthesis of biodiversity benefits. *Australian Forestry* **74**, 218-232.

Ball IR, Lindenmayer DB, Possingham HP (1999) A tree hollow dynamics simulation model. *Forest Ecology and Management* **123**, 179-194.

Benyon TJ, Vettessy RA, Hatton RG, Dawes WR (1996) Long-term growth and water balance predictions for a mountain ash (*Eucalyptus regnans*) forest catchment subject to clear-felling and regeneration. *Tree Physiology* **16**, 221-232.

Bilney RJ (2014) Poor historical data drive conservation complacency: the case of mammal decline in south-eastern Australian forests. *Austral Ecology* **39**, 875-886.

Bilney RJ, Cooke R, White J (2006) Change in the diet of sooty owls (*Tyto tenebricosa*) since European settlement: from terrestrial to arboreal prey and increased overlap with powerful owls. *Wildlife Research* **33**, 17-24.

Bilney RJ, Cooke R, White JG (2010) Underestimated and severe: small mammal decline from the forests of south-eastern Australia since European settlement, as revealed by a top-order predator. *Biological Conservation* **143**, 52-59.

Bradstock RA, Price OF (2014) Logging and Fire in Australian Forests: errors by Attiwill et al. (2014). *Conservation Letters* **7**, 419-420.

Brazenor CW (1932) A re-examination of *Gymnobelideus leadbeateri* McCoy. *Australian Zoologist* **7**, 106-109.

Brunner H, Amor RL, Stevens PL (1976) The use of predator scat analysis in a mammal survey at Dartmouth in North-Eastern Victoria. *Wildlife Research* **3**, 85-90.

Burgman MA, Lindenmayer DB (1998) 'Conservation biology for the Australian environment.' (Surrey Beatty & Sons: Chipping Norton)

Burns EL, Lindenmayer DB, Stein J, Blanchard W, McBurney L, Blair D, Banks SC (2015) Ecosystem assessment of mountain ash forest in the Central Highlands of Victoria, south-eastern Australia. *Austral Ecology* **40**, 386-399.

Cardillo M, Bininda-Emonds ORP, Boakes E, Purvis A (2004) A species-level phylogenetic supertree of marsupials. *Journal of Zoology* **264**, 11-31.

Creedy J, Wurzbacher AD (2001) The economic value of a forested catchment with timber, water and carbon sequestration benefits. *Ecological Economics* **38**, 71-83.

Cunningham RB, Lindenmayer DB (2005) Modeling count data of rare species: some statistical issues. *Ecology* **86**, 1135-1142.

Dean C, Wardell-Johnson GW, Kirkpatrick JB (2012) Are there any circumstances in which logging primary wet-eucalypt forest will not add to the global C burden? *Agricultural and Forest Meteorology* **161**, 156-169.

Deloitte Access Economics (2015) 'Economic assessment of the native timber industry in the Central Highlands RFA Area. Report 1 – Economic and financial impact. Report to VicForests, Melbourne.' Deloitte Access Economics, Melbourne.

Department of Environment and Primary Industries (2014a) 'Action statement no. 62: Leadbeater's Possum *Gymnobelideus leadbeateri*.' Department of Environment and Primary Industries, Melbourne.

Department of Environment and Primary Industries (2014b) 'Code of practice for timber production 2014.' Department of Environment and Primary Industries, Melbourne.

Department of Environment and Primary Industries (2014c) 'Management standards and procedures for timber harvesting operations in Victoria's State Forests 2014.' Department of Environment and Primary Industries, Melbourne.
Department of Environment and Primary Industries (2014d) 'Strategic Bushfire Management Plan, East Central Bushfire Risk Landscape.' Department of Environment and Primary Industries, Melbourne.
Department of Environment and Primary Industries (2014e) 'Victoria's State of the Forests Report 2013.' Department of Environment and Primary Industries, Melbourne.
Department of Environment Land Water and Planning (2015a) 'Supporting the recovery of the Leadbeater's Possum: Progress report October 2015.' Department of Environment Land Water and Planning, Melbourne.
Department of Environment Land Water and Planning (2015b) 'Threatened species survey standard: Leadbeater's possum.' Department of Environment Land Water and Planning, Melbourne.
Department of Natural Resources and Environment (1998) 'Forest management plan for the Central Highlands.' Department of Natural Resources and Environment, Melbourne.
Department of Sustainability and Environment (2008a) 'Fire salvage harvesting prescriptions March 2008.' Department of Sustainability and Environment, East Melbourne.
Department of Sustainability and Environment (2008b) 'Strategic fuelbreaks: construction and environmental management plan. Work unit: Reefton. February–April 2008.' Department of Sustainability and Environment, East Melbourne.
Department of Sustainability and Environment (2012) 'Code of Practice for Bushfire Management on Public Land 2012.' Department of Sustainability and Environment, Melbourne.
Dutta R, Das A, Aryal J (2016) Big data integration shows Australian bush-fire frequency is increasing significantly. *Royal Society Open Science* **3**, 150241.
Edwards D, Westerman M (1992) DNA-DNA Hybridization and the position of Leadbeater Possum (*Gymnobelideus leadbeateri* McCoy) in the Family Petauridae (Marsupialia, Diprotodontia). *Australian Journal of Zoology* **40**, 563-571.
Feikema PM, Sherwin CB, Lane PNJ (2013) Influence of climate, fire severity and forest mortality on predictions of long term streamflow: potential effect of the 2009 wildfire on Melbourne's water supply catchments. *Journal of Hydrology* **488**, 1-16.
Feikema PM, Sherwin CB, Peel MC, Freebairn AC (2010) Modelling the long term water yield impact of wildfire and other forest disturbance in Eucalypt forests. *Environmental Modelling & Software* **25**, 467–478.
Grose M, Abbs D, Bhend J, Chiew F, Church J, Ekström M, Kirono D, Lenton A, Lucas C, McInnes K, Moise A, Monselesan D, Mpelasoka F, Webb L, Whetton P (2015) 'Southern Slopes Cluster Report.' CSIRO and Bureau of Meteorology, Canberra.
Hansen BD (2008) 'Population genetic structure of Leadbeater's Possum *Gymnobelideus leadbeateri*, and its implications for species conservation. Ph.D. thesis.' Monash University, Clayton.
Hansen BD, Harley DKP, Lindenmayer DB, Taylor AC (2009) Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. *Molecular Ecology* **18**, 3346-3362.
Hansen BD, Sunnucks P, Blacket M, Taylor AC (2005) A set of microsatellite markers for an endangered arboreal marsupial, Leadbeater's possum. *Molecular Ecology Notes* **5**, 796-799.
Hansen BD, Taylor AC (2008) Isolated remnant or recent introduction? Estimating the provenance of Yellingbo Leadbeater's possums by genetic analysis and bottleneck simulation. *Molecular Ecology* **17**, 4039-4052.
Harley D (2002) The discovery of Leadbeater's possum *Gymnobelideus leadbeateri* along the Woori Yallock Creek, Yellingbo. *Victorian Naturalist* **119**, 233-235.
Harley D (2004a) A survey for Leadbeater's Possum *Gymnobelideus leadbeateri* in lowland swamp forest at Bunyip State Park. *The Victorian Naturalist* **121**, 158-163.
Harley D (2012) The application of Zoos Victoria's 'Fighting Extinction' commitment to the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri*. *Victorian Naturalist* **129**, 175-180.
Harley D (2015a) 'Translocation plan: establishment of a captive insurance population for the lowland Leadbeater's Possum population at Yellingbo.' Zoos Victoria, Melbourne.

Harley D (2015b) The use of call imitation to establish territory occupancy by Leadbeater's possum (*Gymnobelideus leadbeateri*). *Australian Mammalogy* **37**, 116-119.
Harley D (2016) An overview of actions to conserve Leadbeater's Possum (*Gymnobelideus leadbeateri*). *Victorian Naturalist*, in press.
Harley D, Lowry R (2013) The re-establishment of Zoos Victoria's captive-breeding program for Leadbeater's Possum: a new era of zoo-based conservation to assist wild populations. In 'Leadbeater's Possum - Bred to be Wild. Edition 2'. (Ed. P Preuss).
Harley DKP (2004b) Patterns of nest box use by Leadbeater's Possum (*Gymnobelideus leadbeateri*): applications to research and conservation. In 'The biology of Australian possums and gliders'. (Eds R Goldingay and S Jackson) pp. 318–329. (Surrey Beatty and Sons: Chipping Norton)
Harley DKP (2004c) A review of recent records of Leadbeater's Possum (*Gymnobelideus leadbeateri*). In 'The biology of Australian possums and gliders'. (Eds R Goldingay and S Jackson) pp. 330–338. (Surrey Beatty and Sons: Chipping Norton)
Harley DKP (2005) 'The life history and conservation of Leadbeater's Possum (*Gymnobelideus leadbeateri*) in lowland swamp forest. Ph.D. thesis.' Monash University, Clayton.
Harley DKP (2006) A role for nest boxes in the conservation of Leadbeater's possum (*Gymnobelideus leadbeateri*). *Wildlife Research* **33**, 385-395.
Harley DKP, Holland GJ, Hradsky BAK, Antrobus JS (2014) The use of camera traps to detect arboreal mammals: lessons from targeted surveys for the cryptic Leadbeater's Possum *Gymnobelideus leadbeateri*. In 'Camera Trapping: Wildlife Management and Research'. (Eds P Meek and P Fleming) pp. 233-244. (CSIRO Publishing: Collingwood)
Harley DKP, Lill A (2007) Reproduction in a population of the endangered Leadbeater's possum inhabiting lowland swamp forest. *Journal of Zoology* **272**, 451-457.
Harley DKP, Spring DA (2003) Reply to the comment by Lindenmayer et al. on" Economics of a nest-box program for the conservation of an endangered species: a re-appraisal". *Canadian Journal of Forest Research* **33**, 752-753.
Harley DKP, Worley MA, Harley TK (2005) The distribution and abundance of Leadbeater's possum *Gymnobelideus leadbeateri* in lowland swamp forest at Yellingbo Nature Conservation Reserve. *Australian Mammalogy* **27**, 7-15.
IUCN Standards and Petitions Subcommittee (2013) 'Guidelines for Using the IUCN Red List Categories and Criteria. Version 10.' Gland, Switzerland.
IUCN/SSC (2013) 'Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0.' Gland, Switzerland.
IUCN/SSC (2014) 'Guidelines on the use of *ex situ* management for species conservation. Version 2.0.' IUCN Species Survival Commission, Gland, Switzerland.
Jelinek A, Cameron D, Belcher C, Turner L (1995) New perspectives on the ecology of Lake Mountain: the discovery of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy in sub-alpine woodland. *Victorian Naturalist* **112**, 112-115.
Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee (1997) 'Nationally agreed criteria for the establishment of a comprehensive, adequate and representative reserve system for forests in Australia.' Canberra.
Keith H, Lindenmayer D, Macintosh A, Mackey B (2015) Under what circumstances do wood products from native forests benefit climate change mitigation? *PLoS ONE* **10**, e0139640.
Keith H, Lindenmayer D, Mackey B, Blair D, Carter L, McBurney L, Okada S, Konishi-Nagano T (2014a) Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks. *Ecosphere* **5**, art75.
Keith H, Lindenmayer DB, Mackey BG, Blair D, Carter L, McBurney L, Okada S, Konishi-Nagano T (2014b) Accounting for biomass carbon stock changes due to wildfire in temperate forest landscapes in Australia. *PLoS ONE* **9**, e107126.
Keith H, Mackey BG, Lindenmayer DB (2009) Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. *Proceedings of the National Academy of Sciences* **106**, 11635-11640.

