Title	Dr
First name	Jeremy
Last name	Little
I am making this submission as	Academic
Submission type	Personal
Organisation making the submission (if applicable)	
Your position in the organisation (if applicable)	
Consent to make submission public	Public
Your story	
1.1 Causes and contributing factors	Recent catastrophic examples of unprecedented fire scenarios occurred in Australia over the austral spring-summer of 2019-2020 (Boer et al. 2020; Nolan et al. 2020). These conditions were consistent with observed trends over the last century with increasing bushfire risk, particularly more extreme fire events (Clarke et al. 2013; Little 2017; Dowdy 2018; Harris and Lucas 2019). These observed changes and predicted increased bushfire risk in Australia is at least partly attributable to anthropogenic climate change (Beer & Williams 1995; Cary & Banks 1999; Williams et al. 2001, 2009; Cary 2002; Hennessy et al. 2005; Lucas et al. 2007; Pitman et al. 2007; Hasson et al. 2008; King et al. 2011; Cary et al. 2012; Clarke 2015; CSIRO & Bureau of Meteorology 2015; Dutta et al. 2016)(Abatzoglou et al. 2019)(Di Virgilio et al. 2019). To mitigate increasing risk we need

	transformative change in our action on climate change and our approach to fire management (Head 2020).
1.2 Preparation and planning	Prescribed burning is often the primary focus of bushfire fuel load reduction and risk reduction. Few alternative methods are considered, trialled and tested. Mechanical fine-fuel hazard reduction of the understorey is proposed as a promising alternative. An evidence-based approach to risk mitigation allows for strategic, targeted and measurable fuel load reduction and maintenance programs in locations where it will make the most difference. This approach supports maximising risk mitigation, while minimising works required (cost) and minimising impact on the natural environment. Fuel hazard reduction may occur at different scales and locations in the landscape, however, should be targeted at areas of high risk. The effectiveness of planned burning in bushfire risk reduction, however, has come into question. Planned burns can increase bushfire risk, adversely impact biodiversity, lead to state shifts in native vegetation and fail to meet their objective altogether. Alternative strategies of fuel load reduction should be explored. The nature of the bushfire risk, primarily to life and property, are readily identifiable in the landscape. Creating defensible space by managing fuel within the immediate surrounds of these assets is likely to be the most effective means of protecting life and property from bushfire risk. Planned burning close to high risk areas is not socially or economically effective, nor indeed effective in reducing risk. Mechanical bushfire fuel load reduction, however, may provide the solution. There is insufficient evidence of the success of alternative means of risk reduction, such as by mechanical means. Any successful strategy needs to target understorey fine-fuels; occur near homes; balance environmental, social and cultural values; adopt multiple risk management strategies; alternative fuel hazard reduction approaches to planned burning; reduce the area of land burnt; mechanical fuel hazard reduction; and involve the community. The local government at the Mornington Peninsula operates a comprehensive program of mechanical fine-fuel hazard reduction in the understorey. This case study documents an effective, strategic and targeted alternative to prescribed burning, which is readily transferrable across scales, regions and agencies throughout Australia
1.3 Response to bushfires	
1.4 Any other matters	
Upload files	Bushfire-Enquiry-Response-NSW-JeremyLittle.pdf - Download File

A promising alternative to planned burning: mechanical fine-fuel hazard reduction of understorey

Dr Jeremy Little PhD, BSc[Hons]

Summary

Prescribed burning is often the primary focus of bushfire fuel load reduction and risk reduction. Few alternative methods are considered, trialled and tested. Mechanical fine-fuel hazard reduction of the understorey is proposed as a promising alternative. An evidence-based approach to risk mitigation allows for strategic, targeted and measurable fuel load reduction and maintenance programs in locations where it will make the most difference. This approach supports maximising risk mitigation, while minimising works required (cost) and minimising impact on the natural environment.

Fuel hazard reduction may occur at different scales and locations in the landscape, however, should be targeted at areas of high risk. The effectiveness of planned burning in bushfire risk reduction, however, has come into question. Planned burns can increase bushfire risk, adversely impact biodiversity, lead to state shifts in native vegetation and fail to meet their objective altogether. Alternative strategies of fuel load reduction should be explored.

