Wildfires & the forest logging industry
山火事と森林伐採産業

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2019-2020 Australian fires
2019年〜2020年 オーストラリアの山火事

- ~ 12.3 m ha (>12 x recent Amazon fires)
- \> 3 billion individual animals lost
- Cost ~$100b – (Quiggin, 2020)

- BUT –look deeper than broadscale indicators & only 1 fire

- 〜1230万ha（最近のアマゾン火災の12倍以上）
- 30億匹以上の動物が失われる
- 〜1000億ドルのコスト（Quiggin、2020年）

- しかし、広範な指標やたった1つの火災ではなく、もっと深く見てください

THIS TALK

Before the fire

During the fire

After the fire

Before & after the fire (an interaction)

After the fire (again)

Management things....

本プレゼン

火災前

火災発生時

火災後

火災前と火災後 （相互作用）

火災の後（再び）

管理関係のこと...

CLIMATE & FIRE 気候と火災

Long-term climate & short-term weather = critical drivers of fire

長期的な気候と短期的な天候 =

極めて重要な火災の要因

Account for fire weather in analyzing other effects

他の影響を分析する際に、火災の天候を考慮する

The climate IS changing – and fast
気候は変化している。しかも急速に。

- Background Co2 = 280 ppm in past 800 000 years
- June 4 2022= 421 ppm
- Link between Co2 and temperature
- 2019 = hottest and driest years on record
- IPCC suggest >1.5 degrees by 2030
- Extreme FFDI days –increased 10X since 1960
- 過去80万年のバックグラウンドCo2＝280ppm
- 2022年6月4日＝421ppm
- Co2と気温の関係
- 2019年＝観測史上最も暑く、最も乾燥した年
- IPCCは2030年までに1.5度以上の気温上昇を示唆
- 極端な森林火災危険指数（FFDI）の日数は、1960年から10倍に増加

Climate Change Increases the Risk of Wildfires

気候変動によって山火事リスクが増加

Matthew W. Jones [1], Adam Smith [1], Richard Betts [2,3], Josep G. Canadell [4], I. Colin Prentice [5], and Corinne Le Quéré [1]

[1] Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia (UEA) [2] Met Office Hadley Centre, Exeter [3] College of Life and Environmental Sciences, University of Exeter [4] CSIRO Oceans and Atmosphere, G.P.O. Box 1700, Canberra, ACT 2601, Australia [5] Department of Life Sciences and Leverhulme Centre for Wildfires, Environment and Society, Imperial College, London

Approach. We undertook a Rapid Response Review on the link between climate change and fire risk. 57 scientific articles were gathered and evaluated using ScienceBrief. This document synthesises the key points that emerged from the findings. Our review focuses on papers published since the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), with its cutoff date of March 2013. The papers can be viewed on https://sciencebrief. org/topics/climate-change-science/wildfires. All papers show linkages between climate change and increased frequency or severity of fire weather, though some note anomalies in isolated regions. None of the papers support a widespread decrease in fire risk.

Summary. Human-induced climate change promotes the conditions on which wildfires depend, enhancing their likelihood and challenging suppression efforts. Human-induced warming has already led to a global increase in the frequency and severity of fire weather, increasing the risks of wildfire. This signal has emerged from natural variability in many regions, including the

Quarrie Photography

BEFORE THE FIRE
火災前

Old forests at the time of the fire
老齢林に火災が発生した場合

- **Fire is lower in severity**
- **Animals more likely to persist**
- **Recolonization is earlier**
- **Recovery faster (e.g. seed germination)**
- 火災の深刻度が低い
- 動物が生き残りやすい
- 再びコロニーを作る時期が早い
- 回復が早い（種子の発芽など）

Taylor et al., 2014, Smith et al., 2016, Lindenmayer et al., 2019

Young forest at the time of fire
幼齢林に火災が発生した場合

Fire is more severe
Fewer biological legacies
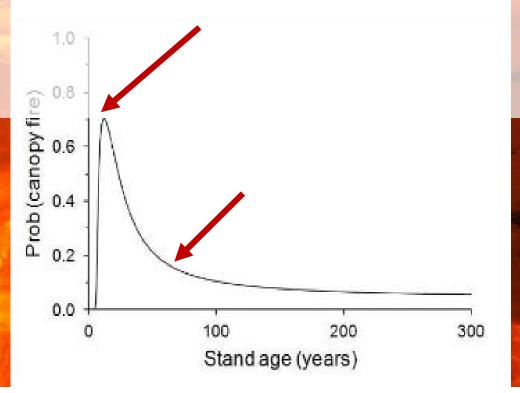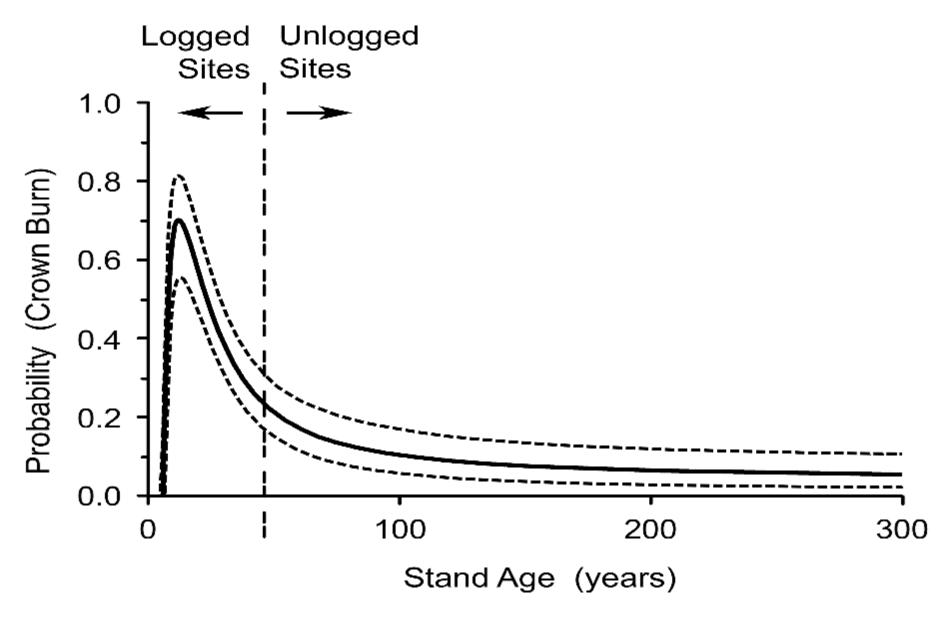**Species recovery slower**
火災がより深刻である
生物学的遺産がより少ない
種の回復がより遅い

Lindenmayer et al., 2017, Nature Ecol & Evol., 2019 Forest Ecol. & Manage

DURING THE FIRE 火災時 (Logging & fire)（伐採と火災）

Lindenmayer et al., 2009, 2020, 2022; Taylor et al. 2014. Conservation Letters, 7, 355-70

Highest fire severity at intermediate forest age
Age-related flammability many studies in many places
壮齢林の火災が最も深刻
樹齢に関連した燃焼性について、多くの場所で多くの研究がなされている

Taylor et al. 2014. Conservation Letters, 7, 355-70
Attiwill et al., 2014
Zald and Dunn 2017
Tirribilli et al. 2017
Taylor et al., 2020
Lindenmayer et al., 2021
Zlystra et al., 2021

Lindenmayer et al. (2022) – in Runge et al. Edited Book

Recent Australian wildfires made worse by logging and associated forest management

The recent fires in southern Australia were unprecedented in scale and severity. Much commentary has rightly focused on the role of climate change in exacerbating the risk of fire. Here, we contend that policy makers must recognize that historical and contemporary logging of forests has had profound effects on these fires' severity and frequency.

David B. Lindenmayer, Robert M. Kooyman, Chris Taylor, Michelle Ward and James E. M. Watson

最近のオーストラリアの山火事
伐採とそれに伴う森林管理によって悪化

More than 5.8 million hectares of Australia burned between September 2019 and January 2020[1], with several million more hectares burned in subsequent months. Discussions among land managers, politicians, policy makers and scientists have now focused on the origins and behaviour of the wildfires to try to ensure they do not happen again. Not unreasonably, much of this discussion has centred around the role of human-forced climate change[2], and the associated prolonged drought and extreme weather conditions as major drivers of these recent conflagrations. It is clear that discussions about links between climate change and fire are warranted and should galvanize action to halt climate change[3].

However, the contribution of land management, and especially forestry practices, to wildfires has often been neglected in these discussions. This is an oversight given that land management is well within the control of Australians (unlike global action to abate climate change) and that there is an extensive body of science available to decision-makers. Some parts of the forest industry are now calling for increased logging within both the burnt and unburnt forest estates[4]. Here we provide a summary of recent scientific evidence of the impacts of forestry on these fires and discuss strategies to limit future catastrophic conflagrations.

Forest logging and fire

Since European settlement, Australian forests have had a long history of land-use change. While the full extent of forest loss and degradation is unknown, some estimates show that at least 30% of eucalypt open forest and 30% of rainforest have been lost due to logging and agriculture[5]. Most of this loss occurred in the latter half of the nineteenth century. More recently, industry reports show that between 1996 and 2018, 161 million cubic metres of native forest was logged
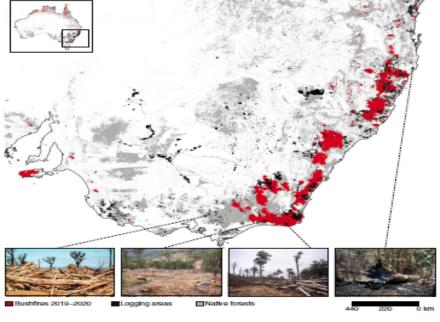

Fig. 1 | Fires within logged areas of native forests. Southeast Australian fires (red) within native forests (grey) and previously logged areas ('logging areas'; black). The first image (left to right) is of the debris remaining after logging in eucalypt forests in central Victoria, the second and third images are of the aftermath of logging in East Gippsland, and the fourth image is of burned Brush Box (*Lophostemon confertus*) within the world heritage Gondwana Rainforest (an ecosystem that has evolved in the complete absence of fire). Logging areas are derived from publicly available data from Forestry Corporation of NSW and VicForests, both of which underestimate the full extent of historic logging. Credit: images 1–3 by C. Taylor; image 4 by R. M. Kooyman

Legend: ■ Bushfires 2019–2020 ■ Logging areas ▨ Native forests 440 220 0 km

by the forestry industry across Australia[6]. Logging operations have had severe impacts on biodiversity; 181 forest-dependent species listed as threatened with extinction are directly affected by loss of habitat specifically due to logging[7]. However, this figure is an

Nothing unusual here
特に変わったことではない

Seen in wet forests globally
世界各地の湿潤林で見られる

Confirmed in new work (Lindenmayer et al. 2021)
新しい研究で確認済（Lindenmayer et al.2021）

Lindenmayer et al. (2009). Conservation Letters, 2, 271-277   Lindenmayer et al. (2021) Ecosphere.

