The Minister approved this conservation advice and retained this species in the Critically Endangered category, effective from 22 June 2019

Conservation Advice

Gymnobelideus leadbeateri

Leadbeater's Possum

Taxonomy

Conventionally accepted as *Gymnobelideus leadbeateri* McCoy, 1867

Summary of assessment

Conservation status

Critically Endangered:

Critically Endangered Criterion 1A4(b)

Endangered Criteria 1A2(a), 1A2(b), 1A3(b), 2B1a,b(iii)

Vulnerable Criterion 3C1

The highest category for which *Gymnobelideus leadbeateri* 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 advice follows assessment of information provided by a nomination from the public to change the listing status of Leadbeater's Possum.

Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 30 business days between 4 July 2018 and 14 August 2018. Any comments received that were relevant to the survival of the species were considered by the Committee as part of the assessment process.

Species/sub-species information

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 (Strahan 1988; Cronin 1991).

Distribution

Leadbeater's Possum is endemic to Victoria.

Leadbeater's Possum consists of two genetically-distinct subpopulations that have historically occupied different habitats (Hansen et al. 2009). 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 Department of Environment and Primary Industries (2014). The small subpopulation is a surviving remnant of a lowland subpopulation that has historically been, and remains, isolated from others (Hansen et al. 2009). The Yellingbo population occurs at 110 m elevation (Harley 2004).

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 montane Ash forest and subalpine woodland comprising *Eucalyptus regnans* (Mountain Ash), *Eucalyptus delegatensis* (Alpine Ash), *Eucalyptus nitens* (Shining Gum) and *Eucalyptus pauciflora* (Snow Gum). Prior to the 2009 fires, the greatest numbers were considered to occur at Lake Mountain, Mt Bullfight, and Mt Baw Baw.

Fossils and historical records indicate that the species was more widely distributed in the past (Lindenmayer et al. 1991b; 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 (Department of Environment and Primary Industries 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 & Brown 1977; Smith 1984). Specimens were collected after the 1960s in new localities in the Central Highlands ((Wilkinson 1961; Rawlinson & Brown 1977).

Recent survey work by the Arthur Rylah Institute, Department of Environment, Land, Water and Planning, has shown Leadbeater's Possum to be distributed widely across the Central Highlands (Nelson et al. 2017) but has demonstrated that an earlier occupancy model (Lumsden et al. 2013), while effective at identifying broad population strongholds, was less effective in finer scale predictions. A recent species distribution model identified a relatively wide area of suitable habitat, with highest probability of occurrence of Leadbeater's Possum around the Baw Baw Plateau and Lake Mountain areas (Taylor et al. 2017). Surveys in 2018 detected Leadbeater's Possums to the east of the previously accepted distributional limit, up 15 kilometres away, near Mount Useful (Lentini et al. 2018; McBride et al. 2019). Surveys further to the east, but within the species' historical range, did not detect additional Leadbeater's Possums (Lentini et al. 2018).

Cultural significance

Leadbeater's Possum is the animal emblem of the state of Victoria.

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 1996). Colonies live in territories that contain multiple den sites (Lindenmayer & 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 1996) 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 1996). 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 & Lill 2007), although other studies have found colonies with two breeding females (Lindenmayer & Meggs 1996). Breeding females reproduce twice per year and mean litter size is approximately 1.5 (Smith 1984; Harley & Lill 2007). Adult longevity is approximately ten years and age at first breeding is typically two years (Lindenmayer et al. 1993; Lindenmayer & Possingham 1995). 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 (hereafter collectively referred to as 'Ash forest') 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 midstorey of *Leptospermum grandifolium* (Mountain Tea Tree) along drainage lines (Jelinek et al. 1995) or forest dominated by *Eucalyptus camphora* (Mountain Swamp Gum) with a dense midstorey 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 & 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 (Smith 1984; Lindenmayer & Meggs 1996; Lindenmayer et al. 2017b) with the distance between a set of nest sites used by a colony possibly exceeding 100 m (Lindenmayer & Meggs 1996; Lindenmayer et al. 2017b). 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 relatively 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. 1994).

Leadbeater's Possum feeds on carbohydrate-rich plant and insect secretions (e.g. sap, manna, honeydew) and invertebrates (Smith 1980; Smith 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 highlighted 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., 1991a). 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 1996).

The key attributes of Leadbeater's Possum habitat across all forest types are:

- Large, hollow-bearing trees (for nest sites and refuge) with large internal dimensions in the order of 30 cm in diameter, (Lindenmayer et al. 2013a). Trees of this size are usually >150 years old.
- Density of hollow-bearing trees is recognised as a critical habitat feature (e.g. Department of Environment and Primary Industries (2014)). There are strong and quantified links between the abundance of hollow-bearing trees and the occurrence of Leadbeater's Possum (Lindenmayer et al. 1991a; Lindenmayer et al. 1994), with nest hollow availability the limiting factor to population size.
- 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 1996; Harley 2004). 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 respectively (Smith & Harley 2008).
- A structurally dense interlocking canopy or secondary tree layer of continuous interconnecting structure (to facilitate movement)(Lindenmayer 1996; Harley 2004), and
- An *Acacia* understorey (providing food) (Smith 1980; Lindenmayer 1989).

Leadbeater's Possums do not occur on burned sites, including those subject to low and moderate severity fire, clear-fell logged, or regenerated montane Ash forest where hollow-bearing trees are largely absent (Lindenmayer et al. 2013b; Lumsden et al. 2013) 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-storey. 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 is highly-connected in the middle-storey or canopy (Harley et al. 2005). Given the genetic distinction of this population (Hansen et al. 2009), its gene pool may include genes involved in adaptation to a lowland swamp environment, adding to the conservation importance of this population.

Threats

Table 1: Threats impacting Leadbeater's Possum in approximate order of severity of risk, based on available evidence

Number	Threat factor	Threat type and status	Evidence base
1.0	Habitat loss and fragmentation		
1.1	Collapse of hollow-bearing trees	Known current	The majority of Leadbeater's Possum's range is across the Mountain Ash forest of the Central Highlands of Victoria. Within Ash forest Leadbeater's Possum is dependent on hollow-bearing trees as a nest resource. Hollows only begin to form in trees from approximately 120 years of age (Ambrose 1982). Most of the Central Highlands was burned in an extensive wildfire in 1939, leaving a limited number of suitable trees standing. As these trees age and collapse, the pool of nesting resources is declining, while the 1939 regrowth trees are not expected to begin to recruit significant numbers of hollow bearing trees until after 2060 (Lindenmayer et al. 2012; Lindenmayer et al. 2013c; Lindenmayer et al. 2017a; Lindenmayer & Sato 2018). The rate of collapse of hollow-bearing trees is also influenced by the other main threats listed here, fire and logging (e.g. Lindenmayer et al. 2018).
1.2	Extensive wildfire	known current	Fire results in direct mortality of Leadbeater's Possums (Lindenmayer et al. 2013b) and loss of habitat (extent and fragmentation). The Central Highlands has a history of occasional extensive wildfires. The 1939 fire burned most of the potential Ash habitat of Leadbeater's Possum (Lindenmayer & Ough 2006) so that currently approximately 98% of the Mountain Ash ecosystem is <80 years old (Lindenmayer & Sato 2018). Thirty four per cent of the potential Ash forest habitat was burned in 2009 (Lumsden et al. 2013). Lumsden et al. (2013) noted that over the last century, bushfires have occurred in the