The nature of the bushfire risk, primarily to life and property, are readily identifiable in the landscape. Creating defensible space by managing fuel within the immediate surrounds of these assets is likely to be the most effective means of protecting life and property from bushfire risk. Planned burning close to high risk areas is not socially or economically effective, nor indeed effective in reducing risk. Mechanical bushfire fuel load reduction, however, may provide the solution. There is insufficient evidence of the success of alternative means of risk reduction, such as by mechanical means.

Any successful strategy needs to target understorey fine-fuels; occur near homes; balance environmental, social and cultural values; adopt multiple risk management strategies; alternative fuel hazard reduction approaches to planned burning; reduce the area of land burnt; mechanical fuel hazard reduction; and involve the community.

The local government at the Mornington Peninsula operates a comprehensive program of mechanical fine-fuel hazard reduction in the understorey. This case study documents an effective, strategic and targeted alternative to prescribed burning, which is readily transferrable across scales, regions and agencies throughout Australia.

Introduction

Recent catastrophic examples of unprecedented fire scenarios occurred in Australia over the austral spring-summer of 2019-2020 (Boer *et al.* 2020; Nolan *et al.* 2020). These conditions were consistent with observed trends over the last century with increasing bushfire risk, particularly more extreme fire events (Clarke *et al.* 2013; Little 2017; Dowdy 2018; Harris and Lucas 2019). These observed changes and predicted increased bushfire risk in Australia is at least partly attributable to anthropogenic climate change (Beer & Williams 1995; Cary & Banks 1999; Williams *et al*. 2001, 2009; Cary 2002; Hennessy *et al*. 2005; Lucas *et al.* 2007; Pitman *et al*. 2007; Hasson *et al*. 2008; King *et al*. 2011; Cary *et al*. 2012; Clarke 2015; CSIRO & Bureau of Meteorology 2015; Dutta *et al*. 2016)(Abatzoglou *et al.* 2019)(Di Virgilio *et al.* 2019). To mitigate increasing risk we need transformative change in our action on climate change and our approach to fire management (Head 2020).

Planned burning dominates fire management and bushfire risk management in Australia, with little demonstrated alternatives. Yet inappropriate fire regimes from planned and unplanned fires may have a greater impact on the ecosystem, than from climate change itself (Williams *et al.* 2009; Little 2017). There is also evidence that planned burning may not be ineffective in reducing bushfire risk, but that in some cases may lead to an increase in bushfire risk (Price and Bradstock 2010; Zylstra 2012; Fairman *et al.* 2016b; Zylstra *et al.* 2016; Cawson *et al.* 2017; Dixon *et al.* 2018; Furlaud *et al.* 2018; Cirulis *et al.* 2019; Florec *et al.* 2019; McColl-Gausden and Penman 2019). With increased fire weather with climate change, the opportunity for planned burns is diminishing (Clarke *et al.* 2019) Alternative and combinations of strategies from the suite of options for bushfire risk reduction are, therefore, required.

Fire management strategies do not always follow current scientific thinking, or based on evidence. Strategies may be strongly influenced by cultural, ecological, economic and political considerations (Neale 2018). Fire behaviour expertise has become institutionalised and is embedded in bushfire management agencies (Neale 2020). There is evidence of a divide between practitioners, with scientists and researchers (Neale, Weir, and Dovers 2016)(Neale, Weir, and McGee 2016). For these reasons, there may be ambivalence of alternative approaches to bushfire risk management, which are new, emerging or evidence-based.

A new, alternative fire management strategy is presented here; mechanical hazard reduction of understorey fine-fuels. A case study from a local government program on the Mornington Peninsula of Victoria provides evidence of the success of such as program.

Fuel Hazard and Bushfire Risk

Fuel hazard and bushfire risk are two separate factors. Fuel hazard is vegetation which has to be "in a flammable state, have an ignition source, and be in a position that fire, embers or smoke emanating from the hazard can adversely impact values which are vulnerable and exposed to fire elements (flame contact, radiant heat, ember attack and smoke) (Australasian Fire and Emergency Service Authorities Council 2014). Risk does not arise from an event (such as a bushfire), but how the event may then impact something (such as a human settlement) (international standard ISO 31000).