オーストラリア南東部における火災の深刻度に影響を及ぼす要因の実証的分析

Empirical analyses of the factors influencing fire severity in southeastern Australia
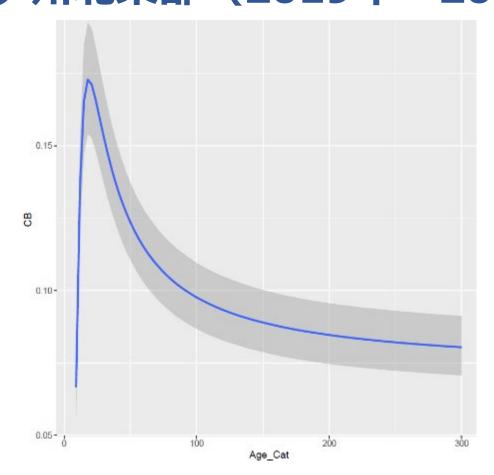
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Abstract. Fire severity is a key component of fire regimes, and understanding the factors affecting it is critical given the increasing incidence of wildfires globally. We quantified the factors affecting the severity of the 2019–2020 fires in Victoria, southeastern Australia. We constructed statistical models of relationships between fire severity (as reflected by two measures: Crown Burn and the composite measure of Crown Burn/Crown Scorch) and the main and interacting effects of five key covariates: fire progression zone (reflecting fire weather), time since previous major disturbance in the forest, forest type, slope, and aspect. The best supported models for the probability of a Crown Burn and the probability of a Crown Burn/ Crown Scorch contained evidence of a three-way interaction between fire weather, forest type, and time since previous major disturbance as well as two-way interactions between (1) fire weather and slope, and (2) fire weather and aspect. There was an increase in the probability of Crown Burn and Crown Burn/ Crown Scorch under more extreme fire weather in all forest types, with the effect especially elevated in dry

Fire severity related to Stand Age
樹齢に関連する火災の深刻度
North-east Victoria (2019-2020)
ビクトリア州北東部（2019年〜2020年）

Check for updates

Logging elevated the probability of high-severity fire in the 2019–20 Australian forest fires

David B. Lindenmayer [1✉], Phil Zylstra [2], Robert Kooyman [3], Chris Taylor[1], Michelle Ward[4] and James E. M. Watson [4]

In their recent article, D. Bowman et al.[1] analysed the severity of the 2019–20 Australian eucalypt forest fires. Their findings are consistent with those of our original article[2], that fires are more severe where logging operations take place. Indeed, their Fig. 3 (ref. [1]) showed that for a given Forest Fire Danger Index (FFDI), logged forests always burned with a higher probability of canopy damage than undisturbed forest (Fig. 1 in this article). Thus, they have demonstrated that logging increased the probability of canopy damage by 5–20% (Fig. 1). In general, the likelihood of canopy damage was similar for logged forests under the mildest conditions as they were for undisturbed forests under high and very high fire danger conditions (Fig. 1). In summary, data from ref. [1] indicate that fire weather had the greatest influence on fire severity over the broader landscape but such effects were amplified by management effects (namely, logging) where these occurred.

Beyond the work by Bowman et al.[1] empirically confirming our original conclusions that logging contributes to fire severity[2], we believe there are some substantial problems in their study that warrant further discussion.

Inappropriate combination of crown fire and canopy damage

Bowman et al.[1] examined canopy damage (sometimes termed crown scorch) rather than crown fire. For the purposes of their paper and this discussion, we believe that distinguishing between these categories of impact is crucial to quantifying relationships between logging and fire severity. Crown scorch affects foliage 8–16 times higher than the flames[3], so that scorch heights of 20–25 m have been recorded from low intensity (200–500 kW m^{-2}) prescribed burns[3]. These scorch heights exceed the canopy height of many dry sclerophyll forests[4] but resulted from flame heights small enough (≤2 m) to be controllable using the most direct and effective means[5,6]. In contrast, crown fires are the most severe and uncontrollable kind of fire behaviour in which entire trees are burning[7], representing flame heights 8–16 times those in the crown scorch category.

Substantial research[8–12] demonstrates that crown fire is far less likely in older and unlogged forests. In logged forests, including

conditions[9,11]. The likelihood of crown fire then declines as forests further mature[13]. For example, a previous study[11] showed that in the 2009 fires in Central Victoria, crown fire was seven times more likely in young Mountain Ash regrowth forest (much of which was logged and subsequently regenerated) compared to unlogged old-growth forest.

In contrast to the strong trends quantified for crown fire in the broader scientific literature (for example, refs. [9,11]), there are weaker trends for canopy damage (which is a composite category of both canopy fire and canopy scorch)[8,9,11]. However, despite the problems in their overall methodology, the data presented in Bowman et al.[1] still show a significant relationship between logging and the probability of canopy damage (Fig. 1).

Logging and lag effects on flammability

A second problem in Bowman et al.[1] is their argument that the rate of native forest logging has declined in eastern mainland Australia and by implication was of limited importance relative to other factors. This ignores long-term lag effects on fire severity resulting from widespread past logging[11]. It also ignores the fact that current logging is concentrated within particular forest types which are often of high value for threatened forest-dependent species[14]. For example, 65% of clearcutting has occurred in wet and damp forest types across Victoria. The impacts of increased fire severity due to past logging can be significant for those localized areas and particular forest types.

Fire severity and plantations

Bowman et al.[1] argue that plantations are at risk of high-severity wildfire. This effect is unsurprising as trees in plantations are typically young (and usually harvested before they reach 25 years old). This places them within an age cohort where they are highly flammable and at risk of high-severity fire. In addition, they state that non-native conifer plantations in New South Wales suffered a greater proportion of area sustaining severe canopy damage (70%), compared with *Eucalyptus* plantations and native forests, where the proportion was similar (51% and 52%, respectively). Plantations

a) Victoria   b) South NSW   c) North NSW

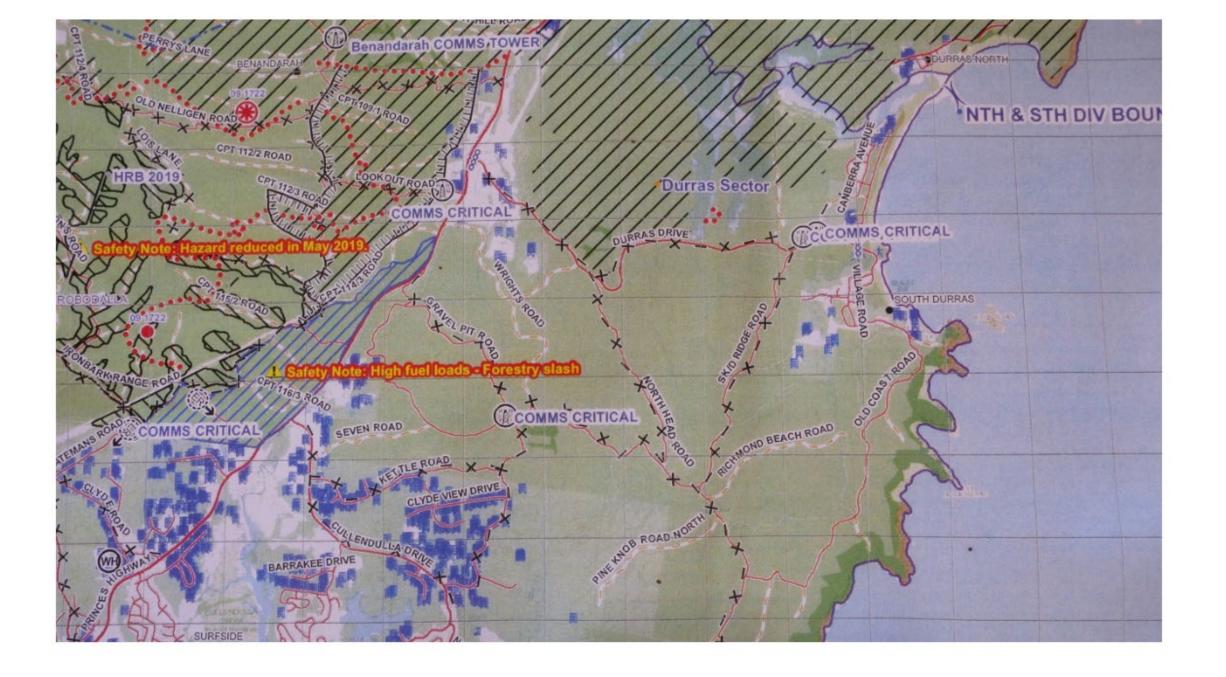*Lindenmayer et al., 2022 – Nature Ecology & Evolution*

SUMMARY まとめ

- Logged forest ALWAYS burns at greater severity than intact forest

- Logged forest burns at greater severity under moderate conditions than intact forest under extreme conditions

- 手付かずの森林よりも、伐採された森林における火災の方が、常に深刻である

- 極端な条件下の手付かずの森林よりも、穏やかな条件下の伐採された森林の方が、より深刻に燃焼する

Lindenmayer et al., 2022 – Nature Ecology and Evolution

Why does this occur?
なぜそうなるのか？

- **Extra logging debris**
- **Dries ground layer (96% less tree ferns)**
- **Dries the soil**
- **Changed forest architecture**
- **More flammable young plants**
- **New work = altered microclimate (Lindenmayer et al. 2022, Forest Ecology & Management)**
- **Forest logged tomorrow = >fire severity to ~2062**

- 余分な伐採残渣
- 地層を乾燥させる（木生シダが96％減少）
- 土壌を乾燥させる
- 森林構造を変化させる
- 燃えやすい若木が増加
- 新たな研究＝変容した微気候（Lindenmayer et al.2022, Forest Ecology & Management）
- 明日伐採される森林＝火災の深刻度は〜2062年まで増加

Taylor et al. 2014. Conservation Letters, Bowd et al. 2019 Nature Geoscience

© Chris Taylor

森林微気候における林齢に関連する差異

Stand age related differences in forest microclimate

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ABSTRACT

Quantifying spatio-temporal variation in forest microclimate is important to understand the habitat associations of some species, identify potential refugia, and manage forests in a changing climate. We quantified relationships between microclimatic conditions and stand age using a detailed case study of the Mountain Ash (*Eucalyptus regnans*) forests in south-eastern Australia. We deployed sensor buttons to capture data on day-time and night-time seasonal (Julian Day) temperature profiles in even-aged stands that were 12-years-old, 30–40-years-old, ~82–95-years-old, and 200+ -years-old. We constructed Bayesian generalised linear models (GLMs) to quantify the main and interacting effects of stand age and topographic factors and foliage cover on seasonal profiles for: median, maximum and variability in day-time and night-time temperature.