Lane PNJ, Feikema PM, Sherwin CB, Peel MC, Freebairn AC (2010) Modelling the long term water yield impact of wildfire and other forest disturbance in Eucalypt forests. *Environmental Modelling & Software* **25**, 467–478.

Larwill S, Belvedere M, Myroniuk P, Larwill S, Westerman M (2003) Evidence of Leadbeater's Possum *Gymnobelideus leadbeateri* in the Macedon Region: an example of the use of molecular genetics in fauna survey. *Victorian Naturalist* **120**, 132-139.

Leadbeater's Possum Advisory Group (2014a) Leadbeater's Possum Recommendations: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security. http://www.depi.vic.gov.au/__data/assets/pdf_file/0004/258214/Leadbeaters-Possum-Advisory-Group-Recommendations-Report_UV.pdf.

Leadbeater's Possum Advisory Group (2014b) Leadbeater's Possum Technical Report: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security. http://www.depi.vic.gov.au/__data/assets/pdf_file/0019/258220/Leadbeaters-Possum-Advisory-Group-Technical-Report.pdf.

Likens GE, Lindenmayer DB (2012) Integrating approaches leads to more effective conservation of biodiversity. *Biodiversity and Conservation* **21**, 3323-3341.

Lindenmayer D (1996a) 'Wildlife and woodchips: Leadbeater's possum: a test case for sustainable forestry.' (UNSW Press: Sydney)

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

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

Lindenmayer D (2013) Why Victoria needs a Giant Forest National Park. *The Conversation*, e18452.

Lindenmayer D, Blair D, McBurney L, Banks S (2014a) Preventing the extinction of an iconic globally endangered species-Leadbeater's Possum (*Gymnobelideus leadbeateri*). *Journal of Biodiversity & Endangered Species* **2**.

Lindenmayer D, Blair D, McBurney L, Banks S, Stein J, Hobbs R, Likens G, Franklin J (2013a) Principles and practices for biodiversity conservation and restoration forestry: a 30 year case study on the Victorian montane ash forests and the critically endangered Leadbeater's Possum. *Australian Zoologist* **36**, 441-460.

Lindenmayer D, Cunningham R, Tanton M, Smith A, Nix H (1990a) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, southeast Australia: I. Factors influencing the occupancy of trees with hollows. *Biological Conservation* **54**, 111-131.

Lindenmayer D, McCarthy MA (2002) Congruence between natural and human forest disturbance: a case study from Australian montane ash forests. *Forest Ecology and Management* **155**, 319-335.

Lindenmayer DB (1989) 'The ecology and habitat requirements of Leadbeater's possum. Ph.D. thesis.' Australian National University, Canberra.

Lindenmayer DB (1996b) 'Forest pattern and ecological processes: a synthesis of 25 years of research.' (CSIRO Publishing: Collingwood)

Lindenmayer DB, Barton PS, Lane PW, Westgate MJ, McBurney L, Blair D, Gibbons P, Likens GE (2014b) An empirical assessment and comparison of species-based and habitat-based surrogates: a case study of forest vertebrates and large old trees. *PLoS ONE* **9**, e89807.

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

Lindenmayer DB, Blair D, McBurney L, Banks SC (2015a) Ignoring the science in failing to conserve a faunal icon - major political, policy and management problems in preventing the extinction of Leadbeater's possum. *Pacific Conservation Biology* **21**, 257-265.

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

Lindenmayer DB, Blair D, McBurney L, Banks SC (2016) The need for a comprehensive reassessment of the Regional Forest Agreements in Australia. *Pacific Conservation Biology* **21**, 266-270.
Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Laurance WF, Stein JAR, Gibbons P (2012) Interacting factors driving a major loss of large trees with cavities in a forest ecosystem. *PLoS ONE* **7**, e41864.
Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks SC, Driscoll D, Smith AL, Gill AM (2013c) Fire severity and landscape context effects on arboreal marsupials. *Biological Conservation* **167**, 137-148.
Lindenmayer DB, Boyle S, Burgman MA, McDonald D, Tomkins B (1994a) The sugar and nitrogen content of the gums of Acacia species in the mountain ash and alpine ash forests of central Victoria and its potential implications for exudivorous arboreal marsupials. *Australian Journal of Ecology* **19**, 169-177.
Lindenmayer DB, Burton PJ, Franklin JF (2008) 'Salvage logging and its ecological consequences.' (Island Press: Washington)
Lindenmayer DB, Clark T, Lacy RC, Thomas VC (1993a) Population viability analysis as a tool in wildlife conservation policy: with reference to Australia. *Environmental Management* **17**, 745-758.
Lindenmayer DB, Cunningham RB (1997) Patterns of co-occurrence among arboreal marsupials in the forests of central Victoria, southeastern Australia. *Australian Journal of Ecology* **22**, 340-346.
Lindenmayer DB, Cunningham RB, Donnelly CF (1993b) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia, IV. The presence and abundance of arboreal marsupials in retained linear habitats (wildlife corridors) within logged forest. *Biological Conservation* **66**, 207-221.
Lindenmayer DB, Cunningham RB, Donnelly CF (1994b) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-eastern Australia, VI. The performance of statistical models of the nest tree and habitat requirements of arboreal marsupials applied to new survey data. *Biological Conservation* **70**, 143-147.
Lindenmayer DB, Cunningham RB, Donnelly CF (1997) Decay and collapse of trees with hollows in eastern Australian forests: impacts on arboreal marsupials. *Ecological Applications* **7**, 625-641.
Lindenmayer DB, Cunningham RB, Donnelly CF, Franklin JF (2000) Structural features of old-growth Australian montane ash forests. *Forest Ecology and Management* **134**, 189-204.
Lindenmayer DB, Cunningham RB, Donnelly CF, Tanton MT, Nix HA (1993c) The abundance and development of cavities in Eucalyptus trees: a case study in the montane forests of Victoria, southeastern Australia. *Forest Ecology and Management* **60**, 77-104.
Lindenmayer DB, Cunningham RB, MacGregor C, Incoll RD, Michael D (2003) A survey design for monitoring the abundance of arboreal marsupials in the Central Highlands of Victoria. *Biological Conservation* **110**, 161-167.
Lindenmayer DB, Cunningham RB, Nix HA, Tanton MT, Smith AP (1991a) Predicting the abundance of hollow-bearing trees in montane ash forests of south-eastern Australia. *Australian Journal of Ecology* **16**, 91-98.
Lindenmayer DB, Cunningham RB, Tanton MT, Nix HA, Smith AP (1991b) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia: III. The habitat requirements of Leadbeater's Possum *Gymnobelideus leadbeateri* and models of the diversity and abundance of arboreal marsupials. *Biological Conservation* **56**, 295-315.
Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP (1990b) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia: II. The loss of trees with hollows and its implications for the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae). *Biological Conservation* **54**, 133-145.
Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP, Nix HA (1991c) Characteristics of hollow-bearing trees occupied by arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-east Australia. *Forest Ecology and Management* **40**, 289-308.