Bushfire risk mapping can identify areas of bushfire (vegetation fuel) hazard, such as the Bushfire Management Overlay (Victorian Department of Environment, Land, Water and Planning, 2019), or can identify the values at risk from bushfire, such as human settlements of the Victorian Fire Risk Register (Emergency Management Victoria, 2020).

Fuel hazard reduction is only one of a number of complimentary strategies in reducing bushfire risk (Australasian Fire and Emergency Service Authorities Council 2014). Careful consideration and importance needs to be given to all strategies and not limited to only one. Furthermore, planned burns are only one fuel hazard reduction strategy and there are a number of other options in reducing fuel hazard that deserve equivalent consideration.

There are a number of different ways in assessing and managing bushfire fuel hazard, including some integrated methods in development (Cruz, 2018). Bushfire fuels are the arrangement, structure and characteristics of vegetation. Vegetation layers are generally consistent between approaches (Hines, 2010) (Cruz, 2018) including canopy, bark, elevated, near-surface and surface fuels. Assessment of the fuels in these layers gives information on the overall fuel hazard.

Different structural layers of vegetation and fuel size contribute disproportionally to flammability. One prominent Australian fuel hazard assessment (Hines, 2010), identified that canopy fuels do not contribute to fire spread and are not included in hazard calculations. Fire spread and behaviour is instead determined by the understorey fuels (surface, near-surface, elevated and bark).

Fuel characteristics, such as size and dryness affect flammability. Fine fuels (fuels thinner than 6mm) “contribute the most to the fire’s rate of spread and flame height” (Hines *et al.* 2010). Therefore, any fuel hazard reduction program should focus on the reduction of the fine fuels in the understorey layers.

Bushfire risk is the potential impact that a bushfire might have on certain values. In risk calculations, consequences and likelihood determine the level of risk. Of particular concern to the community are two primary values; life and property, and the environment (Victorian State Government 2019).

Focusing on the risk to life and property, recent studies demonstrate that fuel hazard treatments need to occur close to houses to mitigate risk of loss (Gibbons *et al.* 2012)(Price and Bradstock 2012) A recent review discovered the consistent trend of proximity of fuel to houses is a key consideration. Vegetation fuel hazard within a 30-metre zone around a house, and vegetation in contact with or close to houses had more impact on house loss than proximity to forest (Penman *et al.* 2019). This evidence indicates that managing the fuel hazard within this zone is the most effective means in reducing the localised risk to life and property.

Bushfire risk - fuel hazard reduction by prescribed burning

Planned burning or prescribed burning is a widely used land management tool for achieving land management objectives, such as fuel hazard reduction, ecological restoration and improving ecosystem resilience (Australasian Fire and Emergency Service Authorities Council 2017).

However, the increased emergence in scientific literature regarding the ineffectiveness of planned burning in fuel hazard reduction seriously questions this methodology (Price and Bradstock 2010; Zylstra 2012; Taylor *et al.* 2014; Zylstra *et al.* 2016; Fairman *et al.* 2016b; Cawson *et al.* 2017; Dixon *et al.* 2018; Furlaud *et al.* 2018; Cirulis *et al.* 2019; Florec *et al.* 2019; McColl-Gausden and Penman 2019).

Prescribed burning effectiveness is small in protecting life and property when weather conditions are severe (Price and Bradstock 2012) with less than 10% likelihood of a planned burn stopping an unplanned fire (Price and Bradstock 2010). Although increasing prescribed burning does improve risk reduction it does so at diminishing returns (Florec *et al.* 2019). Increased wildfire activity since the 1950s has occurred despite progress in fire management strategies (Fairman *et al.* 2016). If planned burns were to be effective they will be most effective near houses (Price and Bradstock 2010), which generally does not occur. There are other options for fuel hazard that are more appropriate and more effective in reducing bushfire risk.

Mechanical Fuel Hazard Reduction: understorey not canopy

Only recently has an overview of mechanical fuel hazard reduction been presented for Australia (Ximenes *et al.* 2017). There are different strategies for mechanical fuel hazard reduction consisting of stem thinning (mechanical thinning) and/ or reductions in understorey fuels. Social acceptability of mechanical fuel load reduction as a fire management strategy is no different to planned burning or grazing (Mylek and Schirmer 2016; Ximenes *et al.* 2017).

