Research Article　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　**Open Access**

Preventing the Extinction of an Iconic Globally Endangered Species – Leadbeater's Possum (*Gymnobelideus leadbeateri*)

David Lindenmayer[1,2,3*], **David Blair**[1,2,3], **Lachlan McBurney**[1,2,3] and **Sam Banks**[1,2]

[1]*Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia*

[2]*Australian Research Council Centre of Excellence for Environmental Decisions, The Australian National University, Canberra, ACT 2601, Australia*

[3]*Long-term Ecological Research Network, Terrestrial Ecosystem Research Network, The Australian National University, Canberra, ACT 2601, Australia*

*****Corresponding author:** Lindenmayer D, Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia, Tel: +612 61250654; Fax: +612 61250746; E-mail: david.lindenmayer@anu.edu.au

Abstract

Leadbeater's Possum is an iconic but globally endangered species largely confined to the wet ash forests of Victoria, south-eastern Australia. The species is at risk of extinction as a result of widespread logging, recurrent wildfire, and the rapid decline of populations of large old hollow-bearing trees – the single most critical habitat element for Leadbeater's Possum. We outline why recent strategies aimed at conserving Leadbeater's Possum appear unlikely to be effective in preventing the species' extinction. We outline what we believe to now be the only current viable approach to conserve this species. This is the rapid transition to a large protected forest reserve system where the primary process threatening the species – widespread industrial clear-felling – is removed.

Keywords: Leadbeater's Possum, Gymnobelideus leadbeateri, Extinction, Hollow-bearing trees, Clear-felling, Management strategy, Conservation strategy, Large ecological reserves

Introduction

Biodiversity loss is a key form of global change [1], with current rates of extinction thought to be 1000 times background rates [2]. Australia is credited with the highest loss of mammals of any continent since 1600 [3]. Indeed, at least 18 species of mammals have been lost from the Australian continent in the last two centuries [4,5]. The ecology of many of these extinct species was poorly known with little or no scientific knowledge of them before they were lost. In this paper, we focus on the potential demise of yet another Australian species which, rather than being poorly known, has been the subject of many detailed studies over the past three decades [6-8], and for which appropriate management and conservation strategies are well understood. This species is the globally endangered arboreal marsupial, Leadbeater's Possum (*Gymnobelideus leadbeateri*).

The overview we present on Leadbeater's Possum indicates that key scientific information that should be used to guide the effective conservation of the species has not found its way into wildlife conservation policy, nor associated on-the-ground management action. The reasons for this disconnect lie with the political power of a major (although now largely uneconomic) native forest logging industry whose actions are eroding short-term and long-term habitat suitability for Leadbeater's Possum. Having conducted decades of population monitoring and research into forest management strategies to better integrate forestry and effective conservation of Leadbeater's Possum [9,10], we outline what we believe to be the only current viable approach to conserve this species. This is the rapid transition to a large protected forest reserve system where the primary process threatening the species – widespread industrial clear-felling – is removed.

The Ecology of Leadbeater's Possum

Leadbeater's Possum is a small (120 grams) non-gliding arboreal marsupial (Figure 1). It is the only mammal endemic to the Australian state of Victoria and has a highly restricted distribution limited to an area of approximately 80 km × 60 km [6]. The species is largely confined to the wet montane ash forests and sub-alpine woodlands of the Central Highlands of Victoria, south-eastern Australia. The primary habitats occupied by Leadbeater's Possum are those located within Mountain Ash (*Eucalyptus regnans*), Alpine Ash (*Eucalyptus delegatensis*) and Shining Gum (*Eucalyptus nitens*) forests which cover approximately 171,200 ha in the Central Highlands of Victoria [7], although much of this forest cover is not suitable habitat for Leadbeater's Possum [11].

Figure 1: Leadbeater's Possum.

Leadbeater's Possum was first described in 1867. Only five specimens were collected by 1909 after which it was thought to be extinct. The species was rediscovered in 1961 and made the faunal emblem of Victoria a decade later [6]. Leadbeater's Possum was not known to occur in montane ash forests prior to its rediscovery in 1961 – all specimens were taken from entirely different areas. The areas from which the species were collected were almost entirely cleared by 1909 and because the species had not been seen for a number of years, it was presumed extinct [6].

Leadbeater's Possum is arguably among the best studied endangered animals globally, and certainly in Australia; more than 100 peer-reviewed scientific articles have been written about the species in the past three decades. Detailed ecological research on Leadbeater's Possum commenced in the late 1970s [12,13] and has expanded since then [11,14-18]. Many key aspects of the species' biology are well documented. For example, field-based empirical studies show that the habitat requirements of Leadbeater's Possum comprise a combination of large, old hollow-bearing trees and a dense understorey of Acacia spp. trees. Hollow-bearing trees are the single most important habitat element for Leadbeater's Possum and sites with many of these kinds of trees are significantly more likely to be occupied by the species [18,19]. Large old hollow-bearing trees provide den and nesting sites in which colonies of up to 12 animals spend almost 75% of their lives [20,21]. Animals swap regularly between different nest trees and up to six hollow-bearing trees may be used within an individual's 1.5-3 ha home range [22]. Leadbeater's Possum typically select particular kinds of large old hollow-bearing trees: those that are at least 150-180 years old and often in the advanced stages of decay [23,24]. Selection of particular kinds of hollow-bearing trees, coupled with between den-tree movements, are the likely reasons for the strong relationships between the occurrence of Leadbeater's Possum and the abundance of hollow-bearing trees [19].