Lindenmayer DB, Dixon JM (1992) An additional historical record of Leadbeater's Possum, *Gymnobelideus leadbeateri* McCoy, prior to the 1961 rediscovery of the species. *Victorian Naturalist* **109**, 217-218.
Lindenmayer DB, Franklin JF (1997) Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. *Conservation Biology* **11**, 1053-1068.
Lindenmayer DB, Hobbs RJ, Likens GE, Krebs CJ, Banks SC (2011a) Newly discovered landscape traps produce regime shifts in wet forests. *Proceedings of the National Academy of Sciences* **108**, 15887-15891.
Lindenmayer DB, Lacy RC (1995a) Metapopulation viability of arboreal marsupials in fragmented old-growth forests: comparison among species. *Ecological Applications* **5**, 183-199.
Lindenmayer DB, Lacy RC (1995b) Metapopulation viability of Leadbeater's possum, *Gymnobelideus leadbeateri*, in fragmented old-growth forests. *Ecological Applications* **5**, 164-182.
Lindenmayer DB, Lacy RC, Thomas VC, Clark TW (1993d) Predictions of the impacts of changes in population size and environmental variablitity on Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy (Marsupialia: Petauridae) using population viability analysis: an application of the computer program VORTEX. *Wildlife Research* **20**, 67-85.
Lindenmayer DB, Laurance WF (2012) A history of hubris–Cautionary lessons in ecologically sustainable forest management. *Biological Conservation* **151**, 11-16.
Lindenmayer DB, Mackey BG, Nix HA (1996) The bioclimatic domains of four species of commercially important eucalypts from south-eastern Australia. *Australian Forestry* **59**, 74-89.
Lindenmayer DB, McCarthy MA (2006) Evaluation of PVA models of arboreal marsupials: coupling models with long-term monitoring data. *Biodiversity & Conservation* **15**, 4079-4096.
Lindenmayer DB, Meggs RA (1996) Use of den trees by Leadbeater's Possum (*Gymnobelideus leadbeateri*). *Australian Journal of Zoology* **44**, 625-638.
Lindenmayer DB, Nix HA, McMahon JP, Hutchinson MF, Tanton MT (1991d) The conservation of Leadbeater's possum, *Gymnobelideus leadbeateri* (McCoy): a case study of the use of bioclimatic modelling. *Journal of Biogeography* **18**, 371-383.
Lindenmayer DB, Norton TW, Tanton MT (1990c) Differences between wildfire and clearfelling on the structure of montane ash forests of Victoria and their implications for fauna dependent on tree hollows. *Australian Forestry* **53**, 61-68.
Lindenmayer DB, Ough K (2006) Salvage logging in the montane ash eucalypt forests of the Central Highlands of Victoria and its potential impacts on biodiversity. *Conservation Biology* **20**, 1005-1015.
Lindenmayer DB, Possingham HP (1995a) The conservation of arboreal marsupials in the montane ash forests of the Central Highlands of Victoria, south-eastern Australia—VII. Modelling the persistence of Leadbeater's possum in response to modified timber harvesting practices. *Biological Conservation* **73**, 239-257.
Lindenmayer DB, Possingham HP (1995b) Modelling the impacts of wildfire on the viability of metapopulations of the endangered Australian species of arboreal marsupial, Leadbeater's Possum. *Forest Ecology and Management* **74**, 197-222.
Lindenmayer DB, Possingham HP (1995c) Modelling the viability of metapopulations of the endangered Leadbeater's possum in south-eastern Australia. *Biodiversity & Conservation* **4**, 984-1018.
Lindenmayer DB, Possingham HP (1996a) Modelling the inter-relationships between habitat patchiness, dispersal capability and metapopulation persistence of the endangered species, Leadbeater's possum, in south-eastern Australia. *Landscape Ecology* **11**, 79-105.
Lindenmayer DB, Possingham HP (1996b) Ranking conservation and timber management options for Leadbeater's possum in southeastern Australia using population viability analysis. *Conservation Biology* **10**, 235-251.
Lindenmayer DB, Possingham HP (2013) No excuse for habitat destruction. *Science* **340**, 680-680.
Lindenmayer DB, Smith AP, Craig SA, Lumsden LF (1989) A survey of the distribution of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy in the Central Highlands of Victoria. *Victorian Naturalist* **106**, 174-178.

Lindenmayer DB, Tanton MT, Cunningham RB (1991e) A critique of the use of nest boxes for the conservation of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy. *Wildlife Research* **18**, 619-623.
Lindenmayer DB, Welsh A, Donnelly C, Crane M, Michael D, Macgregor C, McBurney L, Montague-Drake R, Gibbons P (2009) Are nest boxes a viable alternative source of cavities for hollow-dependent animals? Long-term monitoring of nest box occupancy, pest use and attrition. *Biological Conservation* **142**, 33-42.
Lindenmayer DB, Wood JT (2010) Long-term patterns in the decay, collapse, and abundance of trees with hollows in the mountain ash (*Eucalyptus regnans*) forests of Victoria, southeastern Australia. *Canadian Journal of Forest Research* **40**, 48-54.
Lindenmayer DB, Wood JT, McBurney L, Michael D, Crane M, MacGregor C, Montague-Drake R, Gibbons P, Banks SC (2011b) Cross-sectional versus longitudinal research: a case study of trees with hollows and marsupials in Australian forests. *Ecological Monographs* **81**, 557-580.
Loyn RH (1985) Bird populations in successional forests of Mountain Ash *Eucalyptus regnans* in central Victoria. *Emu* **85**, 213-230.
Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadic TA, Smith SJ, Acevedo S, Cheers G, Jemison ML, Nicol MD (2013) 'A new strategic approach to biodiversity management – research component.' Arthur Rylah Institute for Environmental Research, Heidelberg.
Mac Nally R, Bennett AF, Thomson JR, Radford JQ, Unmack G, Horrocks G, Vesk PA (2009) Collapse of an avifauna: climate change appears to exacerbate habitat loss and degradation. *Diversity and Distributions* **15**, 720-730.
Macfarlane M, Smith J, Lowe K (1997) 'Leadbeater's Possum (*Gymnobelideus leadbeateri*) Recovery Plan.' (Department of Natural Resources and Environment: Melbourne)
Macfarlane MA (1988) Mammal populations in mountain ash (*Eucalyptus regnans*) forests of various ages in the Central Highlands of Victoria. *Australian Forestry* **51**, 14-27.
Macfarlane MA, Seebeck JH (1991) 'Draft management strategies for the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri*, in Victoria.' Department of Conservation and Environment, 111, Melbourne.
McCarthy MA, Lindenmayer DB (2000) Spatially-correlated extinction in a metapopulation model of Leadbeater's Possum. *Biodiversity & Conservation* **9**, 47-63.
McKenney DW, Lindenmayer DB (1994) An economic assessment of a nest-box strategy for the conservation of an endangered species. *Canadian Journal of Forest Research* **24**, 2012-2019.
McMahon ARG, Franklin DC (1993) The significance of Mountain Swamp Gum for Helmeted Honeyeater populations in the Yarra Valley. *The Victorian Naturalist* **110**, 230-237.
Menkhorst P (2008) '*Gymnobelideus leadbeateri*. The IUCN Red List of Threatened Species 2008: e.T9564A13001448. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T9564A13001448.en.'
Menkhorst PW, Lumsden LF (1995) Leadbeater's Possum *Gymnobelideus leadbeateri*. In 'Mammals of Victoria: distribution, ecology and conservation'. (Ed. PW Menkhorst) pp. 104-107. (Oxford University Press: Melbourne)
Milledge DR, Palmer CL, Nelson JL (1991) "Barometers of change": the distribution of large owls and gliders in Mountain Ash forests of the Victorian Central Highlands and their potential as management indicators. In 'Conservation of Australia's forest fauna'. (Ed. D Lunney) pp. 53-65. (Royal Zoological Society of NSW: Mosman)
Morton SR, Hoegh-Guldberg O, Lindenmayer DB, Olson MH, Hughes L, McCulloch MT, McIntyre S, Nix HA, Prober SM, Saunders DA, Andersen AN, Burgman MA, Lefroy EC, Lonsdale WM, Lowe I, McMichael AJ, Parslow JS, Steffen W, Williams JE, Woinarski JCZ (2009) The big ecological questions inhibiting effective environmental management in Australia. *Austral Ecology* **34**, 1-9.
Myroniuk PO (1995) 'Leadbeater's Possum *Gymnobelideus leadbeateri* International Studbook.' (Zoological Board of Victoria: Parkville)
Myroniuk PO, Seebeck JH (1992) In situ and ex situ conservation of Leadbeater's possum *Gymnobelideus leadbeateri*. *International Zoo Yearbook* **31**, 82-90.
Nelson JL, Lumsden LF, Durkin LK, Bryant DB, Macak PV, Cripps JK, Smith SJ, Scroggie MP, Cashmore MP (2015) 'Targeted surveys for Leadbeater's Possum in 2014-2015. Report for the

Leadbeater's Possum Implementation Committee.' Arthur Rylah Institute for Environmental Research Department of Environment, Land Water and Planning Victoria, Heidelberg.

Neyland M, Hickey J, Read SM (2012) A synthesis of outcomes from the Warra Silvicultural Systems Trial, Tasmania: safety, timber production, economics, biodiversity, silviculture and social acceptability. *Australian Forestry* **75**, 147-162.

Osborne MJ, Christidis L (2001) Molecular phylogenetics of Australo–Papuan possums and gliders (family Petauridae). *Molecular Phylogenetics and Evolution* **20**, 211-224.

Possingham HP, Lindenmayer DB, Norton TW (1993) A framework for the improved management of threatened species based on population viability analysis (PVA). *Pacific Conservation Biology* **1**, 39-45.

Preuss P (2006) 'Leadbeater's Possum: born to be wild.' (Trafford Publishing: Victoria)

Seebeck JH, Suckling GC, Macfarlane MA (1983) Leadbeater's Possum - survey by stagwatching. *Victorian Naturalist* **103**, 19-25.

Smales IJ (1994) The discovery of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy, resident in a lowland swamp woodland. *Victorian Naturalist* **111**, 178-182.

Smith A (1984a) Diet of Leadbeaters Possum, *Gymnobelideus leadbeateri* (Marsupialia). *Wildlife Research* **11**, 265-273.

Smith AP (1980) 'The diet and ecology of Leadbeater's possum and the sugar glider. Ph.D. thesis.' Monash University, Clayton.

Smith AP (1984b) Demographic consequences of reproduction, dispersal and social interaction in a population of Leadbeater's Possum (*Gymnobelideus leadbeateri*). In 'Possums and gliders'. (Eds A Smith and I Hume) pp. 359-373. (Surrey Beatty & Sons: Chipping Norton)

Smith AP, Harley DKP (2008) Leadbeater's Possum *Gymnobelideus leadbeateri*. In 'The mammals of Australia'. (Eds S Van Dyck and R Strahan) pp. 226-228. (Reed New Holland: Sydney)

Smith AP, Lindenmayer D (1988) Tree hollow requirements of Leadbeater's possum and other possums and gliders in timber production ash forests of the Victorian Central Highlands. *Wildlife Research* **15**, 347-362.

Smith AP, Lindenmayer D, Begg RJ, Macfarlane MA, Seebeck JH, Suckling GC (1989) Evaluation of the stag-watching technique for census of possums and gliders in tall open forest. *Wildlife Research* **16**, 575-580.

Smith AP, Lindenmayer D, Suckling G (1985) 'The Ecology and Management of Leadbeaters Possum.' (University of New England: Armidale)

Smith AP, Lindenmayer DB (1992) Forest succession and habitat management for Leadbeater's possum in the state of Victoria, Australia. *Forest Ecology and Management* **49**, 311-332.

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

Smith S, Morey J (2001) 'Options for a permanent reserve system for the conservation of Leadbeater's Possum. Central Highlands of Victoria.' Department of Natural Resources and Environment, East Melbourne.

Springa DA, Kennedy JOS, Mac Nally R (2005) Optimal management of a forested catchment providing timber and carbon sequestration benefits: climate change effects. *Global Environmental Change* **15**, 281–292.

Taylor C, McCarthy MA, Lindenmayer DB (2014) Nonlinear effects of stand age on fire severity. *Conservation Letters* **7**, 355-370.

The Working Group for the Great Forest National Park (2015) 'Great Forest National Park: tenure, values and design methodology.' The Working Group for the Great Forest National Park.