The most parsimonious model for median day-time temperature included a main effect of midstory and overstory cover, both of which were inversely related to median day-time temperature. The most parsimonious model for median night-time temperature measures included an additive effect of forest age and seasonality. Temperatures for the youngest forests (that were 12-years-old) were different from other age classes and were characterised by the lowest median and minimum night-time temperatures.

The most parsimonious model for day-time maximum temperature and day-time interquartile range included an interaction between forest age and Julian day. Day-time maximum temperatures were warmest in 12-year-old forest. The coolest maximum day-time temperatures in summer were generally in old growth stands (200+ -year-old). The greatest variability in maximum day-time temperatures was in 12-year-old forest whereas, in general, old growth stands experienced the least variable day-time temperatures. Our sensor data also showed that old growth forests were characterised by fewer days above 30, 35 and 40 degrees than 12-year old forest. Our empirical data contain compelling evidence that the youngest forests were characterised by the hottest day-time temperatures, the coldest night-time temperatures, and the most variable day-time and night-time temperature regimes. Age class differences in stand structure (e.g. canopy height, prevalence of large old trees and dense wet understorey) may explain stand age related seasonal differences in local microclimatic conditions.
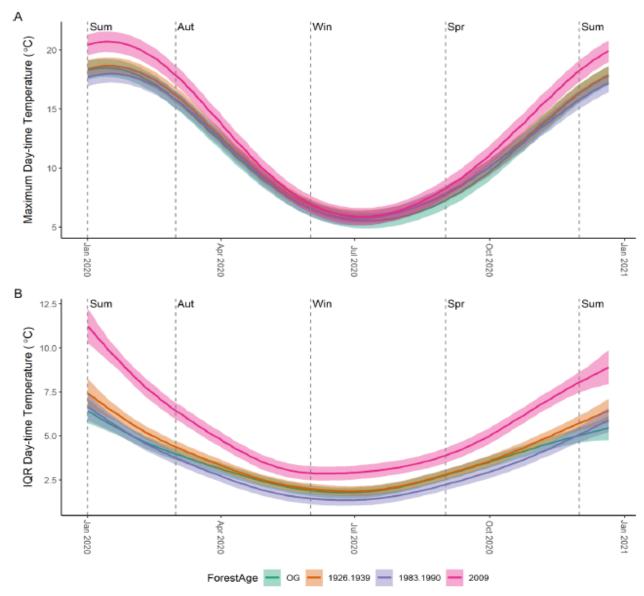
1. Introduction

2019; De Frenne et al., 2021) ranging from birds (Betts et al., 2018) to ants (Boyle et al., 2021).

Fig. 4. Interaction between Julian day (seasonality) and forest age for: (a) maximum day-time temperature and (b) interquartile range of temperature. The other continuous variables in the most parsimonious models have been held at their mean values. We show posterior median estimates, and their associated 95% credible intervals are given by the shaded regions. Vertical dashed lines indicate seasons (Sum = summer, Aut = autumn, Win = winter and Spr = spring).

Will thinning help reduce fire severity?
間伐は火災の深刻さを軽減するのに役立つか？

Analysis after 2009 fire

Analysis after 2019-20 fire

2009年の火災後の分析

2019年～20年の火災後の分析
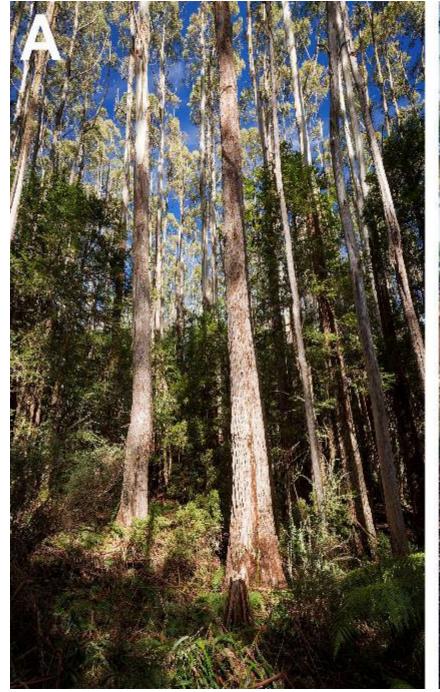
ANSWER
- Generally no
- Some cases thinning = greater high severity fire
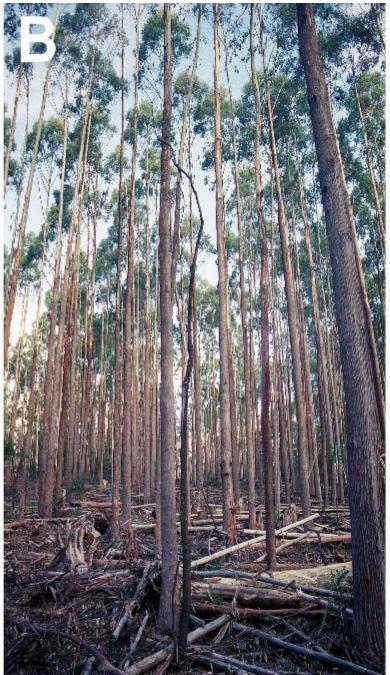
回答
- 一般的には役立たない
- 間伐が火災の深刻度を高める場合もある

Taylor et al. 2020 (*Cons. Letters*); Taylor et al. 2021 (*Austral Ecol*)

AFTER THE FIRE
火災後

New spatial analyses of Australian wildfires highlight the need for new fire, resource, and conservation policies

David B. Lindenmayer[a,1,2] (ID) and Chris Taylor[a,1]

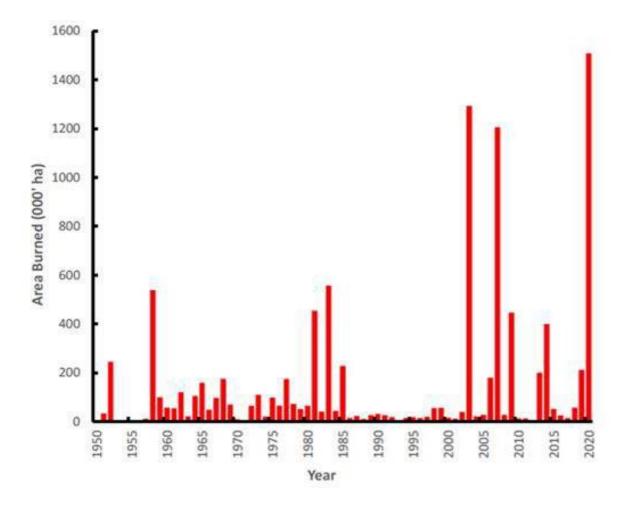[a]Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia

Extensive and recurrent severe wildfires present complex challenges for policy makers. This is highlighted by extensive wildfires around the globe, ranging from western North America and Europe to the Amazon and Arctic, and, most recently, the 2019–2020 fires in eastern Australia. In many jurisdictions, discussions after significant losses of life, property, and vegetation are sometimes conducted in the absence of nuanced debates about key aspects of climate, land, and resource management policy. Improved insights that have significant implications for policies and management can be derived from spatial and temporal analyses of fires. Here, we demonstrate the importance of such analyses using a case study of large-scale, recurrent severe wildfires over the past two decades in the Australian state of Victoria. We overlaid the location of current and past fires with ecosystem types, land use, and conservation values. Our analyses revealed 1) the large spatial extent of current fires, 2) the extensive and frequent reburning of recently and previously fire-damaged areas, 3) the magnitude of resource loss for industries such as timber and pulplog production, and 4) major impacts on
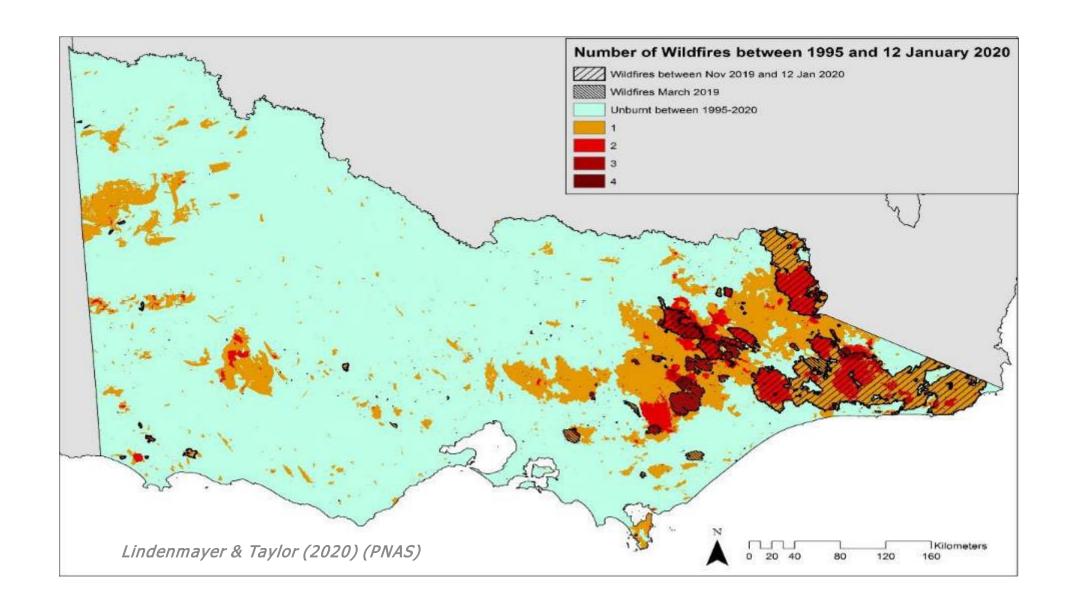
but also recurrent fires for the 23 million-hectare state of Victoria, with a particular focus on forests. The majority of native forest across Victoria is under public ownership and managed by government for either wood production or as conservation reserves. The state is characterized by a wide range of ecosystem types and high levels of biodiversity in many of these ecosystems (8). We completed simple but detailed spatial and temporal analyses that intersected the location and perimeter of current and past fires with ecosystem types, land use, and conservation values. Our analysis revealed pronounced impacts on particular ecosystem types, areas of high conservation value, and the use of resources for industry. These findings, in turn, underscore an urgent need for new policies and approaches to land management that we outline later in this paper.