There have been concerns about the conservation of Leadbeater's Possum since its rediscovery in 1961 (e.g. [8,25,26]). Most of these concerns are associated with the negative impacts of intensive and extensive clear fell logging operations throughout montane ash forests. Leadbeater's Possum is classified as Endangered by the Australian Government under the Australian *Environment Protection and Biodiversity Conservation Act 1999*, although there is currently a proposal to up-list the species to Critically Endangered. Indeed, the species was recently recognized as being Critically Endangered in an overview of the conservation status of Australian mammals [5]. Moreover, Burns et al. [27] recently classified the Mountain Ash (*Eucalyptus regnans*) ecosystem as Endangered under new IUCN Red-listed Ecosystem criteria [28]. It was assigned this ranking under the IUCN criterion because of the susceptibility of the Mountain Ash ecosystem to collapse in the next 30-50 years as a result of the risks of recurrent fire, widespread logging, the paucity of old growth stands, and the rapid collapse of large old hollow-bearing trees which are keystone structural features of these forests [27]. Mountain Ash forest is one of the key ecosystems in which Leadbeater's Possum occurs.

Key Threatening Processes

Three inter-related processes threaten the persistence of Leadbeater's Possum. These are: (1) the collapse of existing large old hollow-bearing trees and the lack of recruitment of new cohorts of such trees, (2) recurrent high-severity wildfire, and (3) widespread clear fell logging. The former two of these processes occur naturally, but can be considered as threatening processes because these drivers of

'background' turnover in habitat suitability now occur in the context of widespread clear fell logging, whereby recruitment of new habitat is greatly reduced. A short summary of the impacts of these threatening processes on Leadbeater's Possum is outlined in the remainder of this section.

The loss of hollow-bearing trees and old growth forest

Large old hollow-bearing trees are the critical habitat resource required by Leadbeater's Possum; the species cannot survive without access to such trees for denning and nesting [19]. The highest abundance of hollow-bearing trees occurs in old growth montane ash stands [29]. This is primarily because it takes 120+ years for montane ash trees to begin to develop the kinds of cavities suitable for occupancy for Leadbeater's Possum [30]. However, a legacy of past fires and past and present logging operations is that only 1887 ha or 1.16% of the Mountain Ash is old growth and 0.37% of Alpine Ash forest is old growth; the remainder is regrowth forest that is 75 years of age or younger [31]. Individual living and dead large old hollow-bearing trees do occur in these regrowth forests, but most of them are old growth trees that were burned in large fires in 1939 and populations of these trees are declining rapidly as a result of natural decay and collapse as well as high rates of mortality as a result of elevated temperatures and depressed rainfall during the prolonged drought in the Central Highlands region [31]. New hollow-bearing trees are not being recruited to replace the ones that have been lost because: (1) It will take at least another 50 years before existing stands of trees will reach an age at which they begin to develop cavities suitable for occupancy by Leadbeater's Possum (as well as up to 40 other species of cavity-dependent vertebrates that inhabit montane ash forests); (2) Fire consumes existing large old hollow-bearing trees and kills regrowth trees before they reach an age and/or size where cavities develop [31]; and (3) Logging both significantly accelerates the collapse of existing hollow-bearing trees and, on the present 40-80 year rotation, results in the removal of regrowth trees before they develop cavities suitable for occupancy by Leadbeater's Possum [8]. Notably, the ecosystem assessment by Burns et al. [27] suggested that populations of hollow-bearing trees within Mountain Ash forests will approach approximately 1% of natural "background" levels by 2050. Projections of population decline in hollow-bearing tree abundance for Alpine Ash ecosystems are more severe than they are for Mountain Ash ecosystems because of the extreme rarity of old growth stands in the Central Highlands of Victoria; less than 0.4% of the Alpine Ash estate in the region is old growth.

As outlined above, only 1.16% of the Mountain Ash is old growth and 0.37% of Alpine Ash forest is old growth. Stand reconstruction and fire modelling analyses [32,33] suggest that historically (i.e. prior to white settlement), the amount of old growth forest was 30-60 times greater than it is currently. It is therefore possible that the extent of old growth forest is at the lowest it has ever been in the evolutionary history of montane ash ecosystems. The paucity of old growth montane ash forest is a major problem for several reasons. First, as indicated above, old growth forest is where the highest abundance of large old hollow-bearing trees occur and hence where essential nesting and denning resources for Leadbeater's Possum are located. A second key reason why old growth forest is important is associated with the effects of natural disturbance and the subsequent structure of the forest. If an area of old growth forest is burned, then the regenerating stands will typically be characterised by many dead and living (but fire-scarred) large old trees which can be colonised by cavity-dependent animals like Leadbeater's Possum and used as nesting and

denning sites [30,34]. However, fires in regrowth forests do not produce a pulse of large old hollow-bearing trees, in part because the small diameter of young trees means they are prone to rapid collapse following fire [31] and also because such trees lack the internal volume appropriate for developing suitable cavities for occupancy by animals such as Leadbeater's Possum [35]. Therefore, future fires in montane ash landscapes dominated by young regrowth stands will not only destroy the limited remaining existing habitat for Leadbeater's Possum, but also will significantly impair the creation of future habitat for the species [7].