Fuel hazard is determined by assessing attributes of the fuel (vegetation) hazard in different structural layers (Hines *et al.* 2010). All of these layers are understorey attributes, focusing on the fine-fuels. The removal of stems and canopy by mechanical thinning, therefore, is unlikely to result in a demonstrable reduction in fuel hazard. It is, therefore, in the understorey that fuel hazard reduction works should be focused. However, almost all of the studies on mechanical fuel hazard reduction relate to mechanical thinning strategies. There were no known examples of understorey only fuel treatments, where the canopy is not modified.

Examples of mechanical thinning strategies have repeatedly demonstrated ineffectiveness in reducing fuel hazard in understorey vegetation (Schwilk *et al.* 2009; Proctor and McCarthy 2015; Volkova *et al.* 2017; Volkova and Weston 2019). Conversely, thinning of forests, including timber harvesting operations is already known to increase bushfire risk (Lindenmayer *et al.* 2009; Price and Bradstock 2012; Wilson *et al.* 2018). Mechanical thinning programs, which remove trees and canopy fuels are not likely to result in the reduction of understorey fine fuels and, therefore, fuel hazard reduction.

The recent bushfire crisis has seen experts across industries call for an end to the logging of all native forests across Australia (Readfearn 2020, Sanger *et al*. 2020). Not just for biodiversity reasons, but also due to the increased bushfire risk that they create. Economically, native forest logging is heavily subsidised and can be allocated to better purposes, such as fire mitigation.

Any land manager working at the peri-urban interface needs to strike a balance between vegetation protection and bushfire risk management (Moskwa *et al.* 2018; MacLeod *et al.* 2019), which may often be conflicting objectives (Driscoll *et al.* 2010). However, tree removal such as by thinning does not reduce bushfire risk. Converselty, tree retention can reduce urban temperature (Thom *et al.* 2016; Duncan *et al.* 2019) and environmental microclimate (Little 2017). Vegetation type, or canopy cover has a very strong effect on microclimate and fire risk (Little *et al.* 2012).

There appear to be serious problems with the effectiveness of planned burning and mechanical fuel hazard reduction of the overstorey. A rethink of management strategies is required to deliver a targeted, strategic, effective and measurable fuel hazard reduction strategy that can be applied at multiple scales. One known program delivers this, through mechanical understorey fine-fuel reduction.

Case Study: Mechanical Bushfire Fuel Load Reduction program – Australian, NSW and Victorian Governments

As part of the **National Bushfire Mitigation Programme**, the Australian Government under a national partnership with the NSW Government is contributing to the **Mechanical Bushfire Fuel Load Reduction Programme**. This programme was a 2013 election commitment, with funding for trials provided in 2015-16 and 2016-17 (Australian Government Department of Agriculture, Water and the Environment, 2016). The project coordinator has advised that this programme has been extended until June 2021 (John Samuel pers. Comm.). No publication or results of these trials have been made publicly available. Now would be a critical time to evaluate this programme, following the fires on 2019-20 which have affected two of the areas in the trials; the Mid-North Coast of NSW and East Gippsland Victoria.

"*The trials aim to establish whether mechanical thinning of forests can reduce bushfire risk in an economical, socially acceptable and environmentally sound manner around key assets, such as conservation areas or townships, where prescribed burning is undesirable for a range of reasons*" (Australian Government Department of Agriculture, Water and the Environment, 2016).

Unfortunately, there is no evidence that this program will result in fuel hazard reduction adequate enough to make a difference. There are, however, other forms of mechanical fuel hazard reduction, which will work.

Case Study: Mechanical understorey fine-fuel hazard reduction program - Mornington Peninsula Shire

Mornington Peninsula Shire fire management includes multiple complimenting programs. These include community engagement and preparedness; fire prevention on private property; regulation of open air burning; prescribed burns; grass mowing; weed management; reserve and roadside management (Mornington Peninsula Shire, 2019). One of these programs, 'Fire Management in Shire Reserves' is a mechanical fuel hazard reduction program. Their mechanical works "aim to reduce fuel hazard and risk to neighbouring properties from potential bushfire" (Mornington Peninsula Shire, 2019). Mechanical fuel hazard reduction works "typically consist of slashing, removing or trimming vegetation to reduce connectivity between shrubs and trees, and removing fallen, dead branches". These works focus on understorey fine-fuels, rather than overstorey (canopy) fuels and trees.