			Central Highlands on average every ten years. 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; Baker et al. 2017). 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 (Emergency Management Victoria 2014).
1.3	Logging	Known current	Clear-felling is currently the conventional form of logging in Victorian Mountain Ash forests (VicForests 2015). 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 clear-felling in coupes averaging 16.5 hectares (Attiwill et al. 2013). A 'regeneration' or 'slash burn' fire is then usually undertaken of the debris (logging slash) before sowing takes place (Attiwill et al. 2013; VicForests 2015). 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. 10-20 years (Lumsden et al. 2013)). It should also be noted that the added exposure to wind and drying can increase mortality and collapse rates not only of habitat trees left during the clearing, but also of trees in adjacent unlogged patches (Lindenmayer et al. 1997; Lindenmayer et al. 2016; Lindenmayer et al. 2018). The amount of logging to occur is determined by VicForests and has been reduced in recent years due to a policy of applying a 200m radius protection zone around new detections of Leadbeater's Possums within the harvestable area (VicForests 2017).
1.4	Climate change	Suspected future	Climate change may exacerbate existing threats. The potential for increasing frequency and intensity of fires is noted above. Other effects may include reduced productivity of Mountain Ash and reduced recruitment. Stand density is expected to be reduced by approximately 15% by 2080 and

			the area of the Central Highlands suitable for natural regeneration may be reduced by up to 80% (Baker et al. 2017).
2.0	Invasive species		
2.1	Predation by Feral Cats	suspected current	Feral Cats are known to prey on the species (McComb et al. 2018) however it is difficult to estimate the overall impact.
2.2	Competition for nest hollows with Sugar Gliders (*Petaurus breviceps*)	suspected current	Sugar Gliders are similar size to Leadbeater's Possum and also nest in hollows. They are increasing in abundance in Mountain Ash forest and thus may exclude Leadbeater's Possums from critical nesting resources.

How judged by the Committee in relation to the EPBC Act criteria and regulations

Criterion 1. Population size reduction (reduction in total numbers)
Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered Very severe reduction	Endangered Severe reduction	Vulnerable Substantial reduction
A1	**≥ 90%**	**≥ 70%**	**≥ 50%**
A2, A3, A4	**≥ 80%**	**≥ 50%**	**≥ 30%**

A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(*a) cannot be used for A3*]

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation [*except A3*]

(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

Evidence:

Eligible under Criterion 1A4(b) for listing as Critically Endangered; eligible under Criteria 1A2(a), 1A2(b), 1A3(b) for listing as Endangered.

Outline of approach

Assessment against this criterion is possible for the past (Criterion 1A2) for both direct observation of possum densities (Criterion 1A2(a)) and using the abundance of the key nesting resource, hollow bearing trees, as an index of abundance appropriate to the taxon (Criterion 1A2(b)).

In adopting hollow bearing trees (HBTs) as an appropriate index of abundance, the Committee notes that the presence and abundance of HBTs does not completely specify the suitability of habitat for the species, because other resources also constrain habitat suitability, especially

understorey *Acacia* providing food, and a dense and connected mid-storey facilitating movement. Nevertheless, it is clear that HBTs are the most limiting resource, that they have the longest renewal time after depletion, that a decline in HBTs should cause decline in LBP abundance and that a projected decline in HBTs indicates an expected future decline in LBP abundance.

Given the substantial research work that has been undertaken into the rates of transition of hollow bearing trees from one form to another, and through to collapse, and the uncertainty about the relative importance of other resources for the possums, the status of Leadbeater's Possum can be assessed against criteria 1A3(b) and 1A4(b) using hollow bearing trees (HBT) as the index of possum abundance.

It should be noted that criterion 1A4 uses a moving window of three generations (in this case 18 years), and IUCN guidelines recommend that the particular window that produces the maximum estimate of reduction should be used in the assessment of this criterion (IUCN Standards and Petitions Subcommittee 2017). Similarly, if a species is shown to be eligible for listing against more than one of these sub-criteria, the appropriate designation is the highest category of risk returned by any one of the sub-criteria.

Assessment against Criterion 1A2(a) (direct observation)

The relevant assessment period for this sub-criterion is **2000-2018** (18 years)**.** The ANU research group have been monitoring possums directly since 1997 at 163 long term field sites, each of one hectare (Burns et al. 2015a). These sites were selected using a stratified sampling design that encompasses different fire histories and land management practices across the distribution of the species. This is the only longitudinal dataset of appropriate scale for this assessment. The presence or absence of possums on these sites has been recorded annually since 1997 (Lindenmayer et al. 2011; Lindenmayer et al. 2017a), using the stag-watching method (Seebeck et al. 1983; Smith et al. 1989).

Analysis of the long term monitoring data shows a decline in Leadbeater's Possum across all the ANU sites over the relevant assessment of over 50% (Lindenmayer & Sato 2018). The proportion of sites where possums are observed, has declined from approximately 20% to approximately 10% of sites. On top of this effect the number of sites with hollow-bearing trees has declined from 166 sites to 139 sites. Additionally, a subset of these sites was selected on the basis that they were high quality habitat. As possum occurrence is more likely in such habitats, the decline seen in these sites is likely less than is occurring across the broader landscape (Lindenmayer 2017).

Importantly, the surveys include sites that were burned in 2009 and thus the estimated population decline of at least 50 percent represents the effects of that fire but not logging, as none of the surveyed sites have been logged (Lindenmayer 2017). Approximately 874 ha/year of the remaining 204,000 ha of habitat has been logged since 2000 (VicForests 2018) and thus the loss of habitat to logging increases the estimate of population decline by 7.7 percent (18 years*874 = 15 732 ha. 15 732/204,400 = 7.7 percent). The directly observed decline of the Leadbeater's Possum population is thus at least 54.3 percent in the Ash forests (50 percent decline x 92.3 percent habitat + 100 percent decline x 7.7 percent habitat).

An additional 8 483 ha (4.2 percent of combined total) of potential habitat is Snow Gum woodland (Leadbeater's Possum Advisory Group 2014). Assuming that a similar proportion burned in 2009, but was not logged, the adjusted total estimated decline is at least 53.5 percent (54.3 percent x 95.8 percent + 35 percent x 4.2 percent) and is likely higher given the biases noted above.

Therefore the Committee considers that the above data demonstrate that Leadbeater's Possum is eligible for listing as Endangered under Criterion 1A2(a).

Assessment against Criteria A2(b), A3(b), A4(b) (index of abundance appropriate to the taxon)

Hollow bearing tree abundance as an index of abundance of Leadbeater's Possum

Here the Committee reiterates that these criteria require an indirect estimate of change in population size of Leadbeater's Possum using an index of abundance appropriate to the taxon. The size of the population *per se* is not important in the context of this criterion if it can be shown that a critical resource is declining in a manner likely to produce a similar decline in the number of mature individuals of the population. Hence, the assessment of the trend in the population of Leadbeater's Possum under criteria A2(b), A3(b), A4(b) is based on an assessment of the trend in their critical nesting resource, hollow bearing trees.

There are abundant data to show that Leadbeater's Possum is dependent on hollows in old trees (Smith & Lindenmayer 1988; Lindenmayer 1989; Lindenmayer et al. 1991a; Lindenmayer & Meggs 1996; Lindenmayer et al. 2011). Furthermore, Leadbeater's Possum occurrence/abundance typically shows a decline in density or probability of occurrence when the density of hollow bearing trees decreases (Lindenmayer et al. 1991a; Lindenmayer et al. 1994) with that decline accelerating as HBT density becomes lower (Figure S3 Lindenmayer and Sato 2018 Supplementary material).

Leadbeater's Possum has greater occupancy rates in hollows in old, dead trees than in hollows of living trees but may be forced to use hollows in living trees as increasing densities of several other arboreal marsupial species compete for a reduced number of hollows (Lindenmayer et al. 2011). Thus, initial losses in HBT density may not be matched by a corresponding decline in the probability of possum occurrence. Nevertheless, such a compensatory response is limited and as the number of hollow bearing trees continues to decrease, decline will inevitably accelerate in the Leadbeater's Possum population. Because of the potential breakdown in tree form preferences, the assessments that follow are applied to hollow bearing trees overall, rather than the nominally preferred forms (which are considerably more limiting).Thus the assessments below are conservative with respect to the estimated declines.