Wildfires

Fire is the primary form of natural disturbance in the montane ash forest ecosystems within which Leadbeater's Possum occurs. More than 10 fires have occurred in the montane ash forests of the Central Highlands of Victoria in the past century [7]. Detailed surveys of a large number of long-term field sites following fires in 2009 indicate that Leadbeater's Possum no longer occurs on burned sites which it occupied prior to the fire [15]. Loss of the species from burned sites occurred irrespective of fire severity; that is, no animals occurred on sites subject to low, moderate or high severity fire [15]. In addition, Leadbeater's Possum was also significantly less abundant on unburned sites where there was fire in the 500-1000 m area of the surrounding landscape, suggesting a greater level of fire susceptibility than previously recognised for the species [15].
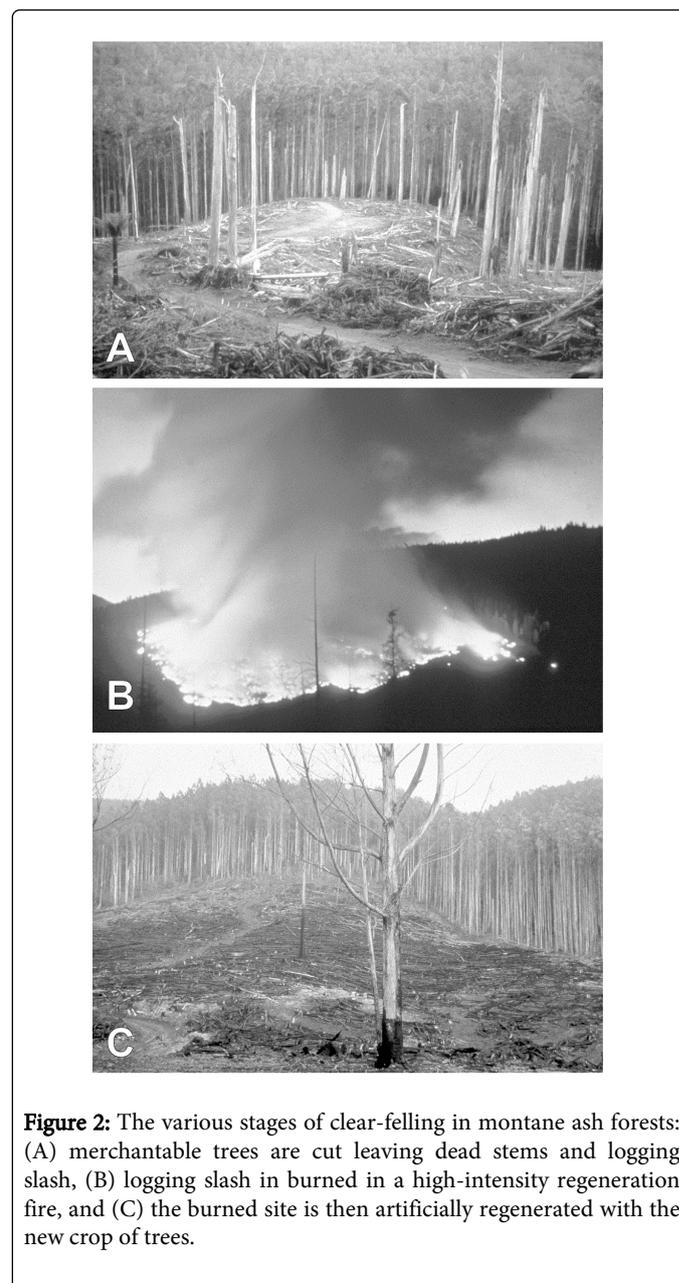
Logging

Clear-fell logging is the major form of human disturbance that is threatening the persistence of many of the remaining populations of Leadbeater's Possum in montane ash forests. Clear-felling involves the removal of all merchantable trees on harvest units of up to 40 ha in size. Large amounts of logging slash in the form of tree crowns, lateral branches, understorey trees and shrubs and bark is left on the forest floor after harvesting and this is burned to create an ash bed in which new stands are artificially regenerated to grow the next crop of trees (Figure 2) [36,37]. Clear-felling operations result in the death of resident animals on harvest units. Clear-felling leads to the loss of existing large old hollow-bearing trees [38]. Furthermore, as outlined above, the rotation time between logging operations is planned to be 40-80 years and therefore cut areas typically do not support the 180+ year old hollow-bearing trees required by cavity-dependent animals like Leadbeater's Possum [38].