The Shire uses standard fire management planning and zoning categories (Department of Sustainability and Environment, 2012) (Australasian Fire and Emergency Service Authorities Council, 2017), applied at varying scale relevant to a local government area (Ellis, 2004). Fire Management Zones currently used include Asset Protection Zones and Bushfire Moderation Zones. There is limited scope for other zones such as Landscape Management Zones or Planned Burns due to the small size of Council Reserves. Rather than relying on landscape-scale treatments (such as prescribed burns), targeted fuel hazard reduction providing defensible space near homes in high bushfire risk areas is providing effective and achievable fuel hazard reduction in the areas where it matters the most. Fire Management Zones are generally located around Shire reserve boundaries adjacent to assets and in high bushfire risk areas.

Landscape risk can be determined from existing mapping, including the Victoria Fire Risk Register (Emergency Management Victoria, 2020), Bushfire Management Overlay (Victorian Department of Environment, Land, Water and Planning, 2019) and Bushfire Prone Areas (Victorian Department of Environment Land, Water and Planning, 2020). Local risk to homes can also be determined such as with the Victorian Fire Risk Register human settlements category (Emergency Management Victoria, 2020).

At the local scale, as it relates to individual homes, the bushfire attack level (BAL) can be assessed to determine an appropriate defendable space (Victorian Department of Environment Land, Water and Planning, 2020). Managing a defensible space of vegetation/ fuels with a 30-metre zone around a house, vegetation in contact with or close to houses, is the most effective means of risk reduction (Penman, 2019). In most situations, this relates to vegetation management on private property. The location of Shire Fire Management Zones near homes, can assist in the provision of defensible space and may vary according to the defendable space on adjacent private property.

Promoting the role of the private property in providing its own defensible space is a key component of the Shire's fire community engagement.

Fire Management Zones are inspected to asses fuel hazard and identify works required to reduce the overall fuel hazard to acceptable limits (depending on the zone category). Identified areas are then prioritised for mechanical fuel hazard reduction works. Post-works fuel hazard assessments demonstrate successful reduction in fuel hazard

This program has been operational for many years and currently has an extensive annual budget of approximately two and half million dollars (pers. comm.). There are 2044 Fire Management Zones across the municipality (Mornington Peninsula Shire, 2019). Collectively, the network of over 2000 Fire Management Zones across the municipality is contributing to managing bushfire risk at a landscape scale. Consideration is also given to ignition risk and potential fire spread scenarios.

Examples of Fire Management Zone effectiveness
Shire Fire Management Zones have been demonstrated their effectiveness in reducing wildfire intensity and impact on homes in a number of fire scenarios including: Hastings, Warringine bushland reserve (Terramatrix, 2015); Mt Eliza, Banool bushland reserve (pers. comm. 2018); and Arthurs Seat – Cemetery Drive (pers. comm. 2019). At Warringine bushland reserve, the Fire Management Zones affected by wildfire were assessed for their effectiveness and they "proved effective in preventing ignition of homes from flames or radiant heat generated by vegetation burning within Warringine Park" (p. 39, Terramatrix 2015).

References

Abatzoglou JT, Williams AP, Barbero R (2019) Global emergence of anthropogenic climate change in fire weather indices. *Geophys Res Lett* **46**(1), 326–336. doi:10.1029/2018GL080959.

Australasian Fire and Emergency Service Authorities Council (2014) Risk management and review framework for prescribed burning risks associated with fuel hazards: report for national burning project - subproject 3. (Melbourne) https://www.aidr.org.au/media/4868/risk-management-and-review-framework-for-prescribed-burning-risks-associated-with-fuel-hazards.pdf.

Australasian Fire and Emergency Service Authorities Council (2017) National Guidelines for Prescribed Burning Strategic and Program Planning – National Burning Project sub-project 4.