The Committee has hereafter adopted the approach of treating all Ash forest and Snow Gum woodland within the species' range in the Central Highlands as potential habitat, following Leadbeater's Possum Advisory Group (2014) with 204,400 hectares available in 2000 (3 generations ago)(VicForests 2014). Ninety six percent of that total area is Ash forest (Leadbeater's Possum Advisory Group 2014). Adopting this broader approach has the advantage of being able to directly apply estimates of areas burnt and logged to estimate proportional loss of HBTs, as the two types of forest are typically not subdivided according to Leadbeater's Possum habitat quality categories. There are no data on the change of nesting resources in Snow Gum woodland and it is not subject to logging, and thus the effects of fire are the only source of potential decline addressed in Snow Gum woodland in this assessment.

The Committee also notes recent data on detections of Leadbeater's Possum in areas outside of the area conventionally accepted as the limit of their distribution (Lentini et al. 2018; McBride et al. 2019). Searches have detected possums up to 15 kilometres from the previously accepted distributional limit, to the east near Mount Useful. However, the Committee notes that Lentini et al. (2018) report substantial survey effort in the broader region to the east, covering the historical range of the species without further detections. Lentini et al. (2018) also suggest that the exposure of this population to wildfire and harvesting mean that its discovery does not substantially alter the risk of extinction for the species. The Committee concurs with this view, noting also that the data are new and the current understanding of the population is geographically and temporally limited. The Committee encourages further research in this area because of the potential relevance of the results to future assessments.

The following discussion focusses on the population of Leadbeater's Possum in the Ash forests and Snow Gum woodlands and does not reference the small lowland population of Leadbeater's Possum at Yellingbo Nature Conservation Reserve. Data collected between 1995 and 2004 indicated that the size of this population over that period was stable at 80–100 individuals (Harley et al. 2005). The number of individuals recorded peaked at 112 in 2003. By 2012 the

number had dropped to 60 individuals (Harley & Lindenmayer 2013) and in 2014 to only 40 individuals. This is a decline of approximately 64 percent. The Committee notes that this is a robust estimate of decline, but that the Yellingbo population is so small relative to that of the Ash forests and Snow Gum woodlands that it has little numerical influence over the assessment against this criterion.

Assessment under Criterion 1A2(b)

The relevant assessment period for this sub-criterion is **2000-2018**. The overall decline in hollow bearing trees is a combination of the areas of habitat that became unsuitable from the effects of fire and logging, plus the ongoing decline of trees in unburnt and unlogged forest due to natural decay (hereafter referred to as ambient decline).

The fires in 2009 had a substantial effect on habitat suitability in the Ash forest. Thirty four per cent of the potential Ash forest and Snow Gum woodland habitat was burnt in the Black Saturday fire (Leadbeater's Possum Advisory Group 2014). Surveys after the fire showed that Leadbeater's Possum was absent on burned sites, and reduced even on unburned sites adjacent to areas burnt (Lindenmayer et al. 2013b; Lumsden et al. 2013). As the mid-storey regenerates, these burnt areas may again become suitable for LBPs if there are HBTs available, but this regeneration and recolonization takes a number of years. Here it is assumed that possums had not returned to burned areas by 2018.

Additionally, approximately 874 ha/year has been harvested since 2000 (VicForests 2018) which totals 15 732 ha over 2000 to 2018. To avoid double counting of areas that were harvested before 2009 and were in the burnt area an approximate correction can be made by removing 34 percent of the estimated harvest 2000-2008 (0.34*8*872 = 2372 ha). Thus, for the purposes of assessment against this sub-criterion only, the estimated loss of habitat due to harvest is 13,360 ha. In subsequent sub-criteria the burned area is included in order to incorporate trees that remained standing after the fire and this correction is not required.

The collapse rates of hollow bearing trees have been estimated a number of times, based on multiple surveys of trees which began in the 1980s (e.g. Lindenmayer et al. 1997, 2011, 2012, Lindenmayer and Sato 2018). However, two key studies (Lindenmayer et al. 2012, Lindenmayer and Sato 2018) (Table 2) provide the most recent estimates of ambient decline and also include the effects of the 2009 fires on rates of HBT decline. The relevant figure from Lindenmayer and Sato (2018), Figure 1, is reproduced below as Figure 1.

Lindenmayer et al. (2012) provides transition matrices summarising the data across multiple surveys. These matrices contain the estimated probability that a tree currently in one structural form will transition to another over a 14 year interval. These estimates can be cautiously applied to HBT survey data to estimate the change in density of HBTs over time. As part of the Leadbeater's Possum surveys conducted by the Arthur Rylah Institute, 1 ha vegetation surveys were undertaken at sites at which possums were detected. HBTs at these sites were designated either as "survey standard' or "ecological" hollow bearing trees:

> Live survey standard trees were defined as mature or senescent Mountain Ash, Alpine Ash and Shining Gum with hollows greater than 3 cm entrance size, and dead survey standard trees were those more than 6 m in height and greater than 1.5 m DBH) (Department of Environment Land Water and Planning 2015). Ecological hollow bearing trees were a broader category including any tree with an observable hollow (Nelson et al. 2017).

Data are available for 422 plots. An additional estimate of the proportions of trees in each decay category (Smith & Lindenmayer 1988) has been estimated using LIDAR, calibrated against the ARI dataset (Jiang et al. 2018). These datasets differ from the ANU dataset in assigning a greater proportion of trees to the younger, less deteriorated structural forms. The practical consequence of that is a reduction in the estimate of decline by approximately five percent relative to the Lindenmayer et al. (2012) estimate.

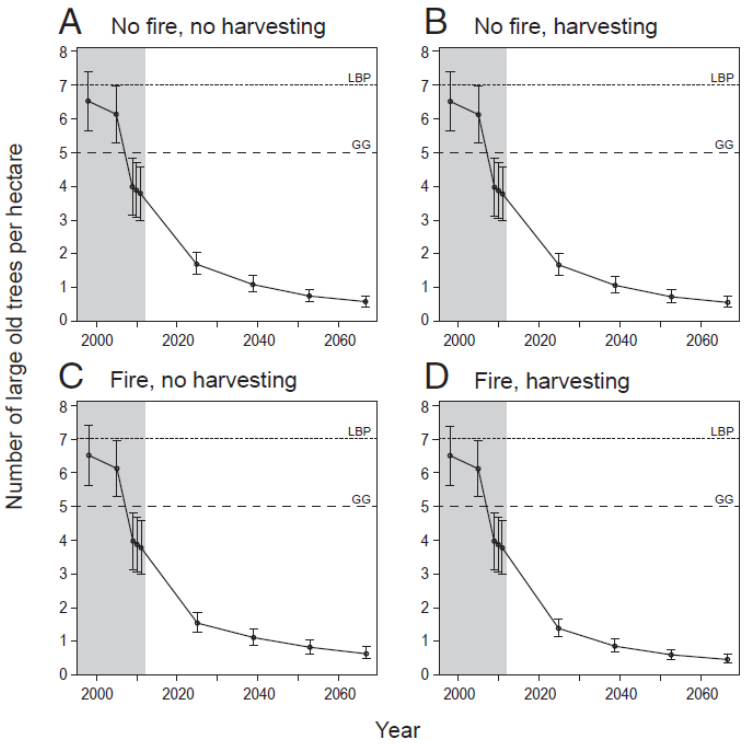

Figure 1 (=Figure 1 Lindenmayer and Sato 2018)**.** Temporal changes in the existing abundance and projected future abundance of large, old-cavity trees in the Ash ecosystem in response to fire and logging. The horizontal lines on each diagram show the approximate number of cavity trees per hectare required to achieve a 0.4 probability of the occurrence of these species [seven trees per hectare for Leadbeater's Possum (LBP) and five trees per hectare for the Greater Glider (GG).