Clear-fell logging has impacts on Leadbeater's Possum beyond those summarised above at the site (harvest unit) level. Such operations often result in landscapes comprising numerous cut blocks (or harvest units) interspersed by strips and narrow blocks of uncut stands (Figure 3). Field data indicate that Leadbeater's Possum only rarely occupies linear strips of retained forest located between clear-felled areas [39]. In addition, the road network created to facilitate the transport of timber and pulpwood from the forest creates barriers to the movement of animals through the forest (R. Van der Ree et al., unpublished data).

Interactions between fire and logging

Fire and logging act independently to threaten the persistence of Leadbeater's Possum. These drivers also interact in two ways to further increase the risk of extinction of the species. First, high-severity fires in montane ash ecosystems are often followed soon afterwards by clear-

felling to recover some of the economic value of fire-damaged trees; a form of forest management called post-fire salvage logging [40]. Salvage logging has similar kinds of long-term negative effects on Leadbeater's Possum as conventional clear-felling [41], and exacerbates the negative effects of fire by removing any remaining dead standing large trees from burnt forest stands, which would have otherwise acted as a denning resource in post-fire regenerating forest stands. Second, forests regenerating after logging are at significantly increased risk of burning in a high-severity crown-scorching fire [42].

Figure 2: The various stages of clear-felling in montane ash forests: (A) merchantable trees are cut leaving dead stems and logging slash, (B) logging slash in burned in a high-intensity regeneration fire, and (C) the burned site is then artificially regenerated with the new crop of trees.

That is, young post-harvest forests regenerating after clear-felling have a significantly elevated risk of burning at higher severity than mature and old growth stands [42]. There are a number of plausible reasons for this including changes in fuel loads, microclimate and stand architecture than characterise young, regenerating stands of montane ash forest following clear-felling [42]. Patterns of spatial

forest cover created by many harvest units distributed throughout a landscape can, in turn, increase the risk of recurrent wildfires within logged regions, leading to what Lindenmayer et al. [43] termed a "landscape trap". Under the landscape trap phenomenon, recurrent stand-replacing fires and widespread logging result in the loss of old growth stands and prevent the recruitment of new areas of old growth forest due to the altered severity and spatial contagion of fire in such landscapes. The young stands which comprise a heavily logged montane ash forest landscape are thereby trapped in young age cohorts by repeated fire events and are unable to persist long enough to progress to ecological maturity [43].
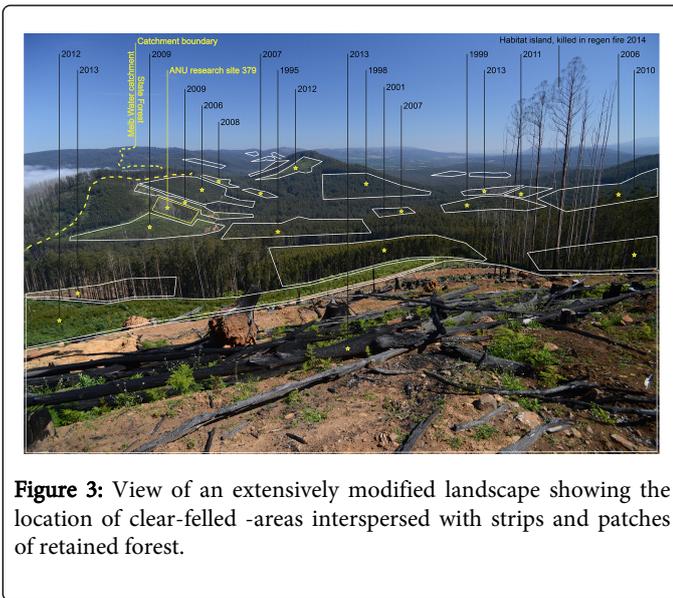

Figure 3: View of an extensively modified landscape showing the location of clear-felled -areas interspersed with strips and patches of retained forest.

The overall effects of salvage logging, logging-mediated elevated fire severity, and the landscape trap phenomenon are ecologically similar. That is, they result in the death of animals on sites, accelerate the loss of existing habitat for Leadbeater's Possum, and preclude the development of new areas of forest habitat for the species.

Past and recent conservation

The risks to the persistence of Leadbeater's Possum have long been recognised [44,45]. On this basis, various conservation strategies have been proposed. These include: (1) The Yarra Ranges National Park that was gazetted in 1994 and which contains approximately 20% of the montane ash forest in the Central Highlands of Victoria. (2) A zoning system in which areas of high quality habitat are identified prior to logging to ensure that they are not then subsequently cut down. And, (3) A reserve system comprising areas of uncut forest set aside as Special Protection Zones within forests otherwise broadly designated for wood production [46]. This reserve system for Leadbeater's Possum was formally recognised in 2008.