Results

Across Victoria, wildfires burned ~1.5 million hectares during

Number of Wildfires between 1995 and 12 January 2020

- Wildfires between Nov 2019 and 12 Jan 2020
- Wildfires March 2019
- Unburnt between 1995-2020
- 1
- 2
- 3
- 4

Lindenmayer & Taylor (2020) (PNAS)

Recurrent fire = 77% loss of old growth since 1995

頻発する火災＝1995年以降、老齢林の77％が消失

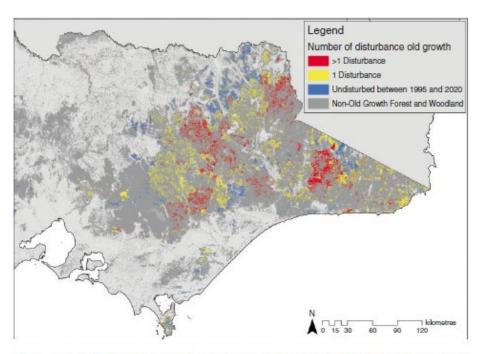Enhanced old growth conservation

Pacific Conservation Biology

Legend
Number of disturbance old growth
- >1 Disturbance
- 1 Disturbance
- Undisturbed between 1995 and 2020
- Non-Old Growth Forest and Woodland

Fig. 3. Disturbance by wildfire, logging or a combination of both in Modelled Old Growth Forest and Woodland between 1995 and 2020.

Lindenmayer and Taylor, Pac. Cons Bio. 2020

Old forest cover 老齢林による被覆

- **1871 ha of 171 200 ha = Mtn Ash unlogged and unburned = 1.16% (was historically 30-60%)**

- **Distributed among 147 patches**

- **Alpine Ash = 0.47% old growth**

- 17万1200ha のうち1871ha
- ＝未伐採・未燃焼の マウンテンアッシュ林
- ＝1.16%（歴史的には30〜60%）

- 147区画に分散

- ユーカリ・デレガテンシス
- ＝0.47%が老齢林

Key summary points 主なまとめポイント

- Significant increase in amt forest burning

- Some areas burning 3-4 times in 25 years

- ~ 60% of areas planned for logging in East Gippsland in next 5 years burnt in 2019-2020

- ~ 30% of everything planned for logging in Victoria burnt in 2019-2020

- Fire is beating forestry for access to trees

- 森林火災の発生件数が大幅に増加

- 25年間に3～4回燃えた地域もある

- 今後5年間にイーストギップスランドで伐採が計画されている地域の～60%では、2019年から2020年にかけて火災が発生している。

- ビクトリア州の伐採予定地の～30%では、2019年から2020年にかけて火災が発生している。

- 林業よりも火災の方が、木々にアクセスしている。

Lindenmayer & Taylor (2020) (PNAS)   *Cary et al. 2021. Int J. Wildl. Fire*

SOME ECOSYSTEMS AT RISK OF COLLAPSE
一部の生態系は崩壊の危機にある

Global Change Biology | WILEY

OPINION

Combating ecosystem collapse from the tropics to the Antarctic
熱帯から南極まで 生態系の崩壊と闘う

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社会生態学的な森林生態系において、隠れた崩壊が火災と伐採によって引き起こされている

Hidden collapse is driven by fire and logging in a socioecological forest ecosystem

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Increasing numbers of ecosystems globally are at risk of collapse. However, most descriptions of terrestrial ecosystem collapse are post hoc with few empirically based examples of ecosystems in the process of collapse. This limits learning about collapse and impedes development of effective early-warning indicators. Based on multidecadal and multifaceted monitoring, we present evidence that the Australian mainland Mountain Ash ecosystem is collapsing. Collapse is indicated by marked changes in ecosystem condition, particularly the rapid decline in populations of keystone

Here, we use data from a series of multifaceted, long-term empirical studies to describe the process of collapse in the Mountain Ash (*Eucalyptus regnans*) forests of southeastern Australia (Fig. S1) (9–11). This ecosystem supports the tallest flowering plants on Earth with large, old trees approaching 100 m in height (12). The Mountain Ash ecosystem provides habitat for species-rich animal and plant assemblages (including critically endangered taxa), generates most of the water for the ~4.5 million people in Melbourne, stores large amounts of biomass

34

気候変動によって、火災時の退避地はより予測しにくくなったのか？

Are fire refugia less predictable due to climate change?

Brendan Mackey[1,*] , David Lindenmayer[2], Patrick Norman[1], Chris Taylor[2] and Susan Gould[1]

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Abstract

Fire refugia—unburnt habitat within a wildfire's perimeter—play a key role in wildlife persistence and recovery. While studies have shown that the location of refugia is influenced by local topographic factors, growing evidence points to extreme fire weather becoming the dominant factor driving high-severity wildfires that result in the location of fire refugia being less predictable. Between September 2019 and February 2020, a series of mega-fires in eastern Australia burned largely in broadleaf forest. We assessed burned and unburned areas of forest in eastern Australia using Sentinel-2 satellite data, aggregated monthly over the fire season to calculate a fire severity layer at a 20 m pixel resolution. We found that fires burned 5.7×10^6 ha^{-1} of forest and woodland. The total percentage area of unburned forest within the wildfire footprint was approximately 10%. The majority (94%) of the unburnt forest and woodland patches within the fire perimeter occurred as patches <1 ha ($n = 842\,622$ and $111\,707$ ha) with far fewer large unburnt patches (>100 ha) ($n = 575$ and $286\,080$ ha). Boosted regression tree analyses of the relationships between

Fire refugia 火災時の退避地

- Extensive burnt forest in 2019-2020

- 10% unburnt within total fire footprint

- 94% unburnt areas are patches < 1 ha

- Forest refugia need to be spared from extra disturbance (not logged)

- 2019年から2020年の大規模な焼失林

- 総火災面積のうち10%が未燃焼

- 未燃焼地域の94%は1ha未満の区画

- 森林の退避地は、余分な撹乱から免れている（伐採されていない）必要がある

Mackey et al. 2022, Env Research Letters

Look at spatial conflict between logging and biodiversity
伐採と生物多様性の空間的な対立に注目

- Top 10% of priority areas for 70 threatened species in Victoria are in coupes targeted for logging under Timber Release Plan

- VicForests legal counsel

- ビクトリア州では、絶滅危惧種70種のための優先地域の上位10％が、木材譲渡計画の下で伐採の対象となった林区に所在
- ビックフォレスツ社の法律顧問

These habitat distribution models (HDMs) use the modelling of a range of environmental variables to rank the relative likelihood of species' occurrence on a scale of 1 (low) to 99 (high). Mr Paul deposes that these HDMs, despite some limitations, are the most useful data available to the defendant absent individual field surveys in each coupe. Taking the greater glider as an example, nearly all of the coupes marked as theoretically available for harvesting contain a likelihood score of at least 32.0–49.3, and the vast majority of the coupes contain habitat modelled with a likelihood score of 49.3–93.

30   As an aside, the Court was not directed in submissions to the specific likelihood scores in the subject coupes. However, given the plaintiff's evidence of actual sightings of at least one of the three species in each of the subject coupes, such information would be of little assistance.

31   Based on his review of the HDM maps, Mr Paul deposes that if the defendant were restrained from harvesting in coupes likely (meaning a score of at least 49.3) to contain at least one of the three species, or their habitat, it would shut down all of the defendant's operations in the Central Highlands.