Table 2. Estimated rates of collapse of hollow bearing trees from studies of the Ash forests, used to estimate decline over the period of time relevant to Criterion 1A2(b). Where available, annual rates are those quoted directly in the source. Otherwise, rates of decline are estimated as indicated for each row.
Note that observations span 2009 and thus include the effect of the 2009 fires. No observations include logging.

Times/Time period of direct measurement	Observed decline (time span)	Annual rate of decline (assumed approximately exponential)	Estimated Decline 2000-2018 (3 Leadbeater's Possum generations)	Source
1993-2007	27% (14 years)	2.2%	33% (ambient)	Lindenmayer and Wood (2010)
1997,2006	13.6% (9 years)	1.8%	28% (ambient)	Lindenmayer et al. (2011)
1997,2006, 2009, 2010, 2011	39% (14 years) [a]	3.42% (2000-2011), 2.52% (2011-2018)	36% (ambient) 43% (ambient + fire)	Lindenmayer et al. (2012)
1997,2006, 2009, 2010, 2011	39% (14 years) [a]	3.42% (2000-2011), 2.52% (2011-2018)	43% (ambient + fire)	Lindenmayer et al. (2012)
1997,2006, 2009, 2010, 2011	39% overall, 49.6% burnt areas, 29.6% unburnt areas (14 years) [b]	2.47% unburnt areas only (2000-2011) 2.52% all areas (2011-2018)	45.9%[c] (ambient + fire)	Lindenmayer et al. (2012)
1997,2006, 2009, 2010, 2011	41.5% (14 years)	4.9% (2011-2018)[c]	58%[d] (ambient + fire)	Lindenmayer and Sato (2018)

[a] This paper estimated rates of transition between forms for 1997-2011. Three transition matrices were produced for: unburnt sites; low intensity burn sites, and; high intensity burn sites. Here the rate of decline is estimated by applying the transition matrices as above for 1997-2011, then the unburnt transition matrix to all sites for 2011-2025. Results are then adjusted assuming exponential decline annually.
[b] As per [a] but effect of fires treated as a single step-change so not adjusted for exponential change from 1997-2011 to 2000-2014.
[c] Estimating using 2.47% decline 2000-2011 for unburned areas, 2.52% from 2011-2018 for entire area.
[d] Read from Fig 1A of Lindenmayer and Sato (2018) (see Figure 1 above).

The overall decline is the combined effect of the Ash forest lost to logging, the decline in hollow bearing trees in remaining Ash habitat due to ambient decline and fire, and the loss of Snow Gum habitat due to fire only (there are no data on ambient decline in Snow Gum). The calculations are summarised in the box below. Uncertainty in the estimates can be accommodated by calculating a plausible range of decline from different combinations of the available estimates.

Note that as the different population structures from the ARI vegetation survey data apply to the 36 percent estimate from row 3 of Table 2, they do not affect the listing outcome as they fall within the range considered below.

Details of calculations:

- Assume initial area of 204,400 ha total habitat in 2000 (195 917 ha Ash, 8483 ha Snow Gum)
- less 6.5 percent (13,360 ha logged outside 2009 fire area, 93.5 percent habitat remaining)
- reduced by 34 percent fire across both Mountain Ash forest and Snow Gum woodland (61.7 percent total habitat remaining – 120,488 ha Mountain Ash, 5599 ha Snow Gum)
- reduced by 28-36 percent ambient decline (rows 1-3 in Table 2) in remaining Mountain Ash forest (does not apply to Snow Gum)(40.5-45.2 percent remaining)

Overall decline 54.8-59.5 percent

Using similar calculations, if estimates of both fire and ambient decline (45.9-58 percent: Table 2) are combined with the estimated loss of trees due to logging, the overall estimate is 53.6-65.7 percent, corresponding well with calculations in the box above.

The decline of hollow-bearing trees, including that due to logging and fire, over the relevant period can also be derived directly from the graphs presented in Lindenmayer & Sato (2018). Figure 1D of that paper (Figure 1D above) shows observed decline 1997-2013 then modelled decline through to 2067. Reading directly from the graph for the values at 2000 and 2018, the decline is 61 percent, again corresponding well with the plausible range of values above. However, it should be noted that the estimates cited in this paragraph may underestimate the extent of decline, for example, because all HBTs are assumed to be equal even though more deteriorated forms host a disproportionately large fraction of animals and collapse at a faster rate than other forms. As noted above, it is assumed for the period 2009-2018 that the burned areas are not occupied by Leadbeater's Possum while the estimates here include habitat trees remaining in the burned areas. In periods subsequent to 2018 (below) these trees are included because foraging habitat has re-grown in the decade since the fires.

Therefore the Committee considers that the above data demonstrate that Leadbeater's Possum is eligible for listing as Endangered under Criterion 1A2(b).

Assessment under Criterion 1A3(b)

The relevant assessment period for this sub-criterion is **2018 to 2036**.

The area of potential habitat at 2018 is approximately 188 688 based on the 204,400 ha cited under criterion 1A2 above less 15 732 logged 2000-2018 (VicForests 2018). In this assessment, the area burned in 2009 is included in estimates of potential habitat, based on the ongoing presence of hollow-bearing trees (albeit reduced number) (Lindenmayer et al. 2012), regrowth of foraging habitat since the fire and increasing records of possums up to three kilometres from the fire edge.

The maximum potential future harvest of Ash (Snow Gum is not logged) is approximately 40,000 ha, or 22 percent of the current potential habitat. This estimate is based on the estimate of all forest available for logging from the previous conservation advice and sources therein (Leadbeater's Possum Advisory Group 2014; VicForests 2014; Threatened Species Scientific Committee 2015), less approximate harvest since the estimate was made. The Committee includes this estimate to provide an upper bound on the potential logging, but notes that it is unlikely that this level would be reached.

A more plausible approximation of expected future harvest can be derived from anticipated future areas of harvest provided to the previous assessment (VicForests 2014), adjusted for the revision of the VicForests Resource Outlook (VicForests 2017). Because the Resource Outlook is provided as volume of logs, it is necessary to estimate the conversion to area logged.

In 2013 the estimated available harvest per year was 220,000 m^3 of ash sawlog but this has been revised down to 153 000 m^3 until 2020/21. From 2020/21onwards the estimated available harvest per year is 130,000 m^3. This estimate is based on a range of regulatory restrictions including the Timber Harvesting Exclusion Zones around identified Leadbeater's Possum records and a projection that the rate of Leadbeater's Possum detections will continue at the current rate for the next 7 years (VicForests 2017). As noted earlier, actual area harvested has been approximately 874 ha/year in the years up 2018. Thus if a future 15 732 ha of harvest is corrected for the reduced Resource Outlook (130,000 m^3/220,000 m^3), then it is anticipated that overall harvest would be 9 296 ha or approximately 4.9 percent of existing potential habitat.

Significant bushfires are likely to occur within Leadbeater's Possum habitat within the three generation timeframe. Bushfires are inherently difficult to predict in timing, scale and distribution. Nevertheless, attempts have been made, as part of the 2017 Victorian Environmental Assessment Council Fibre and Wood Supply Assessment Report (Baker et al. 2017; Victorian Environmental Assessment Council 2017). The focus of that work was the valuable timber in the 1939 regrowth forest in the Central Highlands, but the authors noted that the estimates applied to the Central Highlands broadly (Baker et al. 2017).