Major deficiencies in the effectiveness of conservation strategies for Leadbeater's Possum became apparent in 2009 after the "Black Saturday" wildfires burned more than 72,000 ha of montane ash forest in the Central Highlands of Victoria. These fires destroyed an estimated 36% of suitable habitat for Leadbeater's Possum and 45% of the reserve system for the species [25]. The fires, together with historical and current logging operations have reduced the amount of old regrowth montane ash forest to unprecedented low levels. Finally, the Government of Victoria changed forest survey standards so that

areas of potentially suitable habitat for Leadbeater's Possum would not be properly assessed prior to the commencement of logging operations [47]. These factors clearly indicate there is a high risk of extinction of Leadbeater's Possum. In response to this risk, the Government of Victoria had established a Leadbeater's Possum Recovery Team and university-based scientists produced a document of key strategies that attempted to secure the future of wild populations of the species [14]. The response of the Government of Victoria was to ignore the advice of its own panel of scientific experts (the Leadbeater's Possum Recovery Team) and to create a Leadbeater's Possum Advisory Group (LPAG) containing none of the key experts on the species. Instead the LPAG included the CEO of the state owned logging organisation and the group was co-chaired by the head of the state timber industry association. The terms of reference for the LPAG "supporting the recovery of the Leadbeater's Possum while maintaining a sustainable timber industry" restricted the actions able to be recommended for conserving Leadbeater's Possum. This effectively tied the survival of Leadbeater's Possum to the health of the extractive industry that threatens it. The LPAG subsequently produced a recommendations report and a technical report [48]. The recommendations then formed the basis of an Action Statement for Leadbeater's Possum which dictates management of the species [49].

The LPAG Reports and the Action Statement contained some good initiatives such as a move away from clear-felling to the broad-scale adoption of more environmentally sensitive variable retention harvesting [50] and, for the first time for the species, legislated protection of known colonies. Other initiatives included the establishment of a nest box program, and a reintroduction and translocation program.

A careful ecological and statistical assessment of the LPAG report and associated Action Statement indicate that both documents contain significant flaws and could even have perverse outcomes for Leadbeater's Possum.

First, the LPAG Report was underpinned by a single snapshot field survey of <30 species' records using new call back field methods [25] that draw animals into an area from an unknown distance away. These methods appear to be unrepeatable as animals habituate to the prolonged playing of alarms calls and are not detected subsequently when exposed to the calls multiple times. This is a serious problem for many reasons, but particularly as: (1) LPAG may have seriously over-estimated the abundance of Leadbeater's Possum due to the unknown sampling radius potentially being far larger than estimated; and (2) LPAG recommended pre-logging surveys take place only on those sites deemed from their modelling to have >65% chance of supporting Leadbeater's Possum. This means that many sites likely to contain colonies of animals will inadvertently be logged because they are not subjected to pre-logging surveys. We argue that it was inappropriate to base the conservation planning for an endangered species on the use of a new field method (playback recording) that has been largely untested and for which uncertainty is not quantified. This was especially unfortunate given that carefully tested and widely employed (and repeatable) methods such as stag watching were available [51-53]. Indeed, the stag watching method has been used in a highly effective way for over 30 years.

Second, although the recommended shift away from clear-felling to retention harvesting is a positive step [10], it needs to be accompanied by a significant reduction in sustained yield of timber and pulpwood derived from montane ash forests which the restrictive terms of reference would not allow. Without significant reductions in sustained

yield, the area of forest affected by logging will actually increase to meet largely unaltered pulp log and saw log quotas. This translates to more areas of logged forest that provide unsuitable habitat and more logging roads (which further isolate populations of animals) to access more cut areas.

Third, and again due to limitations imposed by the terms of reference, the LPAG recommendations failed to provide appropriate protection for large old hollow-bearing trees. This is the single most important strategy needed to protect Leadbeater's Possum because such key resources are in steep decline and it takes a very long time to replace these habitat elements within montane ash forests [8]. However, hollow-bearing trees are still being cut/burnt/exposed to wind throw or damaged by logging and roadside clearing.

Fourth, the LPAG Report emphasized the installation of nest boxes to conserve Leadbeater's Possum [48]. However, it has been well known for more than a decade that nest boxes are rarely used by Leadbeater's Possum in montane ash forests [54]. A perverse potential outcome of such a focus on nest boxes is that it has the potential to distract managers from tackling the real problem which is the urgent need to protect all large old trees by excluding them from logging and better protecting them with buffers of uncut forest [8].

Fifth, the LPAG Report emphasized translocation to areas of suitable but unoccupied habitat [48]. But there is no evidence that this strategy works, nor have captive breeding programs for Leadbeater's Possum over the past 30 years made any significant contribution to the conservation of the species.

The LPAG Reports and subsequent Action Statement are characterised by a number of other significant problems that are beyond the scope of this short article to examine in detail. For example, empirical field data indicate that the 200 m areas of unlogged forest proposed to buffer known colonies of Leadbeater's Possum are too small and unlikely to effectively protect the species. In addition, the zoning system used to determine where logging should be excluded to protect Leadbeater's Possum is not based on empirical data on the habitat requirements of the species. Finally, the Action Statement is likely to be ineffective as the document suggests that only 4 of the 35 actions and sub-actions appear intended to be enforceable.