SC:TMS   7   JUDGMENT

大半の林区には、尤度（ゆうど）スコア49.3-93でモデル化された生息地が含まれている。

The adequacy of Victoria's protected areas for conserving its forest-dependent fauna

森林に生息する動物相の保全における
ビクトリア州の保護区の適切さについて

CHRIS TAYLOR[1] AND DAVID B. LINDENMAYER[*1,2]

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Abstract Networks of protected areas are a key component of efforts to conserve biodiversity. However, there are concerns about an uncritical focus on the percentage area of reserves without an assessment of how well formal reserves are actually protecting biodiversity. In response, we completed a spatial analysis of the formal reserve system in the Australian state of Victoria. We quantified how well the reserve system captured a crude surrogate for vegetation communities (viz: Ecological Vegetation Classes) as well as distribution models for an array of threatened forest-dependent species. We found evidence of a high degree of overlap between areas subject to intensive forestry (clearcutting) operations and the modelled distribution of a suite of forest-dependent species. A key outcome of our study was that areas around sites subject to past logging as well as new areas proposed for logging under the Timber Release Plan in Victoria had significantly higher values for threatened forest-dependent species (as determined by habitat distribution models) than areas that had not been logged. We found significant differences in the spatial characteristics of the dedicated reserve systems and informal protected area networks, with the latter featuring much of its area close to a tenure boundary where logging occurs. Our empirical analyses demonstrating the impacts of ongoing logging operations on areas with high environmental suitability for threatened species have important implications. In particular, the current reserve system is inadequate for a suite of forest-dependent taxa, including critically endangered Leadbeater's Possum *(Gymnobelideus leadbeateri)*

Post-fire logging impacts
伐採の影響（火災後）

DAVID B. LINDENMAYER,
PHILIP J. BURTON, AND JERRY F. FRANKLIN

サルベージ伐採とその生態系への影響

SALVAGE LOGGING
AND
ITS ECOLOGICAL
CONSEQUENCES

火災の深刻度が4と評価されたトゥーランギの森林における火災後の伐採

Toolangi, post-fire logging in forests with a fire severity rating 4

Post-fire logging 火災後の伐採

- Removes almost all large old trees
- Sets back new habitat ~ 100-200 years
- Alters vegetation composition – especially resprouters
- Damages soils for up to 80+ years
- Large reductions in water yields
- Major negative impacts on birds, plants, invertebrates
- Elevates medium fire risk
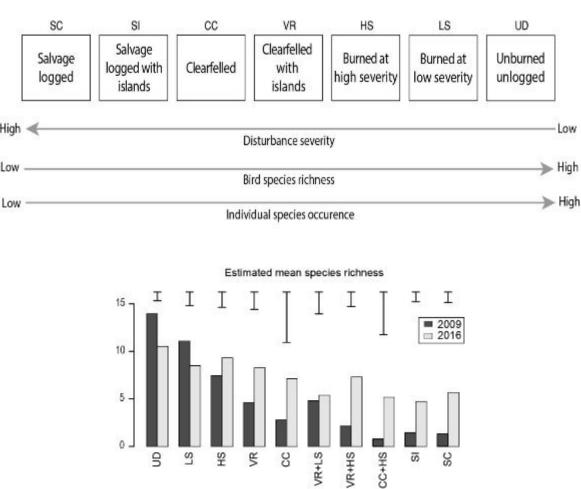
- 大きな老木をほぼすべて撤去
- 新しい生息地を100年から200年も後退させる
- 特に火災後に再発芽する植物に関して、植生組成を変化させる
- 最大80年以上にわたって土壌を損傷する
- 産出水を大幅に減少させる
- 鳥類、植物、無脊椎動物に大きな悪影響を与える
- 中程度の火災リスクを増加させる

Lindenmayer et al. 2006, 2008, 2017, 2018, 2019, Bowd et al., 2018, 2019, 2021, Blair et al. 2016

Disturbance gradient effects on birds
鳥類に対する撹乱勾配効果
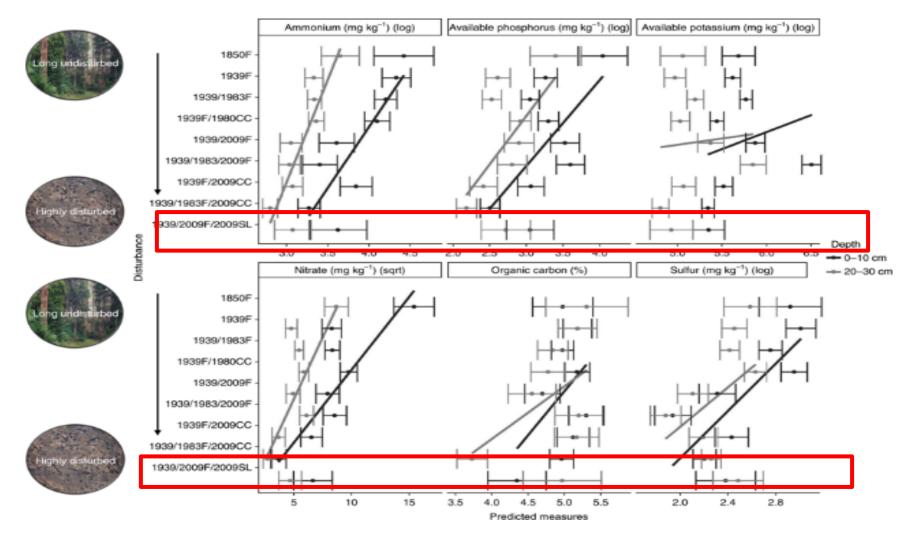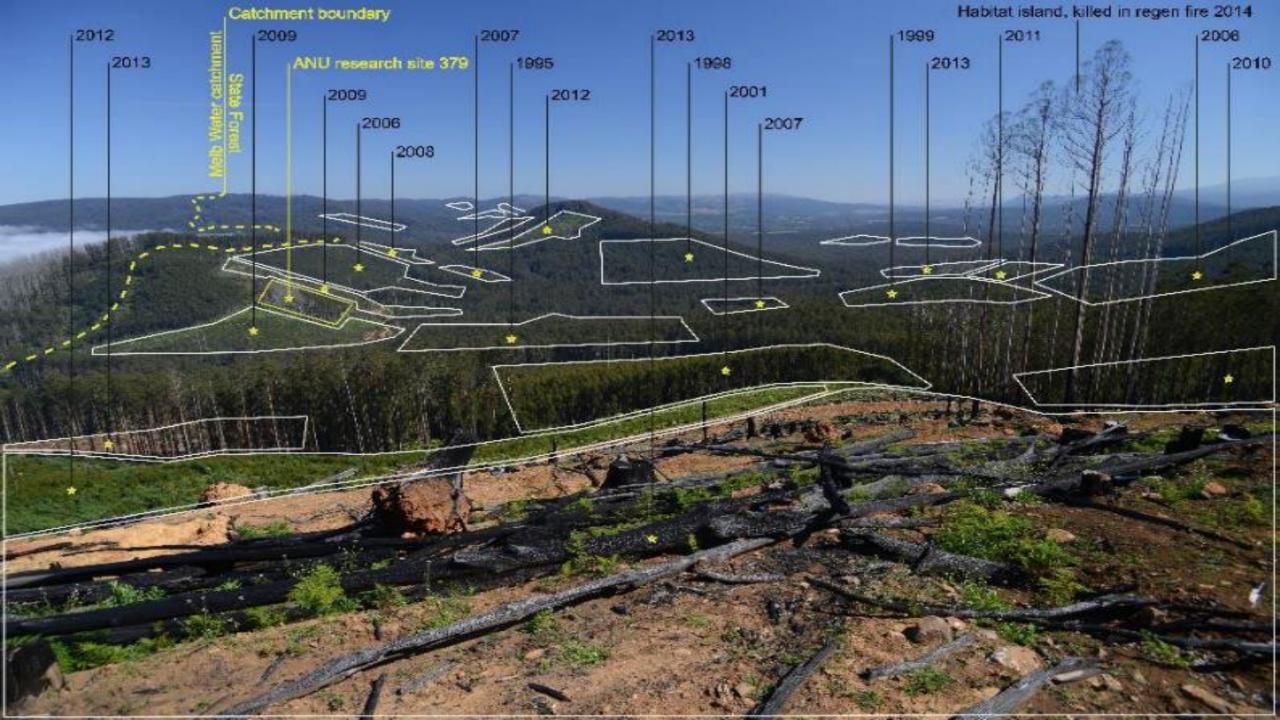

Lindenmayer et al 2018 *J. Appl Ecol* 55 1626-36.

Bowd et al. (2019) *Nature Geoscience, https://doi.org/10.1038/s41561-018-0294-2*

BEFORE AND AFTER THE FIRE (INTERACTION)
火災前と火災後（相互作用）

Fire = main natural disturbance
火災＝主な自然攪乱

Mean interval ~ 75-150 years*

平均的な間隔 ～ 75年～150 年*

5 major fires in <100 years

(More mega-fires > 1m ha)

100年以内に5回の大火災

(100万haを超える大規模火災の増加）

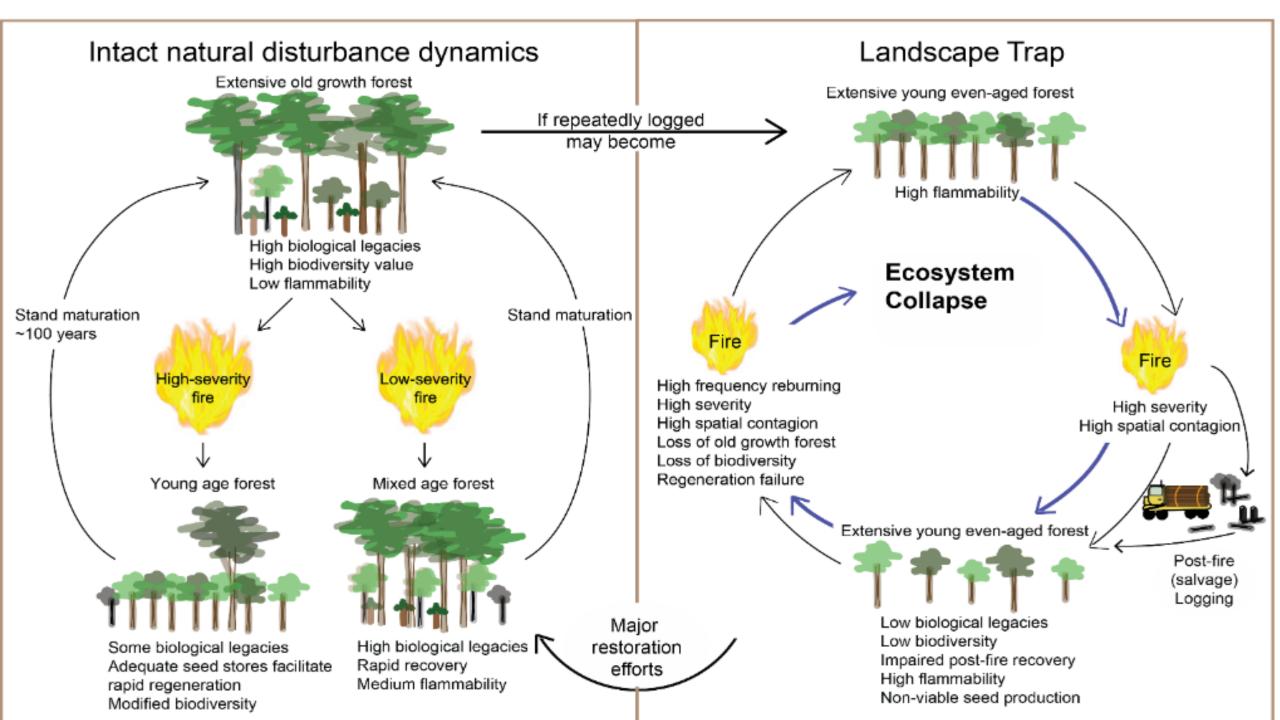*McCarthy, et al. (1999). Forest Ecology & Management, 124, 193-203.