Baker et al. (2017) based the model on observed burnt areas during the 20 year periods 1950-70, 1970-90, 1990-2010, noting that the total area burnt within these periods has been increasing with time. The mean estimate of proportion of 1939 regrowth expected to be burnt in the next 20 years was 20 percent, with a minimum of 3 percent and a maximum of 47 percent (Figure 2), with the risk significantly higher in the northern part of the range. The authors also postulated that activities such as planned burns may reduce the extent of fires, but that climate change effects may have the opposite effect.

Baker et al. (2017) also spatially modelled fires using LANDIS-II, concluding that their results highlighted that it is highly unlikely that the entire 1939 resource would be lost over the next 20 years due to the spatial distribution of the resource and varying risk of bushfire across Fire Management Areas. Similar to the result described above, the landscape fire simulation modelling suggested that, on average, 20 percent of the 1939 ash stands may be affected by fire in the next 20 years with a worst case scenario of ~50 percent of the resource being impacted.

The previous status assessment of Leadbeater's Possum (Threatened Species Scientific Committee 2015), and recent assessments of the effectiveness of the Leadbeater's Possum Reserve (Todd et al. 2016) and the potential for Ash ecosystem collapse (Lindenmayer & Sato 2018) also used 50 percent as maximum extent in future fire scenarios.

There are several reasons why it is appropriate to consider the upper range of future projections of area burnt. Firstly, observed areas burnt in the 1939 fire are relevant to estimated probability of future fire. Almost the entire range of Leadbeater's Possum was burnt in this event. Together with the 1983 and 2009 events, it shows three extensive forest canopy fires occurred within the species' range within 70 years. Second, both modelled projections and weather observations over past decades show with a high degree of certainty that extreme fire weather will increase in frequency over the next three generations and beyond (Clarke et al. 2013; CSIRO and Bureau of Meteorology 2015). Estimates of risk of losses of HBT due to fire in the next three generations are thus likely to be greater than those based on observations of past fire frequencies. Third, recent work in Mountain Ash and ecologically similar Alpine Ash forests have shown evidence of positive ecosystem feedbacks that cause regrowth forest to be more likely to burn than mature forest (Taylor et al. 2014; Zylstra 2018). Lindenmayer and Sato (2018) state that more than 98 percent of the forest habitat area is in a state of regrowth, and hence of elevated flammability.

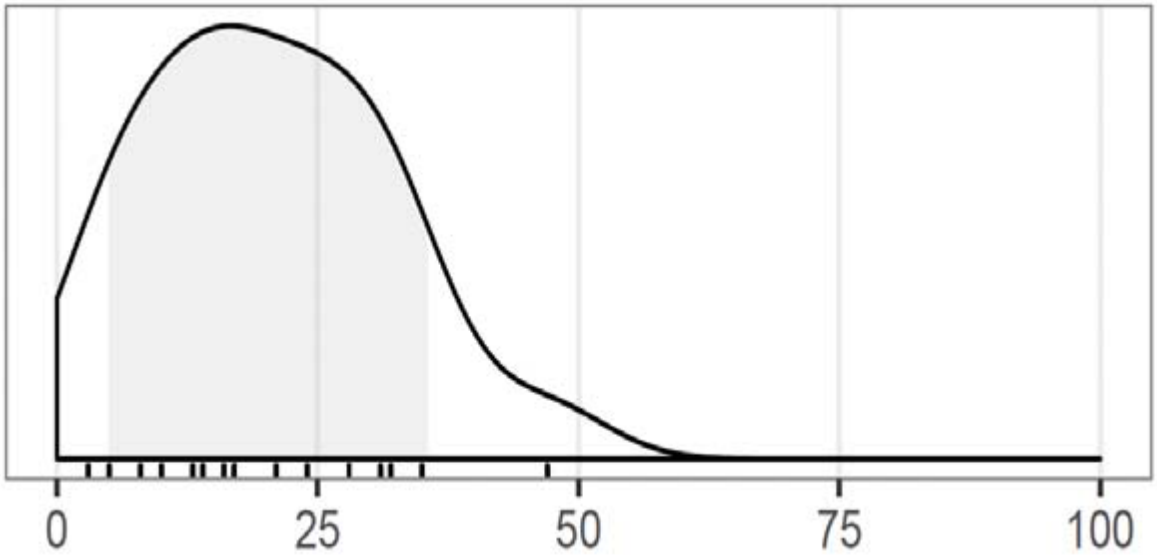

Figure 2. (=Figure 15 from Baker et al. (2017)): Predicted percentage of 1939 ash area burnt over 20 year period (n= 20). The black line is a smoothed probability density curve; the black ticks are the modelled observations; and the shaded area is the 5 to 95 percentile range.

The only data available to estimate ambient rates of hollow-bearing tree collapse for the 2018-2036 period are the projections of tree transitions from the ANU research. The most recent publication by that group suggested decline due solely to collapse of hollow-bearing trees will be approximately 45 percent (18-63 95 percent CI) over the next 18 years (Lindenmayer & Sato 2018)(estimated from Figure 1A above). The decline of hollow-bearing trees does not apply to the Snow Gum woodland. It is also important to note that projections of the decline in hollow bearing trees are based on observed data to date, and thus cannot formally incorporate the effects of increasing changes in landscape context (Lindenmayer et al. 2018) or factors such as future climate change (Lindenmayer et al. 2012) both of which are expected to accelerate the loss of hollow-bearing trees.

Combining the above estimates, the plausible range of projected decline in potential Leadbeater's Possum habitat over 2018-2038 is based on:

- logging 4.9 percent of Ash forest (no logging in Snowgum woodland);
- fire 50 percent (maximum estimate) of Ash forest and Snow Gum woodland, and;
- ambient collapse of hollow bearing trees 45 percent (16.7-63.6 95 percent CI) of the unlogged and unburnt remainder of the Ash forest.

Details of calculations:

- Assume initial area of 188 668 ha total habitat (180,185 ha Ash, 8483 Snow Gum)
- less 9 296 ha Ash logged (95.1 percent total habitat remaining)
- reduce by 50 percent fire across Ash forest and Snow Gum woodland (47.5 percent total habitat remaining)
- reduce by 45 percent (16.7-63.6 95 percent CI) decline of hollow-bearing trees in remaining Ash (27.1 percent (18.7-40.0 95 percent CI) total habitat remaining)

Overall decline 72.9 percent (plausible range 60.0-81.3 percent)

The combined model of hollow-bearing tree collapse, logging and an additional fire (approximating the 2009 fire and occurring in the period 2014-2028) provided by Lindenmayer

and Sato (2018) (Figure 1D) provides comparative figures of 71 percent (57-81 percent CI). However, Lindenmayer and Sato (2018) note, as has the Committee above, that these estimates do not account for demonstrable increases in collapse rate of trees due to fire and logging in the surrounding landscape (Lindenmayer et al. 2018), nor the effect of climate change on drought and increased fire risk or regeneration potential of Ash (e.g. Baker et al. 2017). The plausible range of the projected decline is therefore likely to be higher than 60.0-81.3 percent indicated by the calculations above. There are insufficient data to determine how much this decline might exceed 80 percent.

Cumulatively, the Committee therefore considers that Leadbeater's Possum has met sufficient elements of criterion 1A3(b) to be eligible at least for the Endangered category, and a possibility that it may be eligible for listing in the Critically Endangered category if unquantified uncertainties can be resolved.

Assessment under Criterion 1A4(b)

Criterion 1A4 uses a moving window of three generations, and IUCN guidance is that the particular window should be chosen to provide the maximum estimate of reduction (IUCN Standards and Petitions Subcommittee 2017) as explained above.