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

Turner V (2003) 'Flora and Fauna Guarantee Action Statement Number 130: Sedge-rich *Eucalyptus camphora* Swamp.' Melbourne.

Vertessey RA, Watson FG, O'Sullivan SK (2001) Factors determining relations between stand age and catchment water balance in Mountain Ash forests. *Forest Ecology and Management* **143**, 13-26.

Viggers JI, Weaver HJ, Lindenmayer DB (2013) 'Melbourne's water catchments. perspectives on a world-class water supply.' (CSIRO Publishing: Melbourne)

Welsh AH, Cunningham RB, Donnelly CF, Lindenmayer DB (1996) Modelling the abundance of rare species: statistical models for counts with extra zeros. *Ecological Modelling* **88**, 297-308.

Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DMJS, Clarke PJ, Cook GD, Hennessy KJ, York A (2009) 'Interactions between climate change, fire regimes and biodiversity in Australia – a preliminary assessment.' Report to the Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra, Darwin.

Woinarski JCZ, Burbidge AA, Harrison PL (2014) 'The Action Plan for Australian Mammals 2012.' (CSIRO Publishing: Melbourne)

Woinarski JCZ, Cullen JM (1984) Distribution of invertebrates on foliage in forests of south-eastern Australia. *Australian Journal of Ecology* **9**, 207-232.

Ximenes F, Bi H, Cameron N, Coburn R, Maclean M, Sargeant D, Roxburgh S, Ryan M, Williams J, Boer K (2016) 'Carbon stocks and flows in native forests and harvested wood products in SE Australia. Project No: PNC285-1112. Prepared for Forest & Wood Products Australia.' Melbourne.

Ximenes F, George BH, Cowie A, Williams J, Kelly G (2012) Greenhouse gas balance of native forests in New South Wales, Australia. *Forests* **3**, 653-683.

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Document 3

Threatened Species Scientific Committee

65th Meeting: 6 – 8 September 2016		
Agenda Item	10.4	 Image Credit – Dan Harley
Title	Draft Leadbeater's Possum Recovery Plan	
Purpose	AGREE to recommend the draft revised National Recovery Plan for Leadbeater's Possum (*Gymnobelideus leadbeateri*) to the Minister for making under the EPBC Act.	
Stage	Initial Preparation > Consultation > Draft plan > **Final plan**	
Recommendations	s22 - material irrelevant to scope 3. **Agrees** to advise the Minister that in the Committee's view there would be no clear conservation benefit from pursuing a listing on the Register of Critical Habitat for this species. 4. **Notes** the review of the current Leadbeater's Possum Recovery Plan (Item 10.4.2), the information provided regarding legislative compliance (Item 10.4.6) and assessment of habitat critical to the survival of the species (Item 10.4.8) arising out of the recovery plan.	
Previous Committee Consideration	The Committee previously considered the draft recovery plan at TSSC63. A TSSC Leadbeater's Possum Working group considered the redrafted objectives, actions and implementation sections of the plan on 13 July 2016 following public comment.	
Next Steps for the Committee	s22	
Attachments	Item 10.4.1 National Recovery Plan for the Leadbeater's Possum Item 10.4.2 Review of the *Leadbeater's Possum Recovery Plan* 1997 Item 10.4.3 Paper and attachments TSSC Working Group – 13 July 2016 Item 10.4.4 Draft minutes from the TSSC Working Group – 13 July 2016 Item 10.4.5 Victorian whole of government submission Item 10.4.6 EPBC Act Compliance checklist Item 10.4.7 Main responses through public consultation Item 10.4.8 Critical Habitat Assessment	

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Critical Habitat Considerations

17. In accordance with the EPBC Regulations (Division 7.4) the Minister must, when making or adopting a recovery plan, consider whether to list habitat identified in the recovery plan as being critical to the survival of the species or ecological community on the Register of Critical habitat. Before listing habitat on the Register of Critical Habitat the Minister must:

- consider any advice from the Threatened Species Scientific Committee about whether the habitat is critical to the survival of a listed species or ecological community; and

- if the habitat is not in a Commonwealth area, be satisfied that reasonable steps have been taken to consult with the owner of the property where the habitat is located.

18. To assist the Committee is assessing habitat critical to the survival of this species, the Department has provided an assessment of the information contained in the recovery plan at (Item 10.4.8). This assessment is based on the approach endorsed by the Committee at its 16th meeting in which listings on the Register of Critical Habitat are only to be pursued where there is a clear conservation benefit from doing so.

Background

19. The Victorian Leadbeater's Possum Recovery Plan (MacFarlane, Smith and Lowe, 1997) was adopted by the Australian Government, and was reviewed in 2015, resulting in the recommendation that a new recovery plan be developed.

20. The Leadbeater's possum was identified for emergency intervention in the Threatened Species Strategy Action Plan 215-16, and a Leadbeater's Possum Action Plan was released in August 2015, with a target to develop a recovery plan within one year.

21. Under Section 274 of the EPBC Act, the Minister must obtain and consider the advice of the Threatened Species Scientific Committee on the content of a recovery plan before making or adopting a plan.

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Australian Government
Department of the Environment

Review of the Recovery Plan for the Leadbeater's Possum (MacFarlane, Smith and Lowe, 1997) – February 2016

INTRODUCTION

Leadbeater's possum is a small, nocturnal, arboreal possum which is endemic to Victoria. The core location of the species is an area of approximately 70 x 80 km in the Victorian Central Highlands at altitudes between 400-1,200 m above sea level (Lindenmayer et al., 1989) where it is patchily distributed (Macfarlane et al., 1997) and occupies montane ash forest and subalpine woodland comprising mountain ash, alpine ash, shining gum and snow gum. Genetic work indicates that Leadbeater's Possum consists of two genetically-distinct subpopulations that have historically occupied different habitats (Hansen, 2008). An outlier 'lowland population' located near Yellingbo (Smales, 1994) and a core highland/midland population which is located in the Central Highlands of Victoria (Lindenmayer et al., 1989). The current status of taxon is:

- *Environment Protection and Biodiversity Conservation Act 1999*: Uplisted to Critically Endangered - 2015
- *Advisory List of Threatened Vertebrate Fauna in Victoria:* Endangered – 2013
- *Flora and Fauna Guarantee Act 1988 (Victoria):* Threatened
- *IUCN Red List of Threatened Species:* Endangered

The ongoing reduction in the extent, quality and connectivity of suitable habitat has occurred and continues to occur through a range of drivers:

- impacts of severe fire and changes in fire regime;
- timber harvesting; and
- eucalypt dieback and altered hydrology (for lowland subpopulation)

The original Victorian 'Leadbeater's Possum (*Gymnobelideus leadbeateri*) Recovery Plan was written by MacFarlane, Smith and Lowe in 1997. This recovery plan was adopted as a national plan under the *Endangered Species Protection Act* 1992 in November 1997. Its objective was to downlist Leadbeater's Possum from endangered to vulnerable within ten years based on the IUCN criteria of population trend and size, extent of occurrence, probability of extinction, and the management of habitat towards a target of no more than a one per cent probability of extinction over 250 years throughout the forest within its current range.

In 1998, the Central Highlands Regional Forest Agreement (RFA) was established between the Victorian and Commonwealth Governments to create a framework for forest management in the Central Highlands (DAFF 1998). The Central Highlands Forest Management Plan was also prepared in 1998 and aligned closely with the RFA. Most of the Leadbeater's Possum habitat is within the Central Highlands RFA boundary.

In 1997 the Leadbeater's Possum Management Team (Recovery Team) included representation from academia, the community, Australian Nature Conservation Agency (ANCA) and staff from the relevant Victorian Government areas. Its role was to report on actions being implemented and to provide a forum for discussing problems and recommending modifications to the Plan. The LBP Management Team was to provide an annual written report to the Leadbeater's Possum Steering Committee, which would include an evaluation of progress towards achieving objectives of this original Recovery Plan.

EXECUTIVE SUMMARY

1.0: PROGRESS OF RECOVERY ACTIONS

The majority of the recovery actions have been implemented over the life of the plan and a range of measures have been introduced to protect designated Leadbeater's possum habitat through a formal reserve system, retaining habitat within State forest using a zoning system and prescriptions, habitat resource assessment and early mapping of key habitat requirements has been undertaken. Additional management actions have been implemented recently through the Leadbeater's Possum Advisory Group recommendations.

Extensive population monitoring of the Leadbeater's Possum has been undertaken but this has not been conducted for all the sub-populations over the known range, and the focus has been on population trends rather than absolute numbers, except for at Yellingbo and in some snow gum woodlands.

There has been a very substantial investment over several decades in research and management actions, and notable conservation policy initiatives. Notwithstanding such effort, the current and projected trends for the species and its habitat is one of continuing decline. Existing management and protective mechanisms have been insufficient to stop the decline and support the recovery of the species.

2.0: EVALUATION AGAINST OBJECTIVES

While the recovery plan identified the need for protection of habitat, and protection has been implemented largely in line with the actions outlined in the Recovery Plan, decline has continued and threats have not been abated. In addition, severe bushfires in large parts of the Central Highlands in 2009 have substantially reduced the overall population and the available habitat for Leadbeater's Possum.

3.0: CHANGES IN KNOWLEDGE AND CONSERVATION TRAJECTORY

In its recent assessment of the conservation status of this species, the Australian Government Threatened Species Scientific Committee judged that the population of the species (explicitly based on information on its area of occupancy, extent of occurrence and/or quality of habitat) had declined by more than 80% over its last three generations (18 years) and, further, that it was projected to decline by more than 80% over its next three generations: collectively, an estimated population decline of more than 96% over a 36 year period. Ongoing action is required to facilitate the longer term viability of this species.

4.0: RECOMMENDATIONS

An updated recovery plan is required, providing for the research and management actions necessary to stop the decline of, and support the recovery of Leadbeater's Possum.

Review methods: The Department of the Environment and the Victorian Department of Environment, Land, Water and Planning have collaborated on undertaking this review.