Boer MM, Resco de Dios V, Bradstock RA (2020) Unprecedented burn area of Australian mega forest fires. *Nat Clim Chang* **10**(3), 171–172. doi:10.1038/s41558-020-0716-1.

Cawson JG, Duff TJ, Tolhurst KG, Baillie CC, Penman TD (2017) Fuel moisture in Mountain Ash forests with contrasting fire histories. *For Ecol Manage* **400**, 568–577. doi:10.1016/j.foreco.2017.06.046.

Cirulis B, Clarke H, Boer M, Penman T, Price O, Bradstock R (2019) Quantification of inter-regional differences in risk mitigation from prescribed burning across multiple management values. *Int J Wildl Fire*. doi:10.1071/WF18135.

Clarke H, Lucas C, Smith P (2013) Changes in Australian fire weather between 1973 and 2010. *Int J Climatol* **33**, 931–944. doi:10.1002/joc.3480.

Clarke H, Tran B, Boer MM, Price O, Kenny B, Bradstock R (2019) Climate change effects on the frequency, seasonality and interannual variability of suitable prescribed burning weather conditions in south-eastern Australia. *Agric For Meteorol* **271**(March), 148–157. doi:10.1016/j.agrformet.2019.03.005.

Dixon KM, Cary GJ, Worboys GL, Seddon J, Gibbons P (2018) A comparison of fuel hazard in recently burned and long-unburned forests and woodlands. *Int J Wildl Fire* **27**(9), 609–622. doi:10.1071/WF18037.

Dowdy AJ (2018) Climatological variability of fire weather in Australia. *J Appl Meteorol Climatol* **57**(2), 221–234. doi:10.1175/JAMC-D-17-0167.1.

Driscoll D, Lindenmayer DB, Bennett AF, Bode M, Bradstock RA, Cary GJ, Clarke MF, Dexter N, Fensham R, Friend G, Gill M, James S, Kay G, Keith D a., MacGregor C, Possingham HP, Russel-Smith J, Salt D, Watson JEM, Williams D, York A (2010) Resolving conflicts in fire management using decision theory: asset-protection versus biodiversity conservation. *Conserv Lett* **3**, 215–223. doi:10.1111/j.1755-263X.2010.00115.x.

Duncan JMA, Boruff B, Saunders A, Sun Q, Hurley J, Amati M (2019) Turning down the heat: An enhanced understanding of the relationship between urban vegetation and surface temperature at the city scale. *Sci Total Environ* **656**, 118–128. doi:10.1016/j.scitotenv.2018.11.223.

Fairman TA, Nitschke CR, Bennett LT (2016a) Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests. *Int J Wildl Fire* **25**(8), 831–848. doi:10.1071/WF15010.

Fairman TA, Nitschke CR, Bennett LT (2016b) Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests. *Int J Wildl Fire*. doi:10.1071/WF15010.

Florec V, Burton M, Pannell D, Kelso J, Milne G (2019) Where to prescribe burn: The costs and benefits of prescribed burning close to houses. *Int J Wildl Fire*. doi:10.1071/WF18192.

Furlaud JM, Williamson GJ, Bowman DMJS (2018) Simulating the effectiveness of prescribed burning at altering wildfire behaviour in Tasmania, Australia. *Int J Wildl Fire* **27**(1), 15–28. doi:10.1071/WF17061.

Gibbons P, van Bommel L, Gill AM, Cary GJ, Driscoll DA, Bradstock RA, Knight E, Moritz MA, Stephens SL,