The most significant omission from the LPAG Report [48] and accompanying Action Statement [49] was the need to significantly expand the reserve system, especially as analyses by the Government of Victoria have indicated that the existing network of protected areas is highly inadequate [25]. As with a number of other key aspects of the LPAG Report and accompanying Action Statement, the need for an expanded reserve system was deemed to be outside the terms of reference for examining viable options for the conservation of Leadbeater's Possum [48]. However, establishing an expanded reserve system is the most ecologically effective way to: (1) protect suitable habitat for Leadbeater's Possum from logging; (2) protect hollow-bearing trees from logging; (3) reduce fragmentation associated with logging roads and link existing scattered reserved areas; and (4) restore and therefore eventually increase the size and spatial extent of the old growth forest estate in montane ash forests. An expanded reserve system would aim to secure the future persistence of populations of Leadbeater's Possum as the current (fire-damaged) reserve system is inadequate [25]. The exclusion of logging from large areas of montane ash forest to create an expanded reserve system is also important to minimise the risks of further high-severity fires [42] and also the risk

of collapse of the Mountain Ash ecosystem per se [27] – within which much of the habitat for Leadbeater's Possum occurs.

Effective Conservation

Leadbeater's Possum fulfils the criteria for a Critically Endangered species [5] and is at serious risk of extinction within the next few decades. This is because of the effects of past and recent fires, the risk of future fires, widespread past logging, and further planned logging operations over the coming 10-20 years.

We argue that, based on fundamental conservation biology principles [3,55,56]), the best approach to conserving an endangered species is to remove the key process threatening its persistence. The key process threatening the persistence of Leadbeater's Possum is direct mortality of animals and loss of habitat caused by conventional clear-felling operations, the direct loss of animals and loss of habitat by wildfire, and the indirect feedback inter-relationships between logging and elevated fire severity risks at site and landscape scales [42,43]. The best strategy for removing this threatening process is to set aside a large reserve where logging operations are excluded. There are some reserves already set aside for the conservation of Leadbeater's Possum but Population Viability Analysis clearly indicates that the existing reserve system is inadequate, especially given the risk of future fires. Indeed, that analysis indicates that virtually all of the montane ash forest resource needs to be set aside if remaining populations of Leadbeater's Possum are to have a reasonable chance of persistence in the coming 50 years. Therefore, whilst approaches like adopting more environmentally-sensitive retention harvesting practices could be valuable, a significantly expanded reserve system is the critical strategy to conserve Leadbeater's Possum because of limited viability of remaining populations in the face of additional fires and further logging as well as other factors such as the rapid decline of large old trees and the extreme rarity of old growth forest.

Large ecological reserves have always been the cornerstone of any credible conservation plan but with recognition that off-reserve conservation activities have an important complementary role to protected areas [57]. However, the magnitude of the problems facing Leadbeater's Possum, particularly the amount of habitat loss following the 2009 fires, coupled with the extent of past forest disturbance and the need to regrow (and significantly expand) the size of the old growth forest estate, indicate that a shift to an almost total focus on large ecological reserves is warranted.

Setting aside a large ecological reserve for Leadbeater's Possum will have major negative effects on the pulpwood and timber industries that are presently based on utilisation of montane ash forests. Almost all wood sourced from montane ash forests is used in paper production [58] and we suggest that the extensive existing plantation estate is an appropriate alternative source of fiber for paper production. In fact, plantation-derived wood is considered by industry officials as the preferred feedstock for paper manufacturing. Plantation feedstock for paper manufacturing has the twin advantages of improving the conservation of native eucalypt forests as habitat for Leadbeater's Possum and, at the same time, ensuring that existing plantations will not be cleared and converted to grazing pastures (with significant associated carbon emissions).

Concluding Comments

Leadbeater's Possum is one of Australia's iconic mammal species. It was once thought to be extinct but was then rediscovered. Current

research suggests that significant conservation and policy action is needed to prevent the permanent loss of the species. The scientific basis for the species' protection is well understood from more than three decades of intensive research. The policy and management action to match that science is now urgently required.

Acknowledgements

References

1. Butchart SH, Walpole M, Collen B, van Strien A, Scharlemann JP, et al. (2010) Global biodiversity: indicators of recent declines. Science 328: 1164-1168.

2. Pimm SL, Jenkins CN, Abell R, Brooks TM, Gittleman JL, et al. (2014) The biodiversity of species and their rates of extinction, distribution, and protection. Science 344: 1246752.

3. Lindenmayer DB, Burgman MA (2005) Practical Conservation Biology. CSIRO Publishing, Melbourne.

4. Johnson C (2006) Australia's Mammal Extinctions: A 50,000 Year History. Cambridge University Press, Melbourne.

5. Woinarski J, Burbidge A, Harrison P (2014) Action Plan for Australian Mammals 2012. CSIRO Publishing, Melbourne.

6. Lindenmayer DB (1996) Wildlife and Woodchips: Leadbeater's Possum, a Testcase of Sustainable Forestry. UNSW Press, Sydney.