Date: February 2016

1.0: PROGRESS OF RECOVERY ACTIONS

1.1: Progress in implementing actions

Status progress

No/little progress   Some progress   Action completed

Actions	Action description from 1997 Recovery Plan	Implementation details	
		Activities/achievements/outcomes in meeting Action	Status
1 The Leadbeater's Possum Management Team (LMT) to continue to monitor and review recovery program and recommend further management actions. (Re objective 1)	The Leadbeater's Possum Management Team (LMT) includes representation from academia, the community, Australian Nature Conservation Agency (ANCA) and staff from the relevant NRE areas and policy divisions. It reports on actions being implemented and provides a forum for discussing problems and recommending modification. The LMT provides an annual written report to the Leadbeater's Possum Steering Committee (LPSC), which will include an evaluation of progress towards achieving objectives of this Recovery Plan.	A collaborative management approach was established to implement the Recovery Plan through the Leadbeater's Possum Management Team which incorporated the biodiversity and forestry sections within the state government department. Regular reports were provided on the progress of actions (especially the establishment of the Leadbeater's Possum reserve and Zone 1 habitat). The Management Team (which was later called the Recovery Team) was operational most of the time up to 2014, with a few periods of inactivity. With the establishment in 2013 of Leadbeater's Possum Advisory Group (LPAG) and the implementation of their recommendations which applied to the Central Highland population, the Recovery Team largely focussed on the Yellingbo population. LPAG recommendations to support the recovery of the Leadbeater's Possum while maintaining a sustainable timber industry were accepted by the Victorian Government and implementation commenced in early 2014. Implementation of the recommendations is overseen by a cross agency implementation committee. There was no information made publicly available on the monitoring and reviewing of actions by the early Management Team. There have been two reports on the progress in implementing the LPAG recommendations published in October 2014 and 2015.	
2 Apply conservation strategies in each of the 21 Leadbeater's Possum Management Units (LMUs) (Re objective 1)	For the management of Leadbeater's Possum public forests within the Central Highlands have been divided into geographic units based on the extent and spatial distribution of ash-type forest. These are referred to as Leadbeater's Possum Management Units (LMUs). Each LMU generally contains between 6,000 and 10,000 ha of ash-type forest; the LMUs are composed of one or more forest management blocks containing contiguous patches of ash-type forest. Twenty-one LMUs have been delineated, covering the known distribution of Leadbeater's	The 21 LMUs had been established by the time the Recovery Plan was released and these have been subsequently used to assist with management decisions, especially for designing the Leadbeater's Possum reserve - see Action 5. More recently the LMUs have been used for one of the LPAG recommendations to protect at least 30 percent of ash forest within each LMU which is a new standard introduced with the release of the *Code of Practice for Timber Production 2014.*	

	Possum in the Central Highlands. The target for the conservation of Leadbeater's Possum is to maintain viable populations of the species in all LMUs.		
3 Complete habitat resource assessment across known range of the species. (Re objective 1)	Habitat resource assessment is being undertaken to determine the extent and distribution of current optimum and potentially optimum habitat for Leadbeater's Possum (as defined in this document). The methodology uses aerial photo interpretation to map a vegetation mosaic of the dominant canopy species and age-class or growth-form and the location of individual old ash trees (where they occur outside patches of old ash-type forest) and emergent stags. The habitat resource assessment is complete for 75% of the ash forest throughout the range of Leadbeater's Possum. In addition, proposed logging coupes as set out in 3 year wood utilisation plans are checked by either helicopter survey or ground survey, or both for areas of Zone 1B habitat that cannot be identified by air photo interpretation.	Air photo interpretation (API) to assess habitat resources was undertaken during the 1990s based on the mapping of emergent mature or senescent trees and dead stags. This mapping and a simple model was subsequently used to identify areas that met Zone 1 habitat criteria. These patches were then incorporated into SPZs enacted through the Central Highlands Forest Management Plan in 1998. Patches containing large old trees that did not meet the criteria for Zone 1A habitat remained within the General Management Zone and managed through prescriptions (Action 4). There has been a severe decline in the abundance of large old trees since this time due to bushfires and collapse of stags remaining from the 1939 fires, and a loss of live hollow-bearing trees (Lindenmayer et al. 2012). As a result the earlier API mapping is no longer representative of the current situation and checking for Zone 1 habitat has been undertaken using ground assessments on proposed timber harvesting coupes, and there is currently not a map showing where all the large old trees are across the whole of the Central Highlands. As part of the LPAG recommendations, methods to identify potential Zone 1A habitat at a landscape level using information derived from existing aerial photography and remote sensing technology have been explored. This has been developed further in 2015 with an aerial survey commissioned to collect new data using remote sensing technology, including LiDAR to better enable identification of mature and senescent trees, which can then be used to identify Zone 1A habitat. Habitat distribution models and occupancy models for the Leadbeater's Possum have been developed by ARI (DELWP) to predict the areas most likely to be occupied by Leadbeater's possum. These models will be updated based on new data on the distribution of the species and will incorporate the spatial mapping of mature and senescent trees as well as understorey density.	
4 Zone all areas of forest within known	The management zoning system for Leadbeater's Possum in State forest has been revised to reflect the relative long-term stability of	This action was implemented at the time of the recovery plan and enacted through the Central Highlands Forest Management Plan in 1998. The review of the	

range of Leadbeater's Possum according to habitat suitability. (Re objective 1)	some good habitat with live old trees (Zone 1A) and the impermanence of habitat where most existing nest-trees are dead and likely to collapse in the near future (Zone 1B). Zone 1A: Leadbeater's Possum (and other wildlife) conservation as the major priority. • mature ash forest (> 120 years old) and mixed-aged ash forest where the oldest age class is mature (> 120 years old) • regrowth ash forests with > 12 live hollow-bearing trees per 3 ha. • the minimum area for assessment and establishment of Zone 1A type forest shall be 3 hectares. Zone 1B: Leadbeater's Possum conservation and timber production as joint priorities. • regrowth ash forest with > 12 live or dead hollow-bearing trees per 3 ha. combined with a basal area > 5m2 of *Acacia dealbata, A. obliquinervia or A. frigescens*. • the minimum area for assessment and establishment of Zone 1B type forest shall be 10 hectares. Zones 1A and 1B, regardless of minimum size criteria, have the highest priority in the reserve selection process detailed in Action 5. Areas of Zone 1B, identified and mapped as priority for inclusion in the reserve system, will be protected from timber harvesting. If these areas become unsuitable or offer little potential as habitat for Leadbeater's Possum through successional or other change, (which is likely for Zone 1B during the next 50 years), they will become available for timber harvesting. Conversely, areas that develop the essential components for Zone 1 classification through time, or circumstance will attain Zone 1 status. Zone 1A forest will not be included in sustainable yield calculations whilst Zone 1B will be included. The role of Zone 1B, including the minimum area of assessment, will be reviewed following completed habitat resource assessment, reserve establishment and subsequent population viability analysis (PVA), to determine its effectiveness in contributing to the major conservation objectives.	effectiveness of Zone 1B in contributing to the major conservation objectives including the minimum area requirements, however, was not undertaken. No specific action in relation to Leadbeater's Possum was applied to Zone 2 habitat. Amendment of the definition of Zone 1A habitat to >10 live mature or senescent hollow bearing ash trees per three hectares in patches greater than three hectares was recommended by LPAG in 2014. The revised definition which reduced the requirement from 12 to 10 trees was implemented with the release of the *Code of Practice for Timber Production 2014.* The definitions of Zone 1A and 1B have varied subtly between the various documents in which they are defined (i.e. Recovery Plan, Action Statement, Forest Management Plan), and have been further interpreted in the Leadbeater's Possum survey standard released in April 2015 (available on DELWP website), which introduced additional definitions and requirements for trees and areas to meet the criteria for Zone 1A and 1B habitat.	

	Zone 2: Timber production as the major priority, but including the conservation of existing components of habitat. This zone will consist of remaining forest, where the prescriptions outlined in Action 7 will be applied to protect existing habitat components for their on-site value and to enhance the value of adjacent habitat. GIS based analysis will continue to be used to identify the Leadbeater's Possum management zones, generate maps, examine management options and assess impact on other forest values and uses.		
5 Establish a reserve system across the range of the species based on habitat suitability. (Re objective 2)	NRE will establish a permanent reserve system in each LMU based on the extent and spatial distribution of Zone 1 classified forest, combined with strategic areas of regrowth forest (Zone 2). The intention of the permanent reserve will be to identify, and maintain in the long-term, sufficient areas in the forest that will sustain viable populations of Leadbeater's Possum. The permanent reserve will exist in two forms; large, aggregated patches of ash-type eucalypt forest (>50 ha) and smaller (3-50 ha) patches of Zone 1A habitat that are dispersed throughout the forest. Large patches will be 50 to 100 hectares in size to minimise the impact of threatening processes and be linked by wildlife corridors, streamside reserves, buffer strips and areas of State forest not suitable or available for timber harvesting. The total area of large patches in each LMU will be a target of at least 600 hectares of ash forest, but will vary depending on the extent and spatial distribution of potential and existing habitat, both within and adjacent to each LMU. The reserve system will be implemented through the Central Highlands Forest Management Plan and reflected in the Regional Forest Agreement.	The Leadbeater's Possum reserve system was established in the Central Highlands to protect priority areas of Leadbeater's Possum habitat. When this reserve was established in 2008, it comprised 30,500 ha of high-quality Leadbeater's Possum habitat, distributed throughout the species' range from Toolangi in the north-west to Erica in the south-east. A total of 127 patches, greater than 50 ha in size, and containing predominantly old growth ash forest were selected (Smith and Morey 2001). Areas of old growth were primarily selected as these were likely to provide suitable habitat into the future, compared to areas of 1939 regrowth where the dead hollow-bearing trees were collapsing. The patches were spread across the species' range to reduce the risk of large areas being rendered unsuitable due to bushfire. Areas to be included in the reserve system were assessed tenure blind. The majority of the reserves (85%) were located in areas that were formal parks and reserves or existing Special Protection Zones within state forest (58% in parks and reserves and 27% in Special Protection Zones). 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 Special Protection Zones which excluded timber harvesting. The Recovery Plan recommended linking these patches with wildlife corridors, streamside reserves etc, however, this was not universally implemented. In 2009, 45% of the Leadbeater's Possum reserve was burnt during the bushfires, and hence these areas no longer contain live old growth forests, however as the area regenerates they will provide suitable habitat based on the dead standing hollow-bearing trees and dense regeneration. They are therefore still important	