Catchment boundary

Habitat island, killed in regen fire 2014

2012

2013

Melb Water catchment

State Forest

2009

ANU research site 379

2009

2006

2008

2007

1995

2012

2013

1998

2001

2007

1999

2013

2011

2006

2010

LANDSCAPE TRAPS

Widespread logging = young forest = increased fire risk

Repeated fire – fire burns young forest & keeps it young thru re-burning

Lindenmayer et al. (2011). Newly discovered landscape traps *PNAS*, 108, 15887-91

Intact natural disturbance dynamics

Extensive old growth forest

High biological legacies
High biodiversity value
Low flammability

Stand maturation ~100 years

Stand maturation

High-severity fire

Low-severity fire

Young age forest

Mixed age forest

Some biological legacies
Adequate seed stores facilitate rapid regeneration
Modified biodiversity

High biological legacies
Rapid recovery
Medium flammability

Landscape Trap

Extensive young even-aged forest

High flammability

Ecosystem Collapse

Fire

High frequency reburning
High severity
High spatial contagion
Loss of old growth forest
Loss of biodiversity
Regeneration failure

Fire

High severity
High spatial contagion

Post-fire (salvage) Logging

Extensive young even-aged forest

Low biological legacies
Low biodiversity
Impaired post-fire recovery
High flammability
Non-viable seed production

If repeatedly logged may become

Major restoration efforts

火災、伐採、気候変動の相互作用により
ビクトリア州のユーカリ林に地勢上の罠が生まれた

The interactions among fire, logging, and climate change have sprung a landscape trap in Victoria's montane ash forests
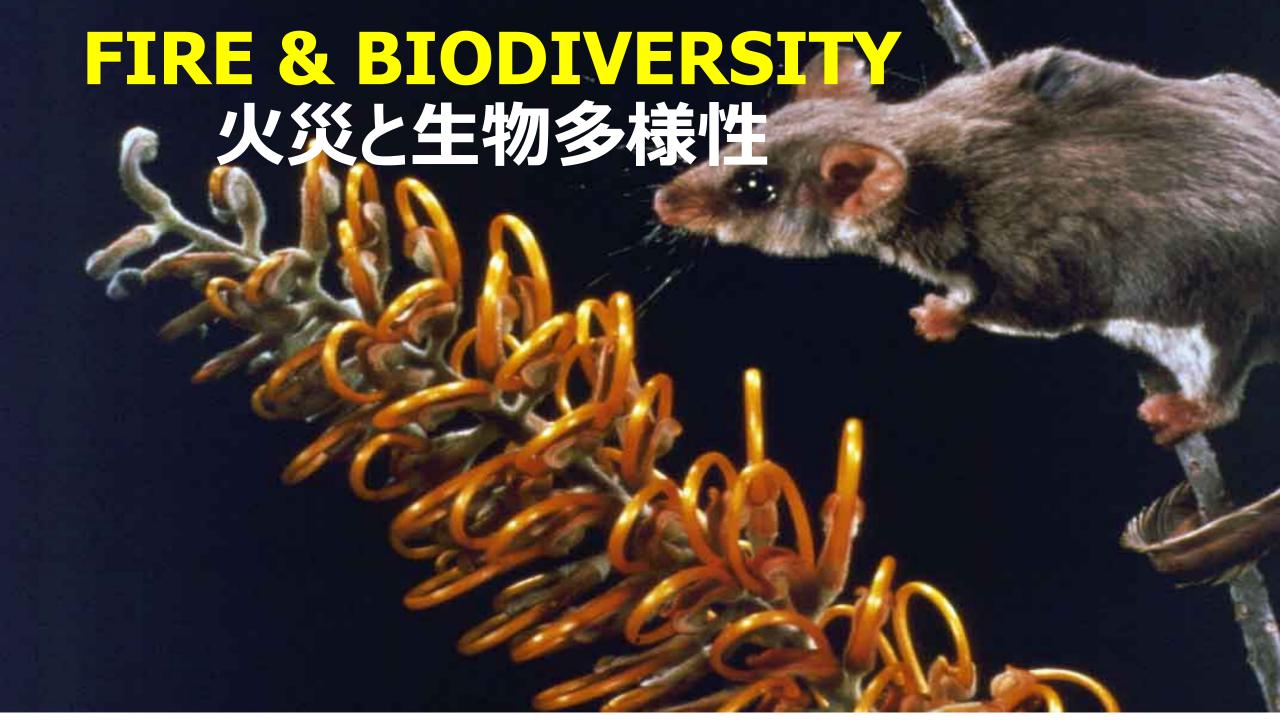
David B. Lindenmayer ⓘ · Elle J. Bowd ⓘ · Chris Taylor ⓘ · Gene E. Likens

Abstract Ecosystems are influenced by multiple drivers, which shape ecosystem state and biodiversity. In some ecosystems, interactions and feedbacks among drivers can produce traps that confine an ecosystem to a particular state or condition and influence processes like succession. A range of traps has been recognized, with one of these – "a landscape trap" first proposed a decade ago for the tall, wet Mountain Ash and Alpine Ash forests of Victoria. wildfire and widespread clearcutting have transformed historical patterns of forest cover from widespread old-growth with small patches of regrowth embedded within it, to the reverse. Indeed, approximately 99% of the montane ash ecosystem is now relatively young forest. Based on new empirical insights, we argue that at least three key inter-related pre-conditions underpin the development of a landscape trap in montane ash forests. A landscape trap has been sprung in these

FIRE & BIODIVERSITY
火災と生物多様性

Some persist
生き残るものもいる

Mountain Brushtail Possum
マウンテンブラシテールポッサム
Kuiter

Some colonize quickly
すぐにコロニーを作るものもいる

Lindenmayer et al. 2014. Diversity & Distributions, 20, 467-477.
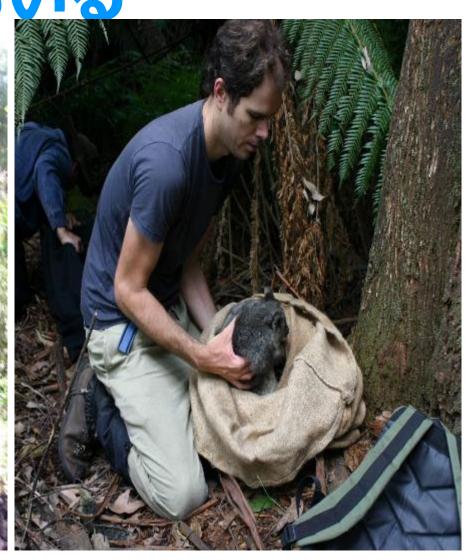
Others lost or continue to decline <u>long</u> after wildfire
他は全滅したり、山火事後も<u>長くにわたり</u>減少し続ける
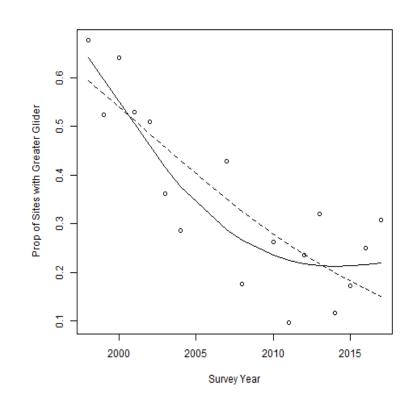
Steep decline – 64% of sites in 1997 to ~18% of sites in 2018/19
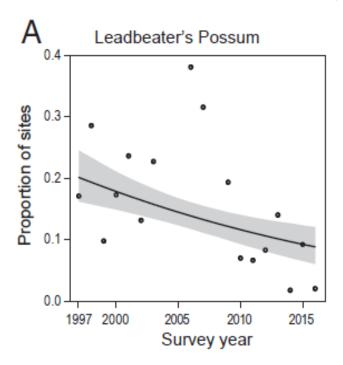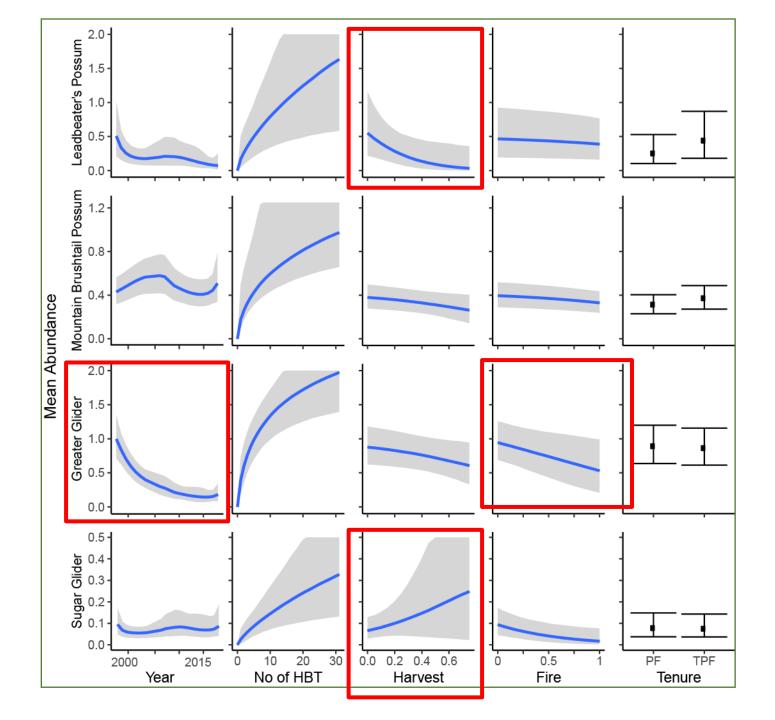## 急減 - 1997年の64%の場所が、2018/19年には～18%の場所に