7. Lindenmayer DB (2009) Forest Pattern and Ecological Process: A Synthesis of 25 Years of Research. CSIRO Publishing, Melbourne.

8. Lindenmayer DB, Blair D, McBurney L, Banks SC, Stein JAR, et al. (2013) Principles and practices for biodiversity conservation and restoration forestry: a 30 year case study on the Victorian mountain ash forests and the critically endangered Leadbeater's Possum. Aust Zool 36: 441-460.

9. Lindenmayer DB (2007) The Variable Harvest Retention System and its Implications for Biodiversity in the Mountain Ash Forests of the Central Highlands of Victoria. Fenner School of Environment and Society, The Australian National University, Canberra.

10. Lindenmayer DB, Knight E, McBurney L, Michael D, Banks SC (2010) Small mammals and retention islands: An experimental study of animal response to alternative logging practices. Forest Ecol Manag 260: 2070-2078.

11. Lindenmayer DB (1989) The Ecology and Habitat Requirements of Leadbeater's Possum. Australian National University, Canberra.

12. Smith AP (1984) Diet of Leadbeater's Possum Gymnobelideus leadbeateri (Marsupialia). Aust Wildl Res 11: 265-273.

13. Smith AP (1984) Demographic consequences of reproduction, dispersal and social interaction in a population of Leadbeater's Possum Gymnobelideus leadbeateri. Possums and Gliders. Eds Smith AP, Hume ID. Surrey Beatty and Sons, Sydney.

14. Lindenmayer DB, Blair D, McBurney L, Banks S (2013) 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.

15. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, et al. (2013) Fire severity and landscape context effects on arboreal marsupials. Biol Conserv 167: 137-148.

16. Harley DK (2004) Patterns of nest box use by Leadbeater's Possum Gymnobelideus leadbeateri: applications to research and conservation. The Biology of Australian Possums and Gliders. Eds Goldingay RL, Jackson SM. Surrey Beatty and Sons, Chipping Norton.

17. Hansen BD, Harley DK, Lindenmayer DB, Taylor AC (2009) Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. Mol Ecol 18: 3346-3362.

18. Lindenmayer DB, Cunningham RB, Tanton MT, Nix HA, Smith AP (1991) The conservation of arboreal marsupials in the mountain ash forests of the Central Highlands of Victoria, south-eastern Australia. III. The habitat requirements of Leadbeaters Possum Gymnobelideus leadbeateri and models of the diversity and abundance of arboreal marsupials. Biol Conserv 56: 295-315.

19. Lindenmayer DB, Barton PS, Lane PW, Westgate MJ, McBurney L, et al. (2014) An empirical assessment and comparison of species-based and habitat-based surrogates: a case study of forest vertebrates and large old trees. Sp.PLoS One 9: e89807.

20. Smith AP, Nagy KA, Fleming MR, Green B (1982) Energy requirements and turnover in free-living Leadbeater's Possums, Gymnobelideus leadbeateri (Marsupialia: Petauridae). Aust J Zool 30: 737-749.

21. Smith AP (1980) The Diet and Ecology of Leadbeater's Possum and the Sugar Glider. Ph.D Monash University, Melbourne.

22. Lindenmayer DB, Meggs RA (1996) Use of den trees by Leadbeater's Possum (Gymnobelideus leadbeateri). Aust J Zool 44: 625-638.

23. Lindenmayer DB, Cunningham RB, Tanton MT, Smith AP, Nix HA (1991) Characteristics of hollow-bearing trees occupied by arboreal marsupials in the mountain ash forests of the Central Highlands of Victoria, south-east Australia. Forest Ecol Manag 40: 289-308.

24. Smith AP, Lindenmayer DB (1988) Tree hollow requirements of Leadbeater's Possum and other possums and gliders in timber production ash forests of the Victorian Central Highlands. Aust Wildl Res 15: 347-362.

25. Lumsden LF, Nelson JL, Todd C, Scroggie P, McNabb E, et al. (2013) A new strategic approach to biodiversity management - research component. Arthur Rylah Institute for Environmental Research, Melbourne.

26. Warneke RM (1968) Leadbeater's Possum. Wildlife in South-eastern Australia. Ed Dempster K. Australian Broadcasting Commission, Sydney.

27. Burns E, Lindenmayer DB, Stein JA, Blanchard W, McBurney L, et al. (2014) Ecosystem assessment of Mountain Ash Forest in the Central Highlands of Victoria, south-eastern Australia. Austral Ecol./:doi: 10.1111/aec.12200.

28. Keith DA, Rodríguez JP, Rodríguez-Clark KM, Nicholson E, Aapala K, et al. (2013) Scientific foundations for an IUCN Red List of ecosystems. PLoS One 8: e62111.

29. Lindenmayer DB, Cunningham RB, Donnelly CF, Franklin JF (2000) Structural features of old growth Australian mountain ash forests. Forest Ecol Manag 134: 189-204.