		areas for the species. Within the Central Highlands there are over 200,000 hectares of potential habitat for Leadbeater's Possum, with 34% of this reserved within national parks and conservation reserves and a further 14% is protected within SPZs, i.e. 48% of the species range is formally reserved (LPAG 2014b). Additional areas have recently been protected as part of implementing the LPAG recommendations through the release of the *Code of Practice for Timber Production 2014* as follows: • Establishment of Special Protection Zones in State forests for 200 metre radius centred on each verified Leadbeater's Possum colony found since 1998 excluding forest areas severely impacted by the 2009 bushfire; • Exclusion of timber harvesting in State forest from within 100 meters of modelled old growth ash forest in the Leadbeater's Possum range.	
6 Implement population monitoring throughout known range (Re objective 3)	Implement monitoring of Leadbeater's Possum populations throughout its range, using rigorous experimental design to assess its conservation status and to assess the effectiveness of the reserve system for Leadbeater's Possum conservation.	Largely complete as there has been extensively monitoring throughout the species range, and this has provided critical information on population trends in various areas and conservation status. Long-term monitoring of 161 one-hectare sites within the ash forests has been undertaken since 1997 that includes count data of arboreal marsupials including Leadbeater's possum (Lindenmayer 2009). Monitoring of populations in snow gum woodland at Lake Mountain, Mt Bullfight and Mt Baw Baw, some of which commenced in 2003, is also ongoing (Harley 2016). Detailed annual population monitoring of the lowland population at Yellingbo has been underway since the mid-1990s, assessing total population size and colony persistence through time (Harley 2016). A recent Population Viability Assessment has assessed the effectiveness of the reserve system for Leadbeater's possum, post the 2009 fires (Lumsden et al. 2013), building on earlier PVAs.	
7 Apply guidelines during logging coupe planning and harvesting and adopt modified or alternative silvicultural	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.	The *Code of Practice for Timber Production 2014* contains regulatory standards for timber harvesting for the Leadbeater's Possum and its habitat in line with government policy. This policy is outlined in the Leadbeater's Possum Action Statement, last revised in 2014. The Leadbeater's Possum Survey Standard was last revised in 2015. These documents are current.	

systems (Re objective 4)	**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. Where possible logging operations should be staggered so that a retained buffer strip is not simultaneously exposed on both sides. **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. **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. 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. **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. **Adoption and refinement of alternative silvicultural systems** Continue to undertake operational trials of retained overwood silvicultural systems with a view to their 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	In addition to the obligatory regulatory standards, VicForests undertakes coupe planning and harvesting methods to manage risks associated with potential impact to the Leadbeater's Possum. These are implemented in line with government policy. Some protection of hollow-bearing trees occurs with pre-1900 live trees not harvested, however they are frequently impacted by regeneration burns. Less protection is provided to dead hollow-bearing trees. Salvage logging prescriptions consider Leadbeater's Possum habitat and treat a burnt area of Zone 1A habitat as if it was unburnt, and hence harvesting does not occur. Alternative silivicultural systems have been adopted and from 2014 onwards, 50% of the ash forest within the range of Leadbeater's Possum will be harvested using retention harvesting approaches and alternatives to high intensity regeneration burns are being investigated.	

	and potential habitat within each Leadbeater's Possum Management Unit (LMU).		
8.1 Assess development proposals which could affect Leadbeater's Possum for areas outside State forest. (Re objective 4)	Assessment of all areas within the known range of Leadbeater's Possum need to be carried out as part of any development proposals which could affect the species, including roading, recreation facilities, fire management.	Referral of forestry operations (within State Forest) is not required under the EPBC Act (covered by RFA). Other actions that may have a significant impact on Leadbeater's possum are required to be referred under EPBC Act to the Australian Government Minister for the Environment. The East Central Bushfire Management Plan identifies known Leadbeater's Possum colonies and the location of high quality habitat and factors this information into bushfire risk planning and risk reduction activities. Assessments are undertaken to examine the risk of other developments.	
8.2 Determine management objectives for the populations of Leadbeater's Possum in the Yellingbo State Nature Reserve and snow gum forests at Lake Mountain and Mt. Baw Baw (Re objective 4)	Investigate the status and determine the necessary management objectives for the recently discovered populations of Leadbeater's Possum in the Yellingbo State Nature Reserve and snow gum forests at Lake Mountain and Mt Baw Baw.	Detailed annual population monitoring of the Leadbeater's Possum population at Yellingbo Nature Conservation Reserve is undertaken, with >80% of the total population sampled each year via nest boxes. Several measures of population condition are evaluated annually, including total population size, colony sizes, colony persistence through time, reproductive rates, and annual recruitment, as well as data on survivorship, longevity and dispersal (Harley 2016). Nest boxes have also been used to monitor populations in snow gum woodlands to investigate distribution and abundance both before and after the 2009 fires (Harley 2016). Management objectives have been developed and are being implemented.	
9 Implement training programs to ensure quality application of, and implementation of, management guidelines. (Re objective 5)	Implement training for all relevant field and planning staff involved with Leadbeater's Possum management and/or timber production within its range, in relation to understanding the ecology of Leadbeater's Possum, habitat assessment and recording, the recovery plan process, and progress towards implementation of Leadbeater's Possum management guidelines.	VicForests has undertaken training of field staff as operational procedures are introduced or revised, most recently following publication of a new Regrowth Retention Harvesting instruction applied in the Central Highlands to implement a LPAG recommendation. Although there are no formalised training programs for DELWP operational field staff, staff have access to a range of up to date Leadbeater's Possum information and are provided with on the job training appropriate to their role in relation to threatened species management issues, including for the Leadbeater's Possum.	
10.1 Research on dispersal and recolonisation capacities (Re objective 6)	Determine the dispersal and recolonisation capacities of Leadbeater's Possum Examine the results of genetic analysis to explore aspects of dispersal behaviour and population genetic variability in several wild sub-populations of Leadbeater's Possum.	Genetic analysis has been undertaken using samples from some subpopulations: mainly from Yellingbo and snow gum woodlands, with less sampling from ash forests (Hansen and Taylor, 2008; Hansen et al, 2009). This provides information on dispersal and genetic isolation, however, detailed information on recolonisation capacities for management purposes and arrangement of reserves is lacking. Nest	

	Design, scope and implement a research project to determine the extent and limitations of dispersal and recolonisation capacities utilising artificial nest boxes as a trapping and recapture methodology. A major outcome of the project would be to determine the best spatial arrangement of reserved areas for the species.	boxes have been used successfully as a trapping and recapture methodology, especially in Yellingbo and in snow gum woodlands (Harley 2016). Annual monitoring of areas of subalpine woodland burnt during the 2009 fires is investigating recolonization rates (Harley 2016).	
10.2 Research response to edge effects (Re objective 6)	Investigate the response of Leadbeater's Possum to edges of habitat.	Information on the impact of edge effects has been investigated in a number of studies. Lindenmayer et al. (1993) found that linear strips set aside and excluded from timber production (e.g., on steep slopes and adjacent to streams, stands of unmerchantable timber and strips set aside for wildlife conservation) supported fewer species and had a lower probability of containing an animal than sites of similar habitat quality within areas of continuous forest. In addition, the number of trees with hollows in contiguous forest that were occupied by an arboreal marsupial was approximately twice that of trees in retained linear strips. Small patches of forest are unlikely to support populations of Leadbeater's possum. Population Viability Analysis suggest that single isolated populations of greater than 200 Leadbeater's possums are required for a high probability of long term persistence (Lindenmayer et al., 1993). Edge effects from additional logging roads and tracks may similarly render these remnants less viable, as possums are reluctant to cross these. Once harvested areas have regenerated however, ecotones between different aged habitat can be used by colonies and many of the sites where Leadbeater's Possums are currently being found during the DELWP targeted surveys are located on or near ecotones such that both foraging and nesting habitat is available (Nelson et al. 2015). Ecotones between some different vegetation types can also be productive, such as where rainforest or montane riparian thickets adjoin ash forest.	
10.3 Research on fire modelling (Re objective 6)	Improve the precision of modelling fire in the ash forests of the Central Highlands, particularly as it relates to the risks of reducing populations of Leadbeater's Possum.	The East Central Bushfire Risk Landscape project uses Phoenix RapidFire, a fire simulation tool, to study how under different weather conditions, a fire is predicted to spread over the landscape and impact on different assets, which in this case is Leadbeater's Possum habitat. The use of this tool can predict where the worst fires will spread and how fuel management actions can be used to reduce the spread and intensity of a fire and potentially protect the species habitat. Currently the East Central Bushfire Risk Landscape Team have modelled and assessed bushfire risk to known colonies and high-quality habitat of Leadbeater's Possum, and chosen some	

		adjacent areas for priority fuel management to reduce the risk. The published Strategic Bushfire Management Strategy (2014) shows the extent to which the strategy will reduce residual risk to Leadbeater's Possum and high-value native timber in the Central Highlands, benefiting the recovery of the possum and the timber industry. Further risk analysis work is being undertaken to refine the model inputs and improve the strategy to define the best fuel management approach to reducing the risk of bushfire to the Leadbeater's Possum	