The most appropriate time frame for assessment under this criterion is just prior to the major fire-related decline of HBTs in response to the 2009 fires. The last measured observations before this event were in 2006, and hence the **assessment period is 2006-2024**. The baseline estimate for available area of habitat is 199 156 ha (204,400 at 2000 less approximately 5 244 logged to 2006). Snow Gum is 8 483 ha, leaving Ash baseline habitat 190,673 ha.

Although 34 percent of Ash burned in 2009, foraging resources will have partly recovered by 2024, enabling possums to reinhabit available hollow-bearing trees assuming unconstrained dispersal and recolonisation. The number of hollow-bearing trees will have declined as per Lindenmayer and Sato (2018) (67.5 percent (54.8-77.1 percent 95 percent CI) from Figure 1A) which incorporates estimation of the hollow-bearing trees remaining standing within the burned areas. However, a future 50 percent fire, across both Ash forest and Snow Gum woodland (see Assessment under Criterion 1A3(b) above) would remove that habitat for the remainder of the assessment period.

Logging within the relevant period would be approximately 874 ha/year from 2006 to 2017, then approximately 516 ha/year 2018-2024, totalling 13 226 ha.

Combined, these total to a projected decline of approximately 83.4 percent (plausible range 77.8-87.7 percent).

Details of calculations:

- Assume initial area of 199 156 ha total habitat (190,673 ha Ash, 8483 Snow Gum)
- less 13 226 ha Ash logged (93.4 percent total habitat remaining)
- reduce by 50 percent fire across Ash forest and Snow Gum woodland (46.7 percent total habitat remaining)
- reduce by (67.5 percent (54.8-77.1 percent 95 percent CI) decline of hollow-bearing trees in remaining Ash (16.6 percent (12.9-23.3 percent 95 percent CI total habitat remaining)

Overall decline 83.4 (77.8-87.7 percent)

The Committee therefore considers that Leadbeater's Possum has met sufficient elements of criterion 1A4(b) to be eligible for inclusion in the Critically Endangered category.

Criterion 2.	Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy			
		Critically Endangered Very restricted	**Endangered Restricted**	**Vulnerable Limited**
B1.	Extent of occurrence (EOO)	**< 100 km^2**	**< 5,000 km^2**	**< 20,000 km^2**
B2.	Area of occupancy (AOO)	**< 10 km^2**	**< 500 km^2**	**< 2,000 km^2**
AND at least 2 of the following 3 conditions:				
(a)	Severely fragmented OR Number of locations	**= 1**	**≤ 5**	**≤ 10**
(b)	Continuing decline observed, estimated, inferred or projected in any of: (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: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Evidence:

Eligible under Criterion 2 B1a,b(iii) for listing as Endangered

Significance of surveys since 2014 using new methodology for assessment of Leadbeater's Possum habitat

Since 2014, extensive work has been put into surveying for Leadbeater's Possum, most notably by scientists from the Arthur Rylah Institute, as well as community groups and the logging industry (Department of Environment Land Water and Planning 2017). Large numbers of additional Leadbeater's Possum colonies have been identified and some have construed this as meaning that the Leadbeater's Possum population is much larger than estimated before and that it is therefore more secure or has recovered. The absence of a time series in this dataset precluded its consideration under Criterion 1. Similarly, the method does not currently allow the generation of a population estimate.

The newer techniques are based on observations of foraging possums. One technique uses call playback to draw in Leadbeater's Possums, a thermal imaging camera to detect them and a white spotlight to make the identification. Over 100 sightings have been confirmed by this technique, many by community groups or members of the public (Department of Environment Land Water and Planning 2017). The other technique uses motion-sensitive cameras mounted at elevations of 3-36 m on trees and baited with creamed honey (Nelson et al. 2015). The technique has been refined over time and has a very high probability (>0.80) of detection of possums if they are present (Nelson et al. 2017). Multiple detections across several nights suggests also that at least some possums are resident nearby, rather than transient. Between 2014 and January 2017 346 new colonies were found in State Forest, mostly using these new techniques (Department of Environment Land Water and Planning 2017). The abundance and wide dispersion of the new locations (Department of Environment Land Water and Planning 2017; Nelson et al. 2017) strongly suggests that the amount and connectivity of occupied habitat is more extensive than was previously thought.

It is also notable that the design of the first two years of the Arthur Rylah Institute surveys was deliberately heavily biased. The intent of the surveys in these years (2014/15 and 2015/16) was to identify areas for protection from logging and thus effort was focussed on areas available for logging and in habitats expected to be suitable to Leadbeater's Possum. They do not constitute a representative survey of habitat across the species' range and nor do those undertaken by community groups. In contrast, Arthur Rylah Institute surveys in 2016/2017 were undertaken at randomly selected sites across all tenures and forest ages to enable extrapolation across the whole of the species' range, model the areas most likely to be occupied, and investigate foraging habitat requirements. These data have yet to be fully analysed and the results are not available for this assessment. Despite the lack of formal analysis, it is notable that Leadbeater's

Possum were detected at 37 percent of randomly selected sites across the Central Highlands (Arthur Rylah Institute 2017).

Assessment under Criterion 2

The extent of occurrence and area of occupancy of this species have been estimated based on all sightings for the last 20 years (ERIN 2017). Extent of occurrence is estimated to be 4,084 km^2. This is restricted under sub-criterion B1.

Area of occupancy based on the IUCN guidance to use a 2 x 2 km grid (IUCN Standards and Petitions Subcommittee 2017) is estimated to be 972 km^2 which is limited under sub-criterion B2. This value is likely to increase in the future due to the accumulation of new sighting locations. The new detections near Mt Useful (Lentini et al. 2018; McBride et al. 2019) are not sufficient to increase area of occupancy beyond the 2000 km^2 limit of the Vulnerable category under this criterion, nor extent of occurrence beyond the 5000 km^2 threshold of the Endangered category.

The IUCN definition of severely fragmented in the context of this criterion is that more than half the individuals must be in small and isolated patches between which there is little or no demographic or genetic exchange (typically less than one successful migrant individual or gamete per year) (IUCN Standards and Petitions Subcommittee 2017). This is difficult to determine in the case of Leadbeater's Possum because it has been evaluated in a number of ways. For example, Lindenmayer *et al.* (2014) note that patches of old growth forest with high densities of hollow bearing trees are small and highly fragmented. The current (as at 2014) 1887 ha area of old growth Mountain Ash forest is distributed across 147 different patches, giving a mean patch size of 12.8 ha. Lindenmayer *et al.* (2014) considered these fragmented patches to be generally likely to support small populations of 20-30 animals (Lindenmayer et al. 2014). Similarly, the Leadbeater's Possum reserve is itself a collection of 127 patches greater than 50 ha in size of predominantly old growth forest (Lumsden et al. 2013)(although the fact that 45 percent of the reserve burned in 2009 means much is no longer old growth).

However, the recent surveys by the Arthur Rylah Institute show that possums are distributed over a wide area and in different forest age classes (Nelson et al. 2017), suggesting at least that possums can relatively easily move between patches of high quality habitat. Indeed, in modelling the population viability within the Leadbeater's Possum reserve Todd et al. (2016) noted the context of the patches of the reserve as "part of the continuum of habitat available". Where sampling by Arthur Rylah Institute has been intensive, the distribution of sightings is almost continuous across several kilometres between patches of the reserve, such as the eastern edge of Yarra Ranges (see Figure 3 in Nelson et al. 2017) and in many areas outside the Leadbeater's Possum Reserve. Genetic analyses also showed considerable admixture across the northern highlands (Toolangi, Mt Margaret, Lake Mountain and Cambarville), but some differentiation from the southern highlands (Powelltown)(Hansen et al. 2009). The Committee also notes in this context the unpublished data from the 2016/17 surveys by Arthur Rylah Institute which were randomly located (and thus not biased by tenure or forest age) had a detection rate of 37 percent overall .The available data suggest that Leadbeater's Possum is not severely fragmented *sensu* IUCN Guidelines.