Lindenmayer & Sato 2018 PNAS,   Lindenmayer et al. 2019 (Australian Zoologist)

Decline in Leadbeater's Possum
フクロモンガダマシの減少

- Site occupancy halved since 1997
- 1997年以降、場所の占有率が半減
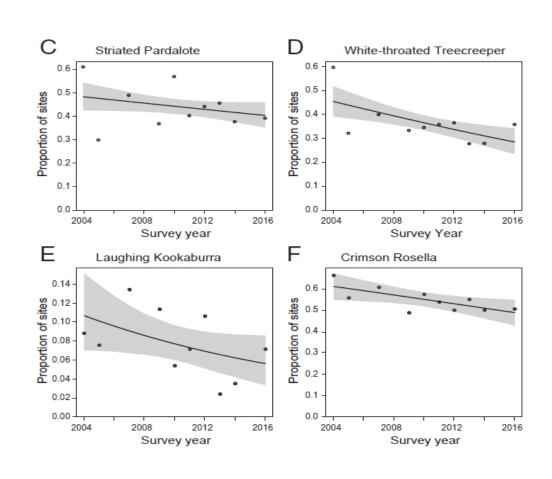
A — Leadbeater's Possum

Many (> 40%) forest birds are declining
森林の鳥類の多く（40%以上）が減少

Summary まとめ

- Possums, gliders and birds are declining

- Logging in the landscape is a driver of decline (fire is another)

- Birds = strongly linked to Old Growth

- Logging under TRP is occurring in forests of high value for threatened species (Taylor + Lindenmayer 2019)

- Logging is heavily fragmenting the forest

- Reserve system inadequate

- ポッサム、グライダー、鳥類が減少している

- 地勢における伐採が減少の要因（火災も もうひとつの要因である）

- 鳥類＝原生林と強く結びついている

- 木材譲渡計画の下での伐採は、絶滅危惧種にとって価値の高い森林で行われている（Taylor + Lindenmayer 2019）

- 伐採により森林が大幅に分断されている

- 保護区制度が不十分

The response of arboreal marsupials to long-term changes in forest disturbance

D. B. Lindenmayer[1,2] iD, W. Blanchard[2], D. Blair[1], L. McBurney[1], C. Taylor[2], B. C. Scheele[1,2], M. J. Westgate[2], N. Robinson[1,2] & C. Foster[2]

1 National Environmental Science Program Threatened Species Recovery Hub, Fenner School of Environment and Society, The Australian National University, Canberra, ACT, Australia
2 Fenner School of Environment and Society, The Australian National University, Canberra, ACT, Australia

Abstract

Quantifying the long-term population trajectory of species and the factors affecting these trends is a fundamental part of animal conservation. We describe the results of a long-term investigation of temporal changes in the occurrence of arboreal marsupials in the wet eucalypt forests of south-eastern Australia. The assemblage includes habitat specialists such as the vulnerable greater glider *Petauroides volans* and the critically endangered Leadbeater's possum *Gymnobelideus leadbeateri*, as well as common and widespread taxa. Using data gathered between 1997 and 2018, we quantified relationships between site occupancy of four marsupial species and spatio-temporal site and landscape-level variables, including the number of hollow-bearing trees at a site, and the extent of fire and logging in the surrounding landscape. We found evidence that: (1) The number of hollow-bearing trees (which are critical den sites for arboreal marsupials) has declined substantially in the past two decades. (2) There was a decline in all species of arboreal marsupials. (3) The presence of all species of arboreal marsupials was positively linked to the number of large old hollow-bearing trees at a site. (4) The extent of logging disturbance in the landscape surrounding a site had a positive impact on the sugar glider *Petaurus breviceps* but a negative effect on Leadbeater's possum. This suggests that ongoing logging will have further negative impacts on Leadbeater's possum. (5) The presence of the greater glider and sugar glider declined with increasing amounts of fire in the landscape. Negative fire effects are a concern as montane ash forests are increasingly susceptible to high-severity wildfires. Stronger efforts are needed to reduce the extent and frequency of logging and fire disturbance in mountain ash forests to protect arboreal marsupial populations.

Introduction

Mannan, 2006) or changes in landscape cover (Tscharntke et al., 2012; Fahrig, 2017).

森林攪乱の長期的変化に対する
樹上性有袋類の反応

Lindenmayer et al., 2022; Animal Conservation

Native forest logging industry in trouble
原生林の伐採産業が抱える問題

- **Rapidly declining resource availability**
- **Rapidly declining employment**
- **Lack of profitability**
- **Conflict with biodiversity conservation**
- **Conflict with other assets (e.g. water)**
- **Logged forests = elevated fire severity**
- **Little public support**
- **Repeated failure to get FSC**

- 利用できる資源の急激な減少
- 雇用の急速な減少
- 収益性の低さ
- 生物多様性保全との矛盾
- 他の資産（水など）との競合
- 伐採された森林＝火災の深刻度が高い
- 公的支援の少なさ
- FSC認証取得に何度も失敗

Cary et al. 2021, Lindenmayer et al., 2022 (Land), Taylor & Lindenmayer (2019), Lindenmayer et al., 2022 (NEE)

Research Note

Effects of altered fire intervals on critical timber production and conservation values

火災発生間隔の変化が、極めて重要な木材生産と保全価値に及ぼす影響

Geoffrey J. Cary[A,C], Wade Blanchard[A], Claire N. Foster[A] and David B. Lindenmayer[A,B]

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[B]National Environmental Science Program, Threatened Species Recovery Hub, Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2600 Australia.

[C]Corresponding author. Email: geoffrey.cary@anu.edu.au

Abstract. Forests exhibit thresholds in disturbance intervals that influence sustainability of production and natural values including sawlog production, species existence and habitat attributes. Fire is a key disturbance agent in temperate forests and frequency of fire is increasing, threatening sustainability of these forest values. We used mechanistically diverse, theoretical fire interval distributions for mountain ash forest in Victoria, Australia, in the recent past and future to estimate the probability of realising: (i) minimum sawlog harvesting rotation time; (ii) canopy species maturation; and (iii) adequate habitat hollows for fauna. The likelihood of realising fire intervals exceeding these key stand age thresholds

Fire regimes & rotation times
火災レジーム（型）とローテーションの数

- Natural fire freq. = 75-150 years (McCarthy et al., 1999)

- Optimal sawlog rotation =~ 100 years (Burgman et al., 1989)

- Relate fire frequency to timber rotation (chance trees get to harvest age)

- P = 0.21 at 80 years; P = 0.14 at 100 years

   Few stands reach harvestable age

   (High uncertainty of resource, poor financial investment, need alternative feedstock)

- 自然火災の発生頻度＝75～150年（McCarthy et al., 1999）

- 伐採木の最適ローテーション＝100年（Burgman et al., 1989）

- 火災頻度と木材ローテーションの関係（木が収穫樹齢に達する見込み）

- 80年でP＝0.21、100 年でP＝0.14

   収穫可能な樹齢に達する樹木はわずか

   （資源の不確実性が高い、金銭的な投資が少ない、代替原料が必要）

森林管理協議会の管理木材評価へのステークホルダーの関与

Stakeholder engagement in a Forest Stewardship Council Controlled Wood assessment

Chris Taylor , David B. Lindenmayer *

Fenner School of Environment and Society, The Australian National University, Canberra, ACT, 2601, Australia
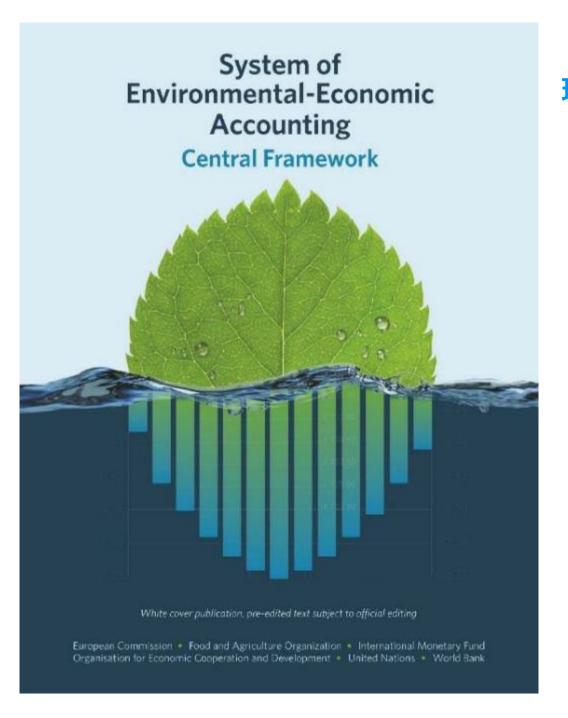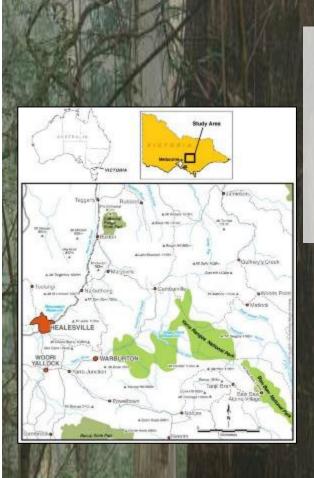
A B S T R A C T

Forest certification has become an important element in the trade of forest and wood products in many countries worldwide. We reviewed the Controlled Wood audit process under the Forest Stewardship Council (FSC), which is one of the world's largest forest certification schemes. We analysed an FSC Controlled Wood audit of logging operations conducted by VicForests (a government owned logging business operating in the Australian state of Victoria) within the Upper Goulburn Water Supply Protection Area. Areas >30° in slope within the catchment are deemed to be *High Conservation Value Forests* and they are not allowed to be logged. We: (1) analysed the level of performance required to demonstrate compliance with the FSC Controlled Wood Standard; (2) identified conflicts in the interpretation of standard; and (3) assessed the effectiveness of stakeholder engagement. Using a Digital Terrain Model, we found that 160 cutblocks or 75 % of the 214 areas logged between 2004 and 2019 in the Upper Goulburn Water Supply Protection Area were characterized by slopes >30°. Hence, they were steeper