2.0: EVALUATION AGAINST OBJECTIVES

2.1: Summary evaluation of achievement against objectives

Overall objective	Comments	Status
To downlist Leadbeater's Possum from endangered to vulnerable within 10 years based on the IUCN (1994) criteria of population trend and size, extent of occurrence, probability of extinction, and the management of habitat towards a target of no more than a 1% probability of extinction over 250 years throughout the forest within its current range.	Not achieved. Species has been uplisted to critically endangered.	🔴
Specific objectives/*recovery criteria*	**Comments**	**Status**
SO1: Identify and implement protection of optimum and potentially optimum habitat including the establishment of a permanent reserve system, using the CAR reserve system consistent with the JANIS criteria. ***RC1:***Identify all optimum and potentially optimum habitat within the known range of the species by 1997 and have this data scanned and entered onto NRE's Geographic Information System (GIS).	Criterion met. See Action 2-5	🟢
SO2: Apply strategies that address the development and continued availability of habitat in each Leadbeater's Possum Management Unit (LMU). ***RC2:*** Establish a permanent reserve system in 10 Leadbeater's Possum Management Units (LMU) by June 1997 and the remaining LMU's by June 1998. The reserve system will include strategic areas of both existing optimum and potentially optimum habitat with a target of at least 600 ha of ash forest in each designated LMU.	Criterion met although full implementation of reserve system delayed until 2008. See Action 5	🟢
SO3: Implement population monitoring of Leadbeater's Possum throughout its range and assess the effectiveness of the reserve system for the species conservation, using rigorous experimental	See Action 6 Long-term monitoring of arboreal marsupials including Leadbeater's possum has	🟢

design. ***RC3:*** Develop and implement a monitoring program based on rigorous experimental design to assess population status of Leadbeater's Possum throughout its range and the effectiveness of the reserve system for the conservation of the species.	been conducted since the early 1980s' focusing on known localities and population strongholds in ash forests to investigate trends. Detailed monitoring has occurred in snow gum woodlands (e.g. Mt Baw Baw, Lake Mountain, Mount Bullfight) and at Yellingbo. Lumsden et al. (2013) undertook new surveys, sampling across the species' range to determine occurrence and population strongholds, and predict areas where they might occur, with current targeted surveys (Nelson et al. 2015) sampling these areas to locate colonies for protection. This is providing additional information on where the species is located but longer term monitoring will be required to investigate persistence at these sites.	
SO4: Develop management guidelines for Leadbeater's Possum throughout its range. Apply modified and alternative silvicultural systems that result in high quality habitat, while providing for commercial timber production. ***RC4:*** Existence of management guidelines that address the conservation of Leadbeater's Possum throughout its range. Including the application of modified or alternative silvicultural prescriptions to protect and promote the availability of hollow-bearing trees, specifically in the Special Management Zone (SMZ) implemented through the Central Highlands Forest Management Plan.	Management guidelines and prescriptions developed. See Action 7. The effectiveness of these prescriptions in protecting and promoting the availability of hollow-bearing trees, however, is debated, particularly in the context of the range of threats operating.	
SO5: Implement training for all relevant field and planning staff. ***RC5*:** Implement training for all relevant field and planning staff, and monitor and report annually on progress towards implementation of Leadbeater's Possum management guidelines as contained in the Central Highlands Forest Management Plan.	Some training has been undertaken by biodiversity staff in DELWP and VicForests. See Action 9. Limited monitoring or annual reporting the implementation of Leadbeater's Possum management guidelines (i.e. the prescriptions).	
SO6: Undertake research on biology and ecology with a particular emphasis on the risk of wildfire reducing populations, the dispersal and recolonisation capacities of the species and response to edge effects. ***RC6:*** Establish research projects by 1997 addressing the dispersal and recolonisation capacities of the species, modelling of fire as it relates to the risks of reducing populations of Leadbeater's Possum and response to edge effects.	Extensive research has been undertaken on Leadbeater's possum since the Recovery Plan was published in 1997, including the impact of wildfires and response to edge effects. Dispersal and recolonization capacities have been investigated for the Yellingbo population but less has been studied on these aspects for the Central Highlands populations. See Actions 10.1-10.3.	

Status progress

	Objective not achieved	No progress towards meeting criteria/Insufficient action to meet criteria
	Objective partly achieved	Criteria not fully met but some progress/Action underway, most elements of criteria met
	Objective achieved	Criteria met, further actions may or may not be required

3.0: CHANGES IN KNOWLEDGE AND CONSERVATION TRAJECTORY

3.1: Evaluation of the current status and conservation trajectory of the species

Previously known status at the time the recovery plan was published	
Habitat/distribution	The possum is mainly confined to montane ash forests dominated by *Eucalyptus regnans, E. delegatensis* or *E. nitens* in the Central Highlands of Victoria, is not uniformly distributed throughout this area – occurring in patches, and is most likely to occur on sites with numerous trees with hollows and dense *Acacia* spp. understory. The species has recently been recorded in snow gum *E. pauciflora* woodland, and lowland swamp forest *E. camphora* and *E. ovata*.
Abundance	No abundance data provided in the plan.
Threats	Reduction of nest trees as a result of logging and natural decay (see below re trajectory for timing). Bushfires
Trajectory predicted	Modelling predicted a reduction in the availability of suitable habitat (nest trees) between the time of writing and the year 2020 followed by a population bottleneck until the year 2075.
Current known status	
Habitat/distribution	No significant change in the overall distribution, however within this area the range has constricted due to loss of suitable habitat following the 2009 bushfires. Detailed knowledge of the distribution has increased significantly in recent years based on surveys at long term monitoring sites (e.g. Lindenmayer 2009), detailed nest box and camera trap surveys at Yellingbo, snow gum woodlands and parts of the ash forest (Harley 2016) and DELWP surveys throughout the ash forests (Lumsden et al. 2013, Nelson et al. 2015). This new information is readily available through the DELWP interactive map (http://lbp.cerdi.edu.au/possum_map.php). Genetic information (Hansen et al., 2009) indicates that the Yellingbo subpopulation in the lowland swamp forest is a distinct evolutionary unit and the last representative of what was a broader distributed population that has suffered from habitat loss. There is now also a greater understanding of habitat requirements in all three main habitat types.
Abundance	A number of rough estimates of current total population size have been made based on extrapolations from survey data, with wide ranging population numbers presented depending on assumptions made. Irrespective of this range in estimates, the true abundance is expected to be significantly less than at time of publication of RP in 1997, due to impact of 2009 fires.
Threats	Same threats. +Habitat decline for lowland populations.
Trajectory predicted	Negative trajectory remains, however a significant proportion of habitat, and therefore the associated populations, have declined since the plan's publication. PVA modelling suggests a continuing decline of population numbers over the next several decades due to changes in forest structure and hollow-bearing trees abundance (Lumsden et al. 2013).
Evaluation of change in conservation trajectory	

The negative change trajectory has continued, and the population has undergone a significant decline, estimated based on significant decline in available suitable habitat as a result of continued loss from fire (especially the 2009 bushfires), timber harvesting and natural decay. The species was considered to be endangered at publication of the plan (1997) and is now listed as critically endangered (2015).

4.0: RECOMMENDATIONS

4.1: Potential recovery objectives

Long-term recovery objective:

Increase the extent, quality and connectivity of currently and prospectively suitable habitat, and its occupancy by Leadbeater's possum in order to maximise the probability of persistence of the species

While acknowledging that the long-term recovery objective is unlikely to be achieved over the ten year period of a new plan, the following interim recovery objectives are recommended for discussion.

Interim Objective	Existing, Modified, New	Link to any existing or new objectives	Comments
All relevant existing and future planning and policy settings are refined, interpreted and implemented in a manner that contributes appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature	Modified	Specific Objectives 1 & 2 in the 1997 Recovery Plan	Management actions alone will not be sufficient to recover the Leadbeater's possum: that objective also needs harmonisation of existing and future planning and policy settings such that they collectively and coherently contribute appropriately to maximising the chances of long-term survival of Leadbeater's possum in nature.
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	Modified	Specific Objectives 1, 2 & 4 in the 1997 Recovery Plan	The key conservation concern for Leadbeater's possum is ongoing decline in the extent, quality and connectivity of suitable habitat, now and into the future. This objective seeks to focus explicitly on the maintenance and management of currently suitable habitat, and to ensure that future habitat is maintained and effectively managed
Where there is a net long-term benefit, translocate individuals or colonies within and adjacent to the known range	New		Strategic translocations within the known range may decrease population fragmentation, and increase subpopulation viability and occupancy of suitable habitat.
Seek to locate, or establish, additional populations outside the core range of the Central Highlands.	New		The conservation future of Leadbeater's possum within its known range in the Central Highlands is precarious. Its overall conservation outlook may be improved by seeking to spread extinction risks by establishing additional populations outside this known range, while the current population size may still allow for such translocation.
Targeted research addresses key knowledge gaps that currently impede effective management.	Modified	Specific objective 6 in the 1997 Recovery Plan	This interim objective aligns closely with the 1st and 2nd interim objective to enhance our knowledge on the current biology, and ecology of this species following on from the original recovery plan prescriptions, new and ongoing research and the 2009 bushfires.
An integrated monitoring program is effectively implemented that publicly reports	Modified	Specific objective 3 in the 1997	Ongoing implementation of a monitoring program to indicate the status of the species to

in a timely manner on possum status, existing and prospective habitat extent, quality and connectivity, and effectiveness of management actions.		Recovery Plan	inform management decisions.
All stakeholders support and where relevant are involved in the implementation of the plan	Modified	Action 1 in the 1997 Recovery Plan	Development of a recovery team or similar governance model to oversee the implementation of this plan, and to facilitate stakeholder engagement and involvement.
Ensure effective and adaptive implementation of the plan including adequate reporting	New		A framework is implemented such that positive or negative recovery aspects are reported upon, and the recovery actions can be adapted (if necessary) to support the overall ongoing recovery of the species.

4.2 Discussion and recommendation for future recovery effort

Based on this review, all key previous threats to this species remain, the species conservation trajectory is declining, and the objective of the original plan has not been achieved. The species has been uplisted under the EPBC Act from Endangered to Critically Endangered.

A range of measures have and currently are being implemented by Victoria resulting from the publishing of the Leadbeater's Possum Action Statement in 2014.

An updated recovery plan is required, providing for the management and research actions necessary to stop the decline of, and support the recovery of Leadbeater's possum, and build upon the work which is already being undertaken to protect the Leadbeater's possum and its habitat over the longer term.

4.3 Recommendation

It is recommended that an updated recovery plan be developed

5.0: INFORMATION SOURCES, REFERENCE MATERIAL, ACKNOWLEDGEMENTS:

Commonwealth of Australian and State Government of Victoria (1998) Central Highlands Regional Forest Agreement. www.agriculture.gov.au/SiteCollectionDocuments/rfa/regions/vic-central-highlands/rfa/vic_cent_rfa.pdf

Hansen BD (2008). Population genetic structure of Leadbeater's possum *Gymnobelideus leadbeateri* and its implications for species conservation. PhD Thesis, Monash University, Clayton, Australia.

Hansen BD, Harley DKP, Lindenmayer DB and Taylor AC (2009). Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. Molecular Ecology 18: 3346–3362.

Hansen BD and Taylor AC (2008). Isolated remnant or recent introduction? Estimating the provenance of Yellingbo Leadbeater's possums by genetic analysis and bottleneck simulation. Molecular Ecology 17: 4039–4052.

Harley, D (2016). An overview of actions to conserve Leadbeater's Possum (*Gymnobelideus leadbeateri*). Victorian Naturalist (in press).