This criterion also allows that distribution is precarious for survival if the number of locations is limited. In this context, "location" is a geographically defined area in which a single threatening event can rapidly affect all individuals of a taxon that are present (IUCN Standards and Petitions Subcommittee 2017). The extensive fire history of the Central Highlands suggests that the range of Leadbeater's Possum can reasonably be considered to be a small number of locations. The 1939 wildfires burned up to 85 percent of the Mountain Ash forest of the Central Highlands (Burns et al. 2015b), while the 2009 fires burned 36 percent of the potential Ash habitat (Lumsden et al. 2013). Baker et al. (2017) suggest a loss of 20 percent to fire is likely in the next 20 years (and up to 50 percent or more is possible). The Committee considers that the Central Highlands can reasonably be inferred to be between two and five locations for the purposes of this assessment.

Continuing decline can be projected in quality of habitat. As described in detail under Criterion 1, hollow bearing trees are a critical resource for Leadbeater's Possum and are subject to ongoing collapse across the Central Highlands (Lindenmayer & Wood 2010; Lindenmayer et al. 2011; Lindenmayer et al. 2012). While this can be a natural process, the fact that extensive areas of the Central Highlands were burned in 1939, killing most trees, means that recruitment of new hollow bearing tree is constrained until approximately 2060 (Lindenmayer & Wood 2010) and this critical resource will become more limited over the intervening period. Additionally, the area of habitat will decline due to the very high likelihood of additional fires and the planned future logging (see detail under Criterion 1).

The Committee considers that the extent of occurrence of Leadbeater's Possum is restricted, it is found at a restricted number of locations and that continuing decline can be inferred in amount and quality of habitat. Leadbeater's Possum is eligible for inclusion in the Endangered category under criterion 2B1a,b(iii).

Criterion 3. Population size and decline			
	Critically Endangered Very low	**Endangered Low**	**Vulnerable Limited**
Estimated number of mature individuals	**< 250**	**< 2,500**	**< 10,000**
AND either (C1) or (C2) is true			
C1 An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	**Very high rate 25% in 3 years or 1 generation (whichever is longer)**	**High rate 20% in 5 years or 2 generation (whichever is longer)**	**Substantial rate 10% in 10 years or 3 generations (whichever is longer)**
C2 An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	**≤ 50**	**≤ 250**	**≤ 1,000**
(a) (ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals			

Evidence:

Eligible under Criterion 3C1 or listing as Vulnerable

Three hundred and forty six new colonies of Leadbeater's Possum were found in state forest between March 2014 and 30 January 2017 in surveys of 6-10 percent of potential habitat (Department of Environment Land Water and Planning 2017). Eighty four new colonies have also been found in parks and reserves (DELWP 2016). Survey efforts by DEWLP/Arthur Rylah Institute have been completed but community groups, VicForests, Zoos Victoria and universities are continuing to find new colonies.

While it has been noted above that a precise estimate of population size cannot be made, some consideration against the broad thresholds of this criterion is possible and necessary. Each new colony is protected by a Timber Harvesting Exclusion Zone (THEZ) of 200 m radius, and any subsequent sighting within that zone is considered to be the same colony (Department of Environment Land Water and Planning 2017). The 200 m THEZ is equivalent to 12.6 ha, which is substantially greater than the average Leadbeater's Possum home range of 1-3 ha (Department of Environment Land Water and Planning 2017) so a single THEZ may cover more than one colony. Nevertheless, the shape of the home range is not necessarily circular and it is possible that if the shape is elongated part of the home range may not be within the THEZ.

Home ranges may also be larger where resources such as hollow bearing trees are less common or where foraging and nesting habitat are spatially separate (Blair et al. 2017). It is possible then that counting the THEZ might either overestimate or underestimate the number of colonies of possums. Noting these concerns, but given that these are the most comprehensive data available to this assessment, the Committee cautiously adopts the following approach:

Three hundred and forty six colonies have been found during surveys in six percent of potential habitat, almost exclusively in state forest. If each colony making up the total is assumed to represent a “true” colony, it is equivalent to approximately 20 percent of the state forest habitat (6 percent x 142,000 ha potential habitat/43 000 ha state forest). If the sampled sites are reasonably representative of the state forest habitat, there may be 1 730 colonies across the state forest (346 x 100/20). The Committee notes that sites chosen for sampling were those expected to have possums present and thus this part of the calculation is likely an overestimate. There is no quantitative adjustment that can be made here, but the Committee uses precaution below in using the low end of the likely range.

Further, If state forest is similar habitat to the parks and reserves, then an additional 3 980 colonies (1 730*99 000/43 000)(total 5 700) may be in the parks and reserves (this does not include the area burned in 2009). Typically a colony consists of one adult female and one to three adult males (Smith 1984) but more than one adult female is not uncommon (Lindenmayer & Meggs 1996). Colonies may consist of up to 12 individuals but are more commonly 6-12 and colony sizes have reduced in recent years (DELWP 2016). An estimate of three individuals per colony on average is thus appropriately cautious here. Notwithstanding the considerable uncertainty in these estimates, the population of possums may exceed 10,000 mature individuals, but is more likely in the range 2,500-10,000 which is low. The Committee also notes that unpublished data from the 2016/17 surveys by Arthur Rylah Institute which were randomly located (and thus not biased by tenure or forest age) had a detection rate of 37 percent overall. The data have not been formally analysed so the Committee considers it inappropriate to use them to generate a formal estimate but notes that they are broadly consistent with a larger population than was previously considered to be the case.

A likely scenario of future decline has been described above for Subcriterion 1A3(b) and 1A4(b). Here the timeframe and threshold vary, but as the decline is consistent and ongoing due to logging and hollow bearing tree collapse (but not fire which is stochastic) they can reasonably be projected for timeframes appropriate to this criterion. A decline of greater than 40 percent may be projected over a single generation, which is a very high rate.

With respect to Criterion 3C2, Yellingbo is clearly separate, as indicated by genetic differences (Hansen et al. 2009). Genetic analyses also showed considerable admixture across the northern highlands (Toolangi, Mt Margarent, Lake Mountain and Cambarville), but some differentiation from the southern highlands (Powelltown)(Hansen et al. 2009). Todd et al. (2016) defined regional groupings within the Leadbeater’s Possum reserve but noted the reserve’s context as “part of the continuum of habitat available” (see Criterion 2 above) so these groupings cannot reasonably be considered subpopulations in the context of this criterion. The genetic data suggest three subpopulations. Two of which are likely to be greater than 1 000 individuals. Leadbeater’s Possum does not exhibit extreme fluctuations in population size (approximately at least an order of magnitude (IUCN Standards and Petitions Subcommittee 2017)). Therefore it does not meet the eligibility criteria for 3C2.

The Committee considers that the population size is limited and that it is projected to decline at a very high rate. Leadbeater’s Possum is eligible for inclusion in the Vulnerable category under criterion 3C1.

Criterion 4. Number of mature individuals			
	Critically Endangered Extremely low	**Endangered Very Low**	**Vulnerable Low**

Number of mature individuals	**< 50**	**< 250**	**< 1,000**

Evidence:

Not eligible

As described above under Criterion 3, the Committee considers the population size of Leadbeater's Possum to be between 2,500 and 10,000.

The Committee consider that the population size is not low. Therefore Leadbeater's Possum is not eligible for inclusion in any category under this criterion.