30. Lindenmayer DB, Cunningham RB, Donnelly CF, Tanton MT, Nix HA (1993) The abundance and development of cavities in Eucalyptus trees: a case-study in the mountain forests of Victoria, southeastern Australia. Forest Ecol Manag 60: 77-104.

31. Lindenmayer DB, Blanchard W, McBurney L, Blair D, Banks S, et al. (2012) Interacting factors driving a major loss of large trees with cavities in a forest ecosystem. PLoS One 7: e41864.

32. Lindenmayer DB, McCarthy MA (2002) Congruence between natural and human forest disturbance: a case study from Australian mountain ash forests. Forest Ecol Manag 155: 319-335.

33. McCarthy MA, Lindenmayer DB (1998) Multi-aged mountain ash forest, wildlife conservation and timber harvesting. Forest Ecol Manag 104: 43-56.

34. Lindenmayer DB, Cunningham RB, Nix HA, Tanton MT, Smith AP (1991) Predicting the abundance of hollow-bearing trees in mountain ash forests of southeastern Australia. Aust J of Eco 16: 91-98.

35. Gibbons P, Lindenmayer DB (2002) Tree Hollows and Wildlife Conservation in Australia. CSIRO Publishing, Melbourne.

36. Lutze MT, Campbell RG, Fagg PC (1999) Development of silviculture in the native State forests of Victoria. Aust Forestry 62: 236-244.

37. Flint A, Fagg P (2007) Mountain Ash in Victoria's State Forests. Department of Sustainability and Environment, Melbourne.

38. Lindenmayer DB (1994) The impacts of timber harvesting on arboreal marsupials at different spatial scales and its implications for ecologically sustainable forest use and nature conservation. Aust J Environ Manag 1: 56-68.

39. Lindenmayer DB, Cunningham RB, Donnelly CF (1993) The conservation of arboreal marsupials in the mountain 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. Biol Conserv 66: 207-221.

40. Lindenmayer DB, Burton PJ, Franklin JF (2008) Salvage Logging and its Ecological Consequences. Island Press, Washington DC.

41. Lindenmayer DB, Ough K (2006) Salvage logging in the mountain ash eucalypt forests of the Central Highlands of Victoria and its potential impacts on biodiversity.Conserv Biol 20: 1005-1015.

42. Taylor C, McCarthy MA, Lindenmayer DB (2014) Non-linear effects of stand age on fire severity. Conserv Lett 7: 355-370.

43. Lindenmayer DB, Hobbs RJ, Likens GE, Krebs CJ, Banks SC (2011) Newly discovered landscape traps produce regime shifts in wet forests. Proc Natl Acad Sci U S A 108: 15887-15891.

44. Macfarlane MA, Seebeck JH (1991) Draft Management Strategies for the conservation of Leadbeater's Possum, Gymnobelideus leadbeateri, in Victoria. Department of Conservation and Environment, Melbourne.

45. Lindenmayer DB, Possingham HP (1995) The Risk of Extinction: Ranking Management Options for Leadbeater's Possum. Centre for Resource and Environmental Studies, The Australian National University, Canberra.

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

47. Lindenmayer DB, Possingham HP (2013) No excuse for habitat destruction. Science 340: 680.

48. Government of Victoria (2014) Supporting the recovery of the Leadbeater's possum. Government of Victoria, Melbourne.

49. Government of Victoria (2014) Leadbeater's Possum Action Statement. Government of Victoria, Melbourne.

50. Gustafsson L, Baker S, Bauhus J, Beese W, Brodie A, et al. (2012) Retention forestry to maintain multifunctional forests: a world perspective. BioScience 62: 633-645.

51. Seebeck JH, Suckling GC, Macfarlane MA (1983) Leadbeater's possum - survey by stagwatching. Victorian Nat 100: 92-97.

52. Lindenmayer DB, Craig SA, Linga T, Tanton MT (1991) Public participation in stagwatching surveys for a rare mammal - applications for environmental education. Aust J of Environ Ed 7: 63-70.

53. Lindenmayer DB, Wood J, McBurney L, Michael D, Crane M, et al. (2011) Cross-sectional versus longitudinal research: A case study of trees with hollows and marsupials in Australian forests. Ecol. Monogr. 81: 557-580.

54. Lindenmayer DB, Welsh A, Donnelly CF, Crane M, Michael D, et al. (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. Biol Conserv 142: 33-42.

55. Caughley GC, Gunn A (1996) Conservation Biology in Theory and Practice. Blackwell Science, Cambridge, MA.

56. Sodhi NS, Ehrlich PR Eds (2010) Conservation Biology for All. Oxford University Press, Oxford, England.

57. Lindenmayer DB, Franklin JF (2002) Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach. Island Press, Washington DC.

58. Keith H, Lindenmayer DB, Mackey BG, Blair D, Carter L, et al. (2014) Managing temperate forests for carbon storage: impacts of logging versus forest protection on carbon stocks. Ecosphere 5(6): Article 75.