Leadbeater's Possum Advisory Group (2014b) Leadbeater's Possum Technical Report: Report to the Minister for Environment and Climate Change and the Minister for Agriculture and Food Security. http://www.depi.vic.gov.au/__data/assets/pdf_file/0019/258220/Leadbeaters-Possum-Advisory-Group-Technical-Report.pdf.

Lindenmayer D (2009) 'Forest Pattern and Ecological Process: A Synthesis of 25 years of Research.' (CSIRO Publishing: Collingwood)

Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, Likens GE, Franklin JF, Laurance WF, Stein JAR and Gibbons P (2012). Interacting factors driving a major loss of large trees with cavities in a forest ecosystem. PLOS One 7, e41864.

Lindenmayer DB, Cunningham RB, Donnelly CF, Tanton MT and Nix HA (1993). The abundance and development of cavities in *Eucalyptus* trees: a case study in the montane forests of Victoria, southeastern Australia. Forest Ecology and Management 60: 77–104.

Lindenmayer DB, Smith AP, Craig SA and Lumsden LF (1989). A survey of the distribution of Leadbeater's possum, *Gymnobelideus leadbeateri* McCoy in the Central Highlands of Victoria. Victorian Naturalist 106: 174-178.

Lumsden LF, Nelson JL, Todd CR, Scroggie MP, McNabb EG, Raadic 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.

Macfarlane M, Smith J, and Lowe K (1997). Leadbeater's Possum Recovery Plan. Department of Natural Resources and Environment, Victoria.

Nelson JL, Lumsden LF, Durkin LK, Bryant DB, Macak PV, Cripps JK, Smith SJ, Scroggie MP and Cashmore MP (2015) 'Targeted surveys for Leadbeater's possum in 2014-15 '. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning. Report for the Leadbeater's Possum Implementation Committee. (http://www.delwp.vic.gov.au/environment-and-wildlife/conserving-threatened-species-and-communities/leadbeaters-possum)

Smales IJ (1994). The discovery of Leadbeater's possum *Gymnobelideus leadbeateri* McCoy, resident in a lowland swamp woodland. Victorian Naturalist 111: 178-182.

Smith S and Morey J (2001) 'Options for a permanent reserve system for the conservation of Leadbeater's Possum. Central Highlands of Victoria.'Department of Natural Resources and Environment, East Melbourne.

State Government Victoria NRE (1998) Forest Management Plan for the Central Highlands. Department of Natural Resources and Environment, Victoria.

State Government Victoria DEPI (2014). Action Statement No 62 Leadbeater's Possum *Gymnobelideus leadbeateri Flora and Fauna Guarantee Act 1988*. Victorian Government Department of Environment and Primary Industries.

State Government Victoria DELWP (2015). Threatened Species Survey Standard Leadbeater's possum. Department of Environment, Land, Water and Planning, Victoria.

State Government Victoria (2014). Supporting the recovery of Leadbeater's possum – Report on Progress. Victorian Government.

TSSC (2014). Conservation advice *Gymnobelideus leadbeateri* Leadbeater's possum. Threatened Species Scientific Committee.

VicForests (2013 draft). Forest Management Plan. Victorian Government.

VicForest (2013 draft). VicForests Strategy. Victorian Government.

Threatened Species Scientific Committee - Leadbeater's Possum Working Group

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THREATENED SPECIES SCIENTIFIC COMMITTEE

Leadbeater's Possum Recovery Plan Working Group Teleconference

Wednesday 13 July 2013 – 9 till 10.30am

Draft **MINUTES**

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RECOVERY PLANNING – COMPLIANCE CHECKLIST FOR LEGISLATIVE AND PROCESS REQUIREMENTS

to be provided with recovery plans for terrestrial threatened species and ecological communities

This checklist guides assessment of a recovery plan against the legal requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and Regulations, and policy requirements of the Department of the Environment and Energy.

Title of Plan: National Recovery Plan for Leadbeater's possum (*Gymnobelideus leadbeateri*)
Author: Department of the Environment and Energy **Date of Plan: 2016**

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Habitat critical to survival: EPBC Act s270(2)(d); s270(2A); Reg 7.09; 7.11(1)(b); 7.11(3)		
13. To the extent practicable, does the plan concisely define the habitats that are critical to the survival of the species or ecological community concerned, based on matters in EPBC Reg 7.09?	**YES**	Given the current Critically Endangered status of Leadbeater's possum, and its predicted severe ongoing decline, including significant risks of extinction, all current and prospective suitable habitat is critical for its survival, and necessary for its recovery. This is identified in Section 3.4.9 Habitat Critical to Survival.
14. To the extent practicable, does the plan describe, with spatial information, these areas, OR state that habitat critical can't be located? NOTE: If this information is confidential, please provide separately, and include generic location information only within the plan.	**YES**	The Recovery Plan outlines a suite of Actions to protect existing known suitable habitat, and to protect prospective habitat once identified under Objective 2. Through Actions 2.3, 2.5, 2.6 and 2.7.

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Actions EPBC Act s270(1); s270(2)(a), (c), (d) & (e); s270(2A); Reg 7.11(2)(a) **21.** Does the plan identify appropriate on-ground actions necessary to: – stop decline and support recovery? – achieve the objectives? – measure against all performance criteria? – reduce and manage the threats? – protect and restore habitat, including habitat critical to survival (to the extent that it has been identified)? – protect important populations and populations under particular pressure (to the extent that they have been identified)? – fill critical information gaps?	**YES** yes yes yes yes yes yes yes	Actions to meet the Objectives of the Plan are addressed in Section 7 and Section 8 the Plan Implementation. These actions have been developed through consultation with experts, stakeholders and submission received during the public consultation process.

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DEPARTMENT OF THE ENVIRONMENT AND ENERGY
The recovery plan complies with the EPBC Act and regulations

CHECKED BY: DATE:

Leadbeater's Possum Recovery Plan – Responses to 11 Main Submissions received during public consultation

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[redacted]

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	List critical habitat for the species on the critical habitat register	No Change

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Advice to the TSSC on habitat critical to the survival of the species as identified in the National Recovery Plan for the Leadbeater's Possum

Scientific Name/Ecological Community Title	*Gymnobelideus leadbeateri*
Common Name (*if applicable*)	Leadbeater's Possum
Species/Community Distribution:	
Recovery Plan has been developed for the entire distribution within Victoria, Australia.	

CONSIDERATION OF CRITICAL HABITAT	
1. Does the draft Recovery Plan provide enough information to identify habitat that is critical to the species or ecological community, i.e. does the habitat meet at least one criterion identified in the EPBC regulations?	Yes
2. Does the draft Recovery Plan provide enough information to identify the area of critical habitat on the ground, including its location and extent? For example, are the boundaries of the habitat clearly described, or is there a series of grid references which allow the boundaries to be ascertained on the ground?	Yes
3. Will the listing of Critical Habitat provide a clear conservation benefit?	No

CONCLUSION	
Based on the answers to the above, is there sufficient information to determine and identify Critical Habitat, and is it considered that the listing of Critical Habitat will provide a clear conservation benefit?	No

Matters to be taken into account in identifying critical habitat (Regulation 7.09):

a) whether the habitat is used during periods of stress;
b) whether the habitat is used to meet essential life cycle requirements (e.g. foraging, breeding, seed dispersal processes, etc.);
c) the extent to which the habitat is used by important populations;
d) whether the habitat is necessary to maintain genetic diversity or long-term evolutionary development;
e) whether the habitat is necessary for use as corridors to allow the species to move freely between sites used to meet essential life cycle requirements;
f) whether the habitat is necessary to ensure the long-term future of the species/community through reintroduction/re-colonisation;
g) any other way in which the habitat may be critical to the survival of the species or ecological community.

FOI 171107
Document 4

THREATENED SPECIES SCIENTIFIC COMMITTEE

65th meeting

6 – 8 September, 2016 Canberra

Draft **MINUTES**

Committee attendance		
Professor Helene Marsh (Chair)		
Professor Stuart Bunn	Professor David Keith	Ms Louise Gilfedder
Professor Colin Simpfendorfer	Dr David Kendal	Dr Nicola Mitchell
Professor Kingsley Dixon	Dr Sarah Legge	

Meeting opened at 9.02 am

1. OPENING REMARKS

1.1 Welcome to members and Chair's opening remarks

The Chair **acknowledged** the Ngunnawal people as the traditional owners and custodians of land on which members were meeting, and:

- **welcomed** members to the meeting.
- **acknowledged** the apologies of Dr Campbell for TSSC65, and of Professor Bunn and Professor Keith for the first day of the meeting (Tuesday 6 September).
- **Noted** that Dr Campbell and Professor Bunn provided written input for some items to be discussed in their absence on Tuesday 6 September, which would be presented by the Chair.

s22 - material irrelevant to scope

[1] the National Environmental Science Programme (NESP).

[2] International Union for the Conservation of Nature (IUCN)

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10.3 Recovery plan for *Pseudocheirus occidentalis* (western ringtail possum)

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10.4 Draft revised National Recovery Plan for Leadbeater's possum (*Gymnobelideus leadbeateri*)

- Members noted the updates made to the draft recovery plan in light of the working group and submissions received during the public consultation, and commended the progress that had beenmade.
- s47C [redacted]
- Members discussed amendments to the objective.
- Members requested the suggested modifications be made to the plan, and then the revised draft be resubmitted to the Leadbeater's possum working group out of session.

The Committee:

- ➢ s22 [redacted]
- ➢ **agreed** to advise the Minister that in the Committee's view there would be no clear conservation benefit from pursuing a listing on the Register of Critical Habitat for this species.
- ➢ **noted** the review of the current Leadbeater's Possum Recovery Plan (Item 10.4.2), the information provided regarding legislative compliance (Item 10.4.6) and assessment of habitat critical to the survival of the species (Item 10.4.8) arising out of the recovery plan.
- ➢ **requested** a letter be drafted from the Chair to Dr Lindy Lumsden and Professor John Woinarski, thanking them for their contribution to the development of the Draft Recovery Plan.

10.5 Draft national recovery plan for the Australian lungfish (*Neoceratodus forsteri*)

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CLOSING REMARKS

The Committee:

- **formally thanked** the Departmental officers and members of the TSSC for their work on TSSC64.

The meeting closed at 2:45pm on 8 September 2016

The Committee declares that these minutes are an accurate record of the 65th meeting.

Threatened Species Scientific Committee

[Input date when minutes are approved by the Committee]

Annex A

Guest and Departmental attendance

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