Criterion 5. Quantitative Analysis			
	Critically Endangered Immediate future	**Endangered Near future**	**Vulnerable Medium-term future**
Indicating the probability of extinction in the wild to be:	**≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)**	**≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)**	**≥ 10% in 100 years**

Evidence:
Insufficient data to determine eligibility

There have been a number of population viability analyses undertaken for Leadbeater's Possum (Lindenmayer et al. 1993; Lindenmayer & Lacy 1995a, b; Lindenmayer & Possingham 1995). Only one has been undertaken since the 2009 fires (Todd et al. 2016). However, the purpose of the Todd et al. (2016) study was specifically to assess the effectiveness of the Leadbeater's Possum Reserve. The population model was run for 40 generations (200 years) and does not provide specific probabilities within the timeframes specified under this criterion. The figure defined in the paper as being the criterion for success was less than five percent chance of falling below 500 adult females in 40 generations (Todd et al. 2016). The Committee considers that the specifications of this study differ too greatly from the requirements of this criterion to enable an effective assessment. The model would need to be re-parameterised and re-run to enable its application in this context.

Leadbeater's Possum is data deficient and thus ineligible for inclusion in any category under this criterion.

Conservation actions

Recovery Plan

A recovery plan was recommended by the Committee in 2015 (Threatened Species Scientific Committee 2015) and this recommendation was accepted by the Minister. The recovery plan is in the advanced stages of preparation. The Committee again recommends a recovery plan be prepared and that the current draft be finalised as soon as possible. The objectives and actions below are drawn from the draft recovery plan which may be refined as the recovery plan is finalised.

Conservation objectives

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

2: A whole of landscape management regime is in place ensuring that all current and future suitable habitat across the species' known range is maintained, enhanced and effectively managed to maximise its suitability for Leadbeater's Possum.

3: Where there is net long-term benefit (i.e. likelihood of increase in overall population viability), translocate individuals or colonies *within* the known range, and maintain a captive breeding colony for the lowland swamp forest subpopulation.

4: Seek to locate, or establish, additional populations *outside* the core range of the Central Highlands, and protect any such populations.

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

6: An integrated monitoring program is effectively implemented and maintained that publicly reports in a timely manner on possum status, existing and future habitat extent, quality and connectivity, and effectiveness of management and research activities.

7: Stakeholders support and where relevant are involved in the implementation of recommended actions.

Conservation actions

Conservation and Management priorities

- 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.
- Ensure that future relevant planning and policy settings provide for maximising the chances of long-term survival of Leadbeater's Possum.
- Protect all known colonies of Leadbeater's Possum in state forest, with a timber harvesting exclusion zone around all known (post 1998) verified records.
- Ensure no timber harvesting is permitted in any area of the Central Highlands montane Ash forests unless comprehensive pre-harvest surveys (as per the approved Leadbeater's Possum survey standards) demonstrate, with a high level of confidence, absence of Leadbeater's Possum from the prospective harvest area
- Retain and protect, with appropriate buffers, all live and dead trees that are either large (>150 cm DBH) or hollow-bearing (where >80 cm DBH) in montane Ash forests within the distribution of Leadbeater's Possum.
- Review the conservation effectiveness of other timber harvesting regulatory prescriptions and related guidelines relevant to the protection of Leadbeater's Possum and its habitat and revise where required.
- Refine and update occupancy and other relevant distributional and population viability modelling, in all land tenures across the full range of the species.
- 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 percent over 100 year period) for Leadbeater's Possum.
- Expand the dedicated reserve system to incorporate sufficient areas of current and future suitable habitat to ensure that it is adequate to maintain and enhance the long-term population viability of Leadbeater's Possum.
- 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, quality and connectivity of current and future suitable habitat.
- Develop and implement fire management that effectively secures and promotes long-term, strategic and effective protection of known colonies and suitable habitat.

- Develop a priority suite of responsive actions designed to maintain or recover populations as rapidly as possible after extensive bushfire.
- Where research on habitat augmentation (including the provision of nest boxes, artificially excavated hollows, and manipulation of mid-storey) demonstrates that benefits can be obtained effectively, strategically implement these mechanisms to enhance the current and future extent of suitable habitat in the Central Highlands.
- Enhance current and future habitat suitability and extent of swamp forest habitat for the lowland subpopulation.
- Identify priority areas within 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 translocation.
- Assess the risks, benefits, practicality, cost-effectiveness and consequences of 'gene pool mixing' to increase the viability of the lowland subpopulation.
- Where actions indicate likelihood of net benefit, undertake carefully monitored trial translocations, and – if successful – extend translocations to other priority areas.
- Maintain a captive breeding population for the lowland swamp forest subpopulation to act as insurance and potential source for local translocations.
- Using recently developed survey approaches, survey potentially suitable areas (in Victoria) outside the currently known range, including in areas predicted by habitat modelling to provide suitable habitat and/or where there are previous verified and plausible unverified records.
- If such surveys locate 'new' existing populations (beyond the Central Highlands), assess their status, population size, genetic affinities, habitat relationships, extent of suitable and future habitat and management requirements; and implement appropriate management actions and prescriptions.
- If such surveys fail to locate existing populations, identify the most suitable candidate areas (in Victoria) for potential translocation.
- 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.
- Establish appropriate governance and protocols to be able to respond to emergency events, such as significant losses of possums to extensive bushfire.

Stakeholder Engagement

- Establish (or build from existing mechanisms) and maintain an effective and fit-for-purpose recovery team or similar governance model with clear, explicit and practical terms of reference to oversee coordination and implementation.
- Enhance the community's involvement in Leadbeater's Possum recovery.
- Provide enhanced opportunities for the participation of Indigenous groups in research, monitoring and management.
- Raise awareness of Leadbeater's Possum and its conservation among the general public.
- Promote and publicise conservation effort for Leadbeater's Possum.

Survey and Monitoring priorities

- 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.

- Collate existing monitoring data and programs that assess trends in abundance and incidence of Leadbeater's Possum, extent and suitability of habitat (including key habitat attributes, such as the abundance of hollow-bearing trees), and management effectiveness.
- Identify key trigger events (e.g. future widespread fires) or thresholds in monitoring results that would catalyse priority emergency response (and identify such emergency response options).
- 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.
- 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.

Information and Research priorities

- 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.
- Undertake research that provides more robust knowledge of key demographic and other ecological characteristics of Leadbeater's Possum relevant to conservation management, specifically including population size, subpopulation structuring, dispersal characteristics, social systems, and home range size. This should include research
    - aimed at increasing 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 enhance site fidelity post-release in order to reduce dispersal-related mortality.
- Investigate key aspects of the post-fire ecology of Leadbeater's Possum, especially in relation to the 2009 bushfires. This research should include at least
    - (i) assessment of current hollow availability and the importance of large dead and any live hollow-bearing trees in the burnt landscape;
    - (ii) investigation of hollow development within trees that were 1939 regrowth before being burnt, to determine their potential to provide denning sites into the future;
    - (iii) investigation of the 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; and
    - (iv) monitoring of rates of natural recolonisation of forest regrowing after fire
- Design and implement clearly-defined experimental trials that rigorously assess the relative benefits of forest management prescriptions, actions and other options, in a manner that allows results to inform ongoing refinement of those prescriptions and recommended conservation actions. Such research should explicitly include an assessment of the conservation effectiveness and resilience of buffers of various sizes around colonies, and retained large and hollow-bearing trees.
- Assess the practicality and effectiveness of habitat augmentation actions including the provision of nest boxes, artificially excavated hollows, and manipulation of mid-storey to accelerate the development of key habitat features.

Recommendations

(i) The Committee recommends that *Gymnobelideus leadbeateri* be confirmed in its current listing status of Critically Endangered in the list referred to in section 178 of the EPBC Act as there is sufficient evidence to support the category since the species' rediscovery in the wild

(ii) The Committee recommends that there should be a recovery plan for this species.

Threatened Species Scientific Committee

26/02/2019

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