74% of all cutblocks > 30 degrees, 72% cutblocks logged harvesting exclusion zones
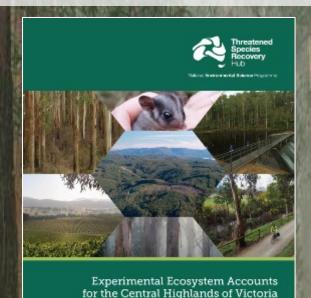全伐採区画の74％が30度以上、72%の伐採区画は収穫排除区域を伐採

環境経済会計のシステム
中心的な枠組み

Ecosystem accounting in the Central Highlands of Victoria

ビクトリア州中央高地における生態系会計

Data on ecosystem
services and values for:
- water
- carbon*
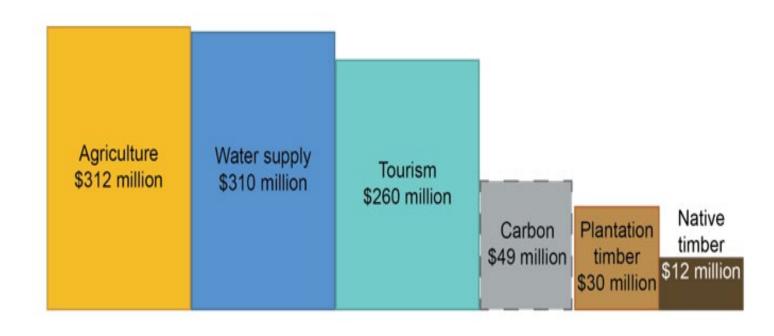- timber*
- tourism
- agriculture
- biodiversity*

*From LTER sites (1983-present)

以下に関する生態系
サービス・価値に関する
データ：
- 水
- 炭素※
- 木材
- 観光
- 農業
- 生物多様性※

※LTERサイトより（1983年〜現在）

Experimental Ecosystem Accounts
for the Central Highlands of Victoria
Summary Report

Look in detail at the economics
経済性を詳しく見る

Agriculture $312 million · Water supply $310 million · Tourism $260 million · Carbon $49 million · Plantation timber $30 million · Native timber $12 million

Keith et al. 2017, *Nature Ecology & Evolution*

経営・事業計画

Corporate and Business Plans

2013-14 to 2015-16

VicForests

Initiative 7: Determine the future of East Gippsland mixed species operations

Forecast initiative cost: internal costs only

イースト・ギップスランドの森林管理区域（FMA）での木材収穫事業は、長年にわたってVicForests社に利益をもたらしていない。現在、事業活動は、会社の諸経費を分配した後、1年あたり最大550万ドルの損失を出している。

現在の形態では、イースト・ギップスランドFMAにおける木材収穫事業は商業的なものではない。

Timber harvesting operations in the East Gippsland Forest Management Area (FMA) have not been profitable for VicForests for many years. Operations currently lose up to $5.5 million per annum, after the distribution of corporate overheads.

The reason for this loss is primarily related to the quantity and quality of the available timber resources. Ongoing harvesting since the 1960s, and the addition of large areas of forest to the conservation reserve system since the 1980s has led to a situation where few productive stands, that are suitable for harvesting, remain. For the foreseeable future, harvesting in East Gippsland FMA will, in general, be in coupes that are poorer quality, yield only low volumes of sawlog, are smaller in area and in locations that

Given the precarious nature of residual log sales to SEFE, VicForests will no longer be entering into any longer-term sawlog sales agreements following the Timber Sales Process 2013 unless proposals to purchase sawlogs include a complementary proposal that has the effect of removing the commercial risk to VicForests following the loss of sales of residual logs to SEFE.

VicForests' Order in Council requires VicForests, amongst other things, to operate on a commercial basis. In the current form, timber harvesting operations in East Gippsland FMA are not commercial. To address this situation in 2013-14, VicForests intends to:

○ work on a number of options during 2013-14 regarding future operations in East Gippsland

Look in detail at the economics
経済性を詳しく見る

- VicForests losses quadrupled in past 4 years
- VicForests社の損失は過去4年間で4倍に

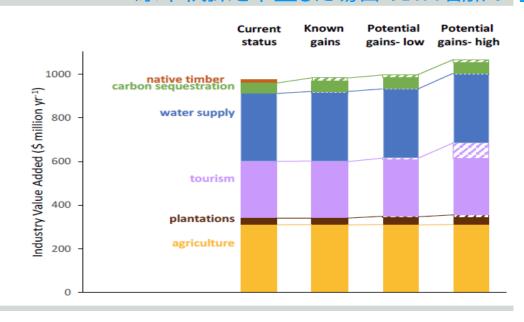# Trade-off benefits versus costs
メリットとコストのトレードオフ

- Victoria $110m-$192m better off without a native forest sector
- ビクトリア州は、原生林部門がない方が1億1000万ドル～1億9200万ドル得である

Potential gains in IVA with cessation of native timber harvesting　原木伐採を中止した場合のIVA増加の可能性

Cessation of harvesting native timber would contribute net economic, social and environmental benefits to the Central Highlands. Known gains: calculated gains in carbon sequestration and water supply. Potential gains: assumed gains in plantation timber production to substitute for native timber and estimated increase in tourism.

Ecosystem accounts define explicit and spatial trade-offs for managing natural resources

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Decisions about natural resource management are frequently complex and vexed, often leading to public policy compromises. Discord between environmental and economic metrics creates problems in assessing trade-offs between different current or potential resource uses. Ecosystem accounts, which quantify ecosystems and their benefits for human well-being consistent with national economic accounts, provide exciting opportunities to contribute significantly to the policy process. We advanced the application of ecosystem accounts in a regional case study by explicitly and spatially linking impacts of human and natural activities on ecosystem assets and services to their associated industries. This demonstrated contributions of ecosystems beyond the traditional national accounts. Our results revealed that native forests would provide greater benefits from their ecosystem services of carbon sequestration, water yield, habitat provisioning and recreational amenity if harvesting for timber production ceased, thus allowing forests to continue growing to older ages.

Ecosystem accounting has the potential to contribute to the policy process by re-framing debates about natural resource management[1,2]. Accounts help circumvent polarized arguments about the relative importance of environmental versus economic factors by systematically and regularly assessing the costs and benefits of changing ecosystem assets and services. Accounting involves quantification, both spatially and temporally, in physical terms that can be linked to monetary values. By incorporating a range of ecosystem services in the accounts, the analysis becomes broader than the often two opposing viewpoints. Such an approach may facilitate a convergence of opinion about the need for change—by demonstrating explicit comparisons between land uses—and a process for change by quantifying physical and monetary metrics[3]. Finding solutions to conflicting land uses becomes a process of maximizing benefits for the public good, and not just economic growth and private gain. Hence, ecosystem accounts may be critical for setting agendas for natural resource management at many levels: regional land use conflicts, national policies such as State of the Environment report recommendations and international agreements such as the Sustainable Development Goals[4].

The System of Environmental Economic Accounting (SEEA)[5] is an internationally agreed statistical standard for combining environmental and economic information in a form appropriate for policy-makers. This system provides a standard model for the policy process in which the production boundary of the economy lies the stages at which quantification in physical and/or monetary terms can be applied to make comparisons.

Ecosystem accounting provides information for decision-making about trade-offs between the economy and the environment and activities within the economy, as well as evaluating trends over time and management options[8]. Indeed, ecosystem accounts have shown that gains in environmental benefits can be achieved alongside economic growth[9]. However, demonstrating the utility of accounting for specific decisions has been difficult[10–12], and is probably best tackled at the scale of a region in which decisions are made. The technical nature of accounting is often poorly understood by policy-makers and their reluctance to engage with accounting may result from the difficult choices revealed[10]. Ecosystem services constitute one component of the SEEA; they have been ascribed financial values[13,14] and applied to comparisons of multiple land uses[15], but it has been similarly difficult to demonstrate their direct application to decision-making[11].

Here, we present a key advance in ecosystem accounting by linking spatially quantified ecosystem assets and services with their contributions to industries, in a form consistent with the SNA[7], as well as identifying the contributions of ecosystem services not included in the SNA. Such ecosystem accounts have broad applications for informing land use and meso-scale economic management decisions because many sources, types and scales of information are integrated. Information includes collections of economic units, such as businesses to industries, capital within and outside the

NOT THE END OF TIMBER INDUSTRY
木材産業は終わりではない

- 87% of native forests = chips+pulp -ABARES 2018

- Hardwood pulp logs from plantations (3.9 m tonnes BUT 2.9 m exported) (ABARES 2018)

- 88% of sawn wood in Victoria from plantations (from 5% of land cover) (ABARES 2018)

- Most forestry employment in plantations (Schirmer et al. 2018)

- Plantations more defendable against fire

- 原生林の87％＝チップ＋パルプ - ABARES 2018

- 大規模植林からの広葉樹パルプ丸太（390万トンだが、290万トンは輸出）（ABARES 2018）

- ビクトリア州の製材の88％は大規模植林から（土地被覆の5％から）（ABARES 2018）

- ほとんどの林業雇用は大規模植林で行われている（Schirmer et al. 2018）

- 大規模植林は火災に対してより防御しやすい

The future of forestry
林業の未来

- Exit native forest logging – better to manage for biodiversity, fire, carbon, water

- Plantation-based industry for wood products – reduces GHG emissions, best and highest return on natural asset

- Increase focus on plantation design, urban forests, farm forestry

- 原生林伐採の終了 - 生物多様性、火災、炭素、水のために管理した方がよい

- 木材製品のための大規模植林をベースとした産業 - GHG排出量の削減、自然資産に対する最良かつ最高のリターン

- 大規模植林デザイン、都市林、農地林業への注力を高める