Lindenmayer DB (2012) Land management practices associated with house loss in wildfires. *PLoS One* **7**(1), . doi:10.1371/journal.pone.0029212.
Harris S, Lucas C (2019) 'Understanding the variability of Australian fire weather between 1973 and 2017.' doi:10.1371/journal.pone.0222328.
Head L (2020) Transformative change requires resisting a new normal. *Nat Clim Chang* **10**(3), 173–174. doi:10.1038/s41558-020-0712-5.
Hines F, Tolhurst KG, Wilson AAG, McCarthy GJ (2010) Overall fuel hazard assessment guide. (Melbourne)
Lindenmayer DB, Hunter ML, Burton PJ, Gibbons P (2009) Effects of logging on fire regimes in moist forests. *Conserv Lett* **2**, 271–277.
Little JK (2017) A song of fire and water: will climate change interacting with fire affect the distribution of vegetation in the Australian Wet Tropics? James Cook University. https://researchonline.jcu.edu.au/46828/.
Little JK, Prior LD, Williamson GJ, Williams SE, Bowman DMJS (2012) Fire weather risk differs across rain forest-savanna boundaries in the humid tropics of north-eastern Australia. *Austral Ecol* **37**(8), . doi:10.1111/j.1442-9993.2011.02350.x.
MacLeod TA, Hahs AK, Penman TD (2019) Balancing fire risk and human thermal comfort in fire-prone urban landscapes. *PLoS One* **14**(12), 1–19. doi:10.1371/journal.pone.0225981.
McColl-Gausden SC, Penman TD (2019a) Pathways of change: p redicting the effects of fire on flammability. *J Environ Manage* **232**, 243–253. doi:10.1016/j.jenvman.2018.11.063.
McColl-Gausden SC, Penman TD (2019b) Pathways of change: Predicting the effects of fire on flammability. *J Environ Manage* **232**(May 2018), 243–253. doi:10.1016/j.jenvman.2018.11.063.
Moskwa E, Bardsley DK, Robinson GM, Weber D (2018) Generating narratives on bushfire risk and biodiversity values to inform environmental policy. *Environ Sci Policy* **89**(May), 30–40. doi:10.1016/j.envsci.2018.07.001.
Mylek MR, Schirmer J (2016) Social acceptability of fuel management in the Australian Capital Territory and surrounding region. *Int J Wildl Fire* **25**(10), 1093–1109. doi:10.1071/WF15164.
Neale T (2018) 'Are we wasting our time?': bushfire practitioners and flammable futures in northern Australia. *Soc Cult Geogr* **19**(4), 473–495. doi:10.1080/14649365.2017.1285423.
Neale T, Weir JK, Dovers S (2016) Science in motion: integrating scientific knowledge into bushfire risk mitigation in southwest Victoria. *Aust J Emerg Manag* **31**(2), 13–17.
Neale T, Weir JK, McGee TK (2016) Knowing wildfire risk: scientific interactions with risk mitigation policy and practice in Victoria, Australia. *Geoforum* **72**, 16–25. doi:10.1016/j.geoforum.2016.03.008.
Nolan RH, Boer MM, Collins L, Resco de Dios V, Clarke H, Jenkins M, Kenny B, Bradstock RA (2020) Causes and consequences of eastern Australia's 2019–20 season of mega-fires. *Glob Chang Biol* **26**(3), 1039–1041. doi:10.1111/gcb.14987.
Penman SH, Price OF, Penman TD, Bradstock RA (2019) The role of defensible space on the likelihood of house impact from wildfires in forested landscapes of south eastern Australia. *Int J Wildl Fire* **28**(1), 4–14. doi:10.1071/WF18046.
Price OF, Bradstock RA (2010) The effect of fuel age on the spread of fire in sclerophyll forest in the Sydney region of Australia. *Int J Wildl Fire* **19**(1), 35–45. http://www.publish.csiro.au/?paper=WF08167.
Price OF, Bradstock RA (2012) The efficacy of fuel treatment in mitigating property loss during wildfires: Insights from analysis of the severity of the catastrophic fires in 2009 in Victoria, Australia. *J Environ Manage* **113**, 146–157.
Proctor E, McCarthy G (2015) Changes in fuel hazard following thinning operations in mixed-species forests in East Gippsland, Victoria. *Aust For* **78**(4), 195–206. doi:10.1080/00049158.2015.1079289.
Schwilk DW, Keeley JE, Knapp EE, Mciver J, Bailey JD, Fettig CJ, Fiedler CE, Harrod RJ, Moghaddas JJ, Outcalt KW, Skinner CN, Stephens SL, Waldrop TA, Yaussy DA, Youngblood A (2009) The national Fire and Fire Surrogate study: Effects of fuel reduction methods on forest vegetation structure and fuels. *Ecol Appl* **19**(2), 285–304. doi:10.1890/07-1747.1.
Taylor C, McCarthy MA, Lindenmayer DB (2014) Nonlinear effects of stand age on fire severity. *Conserv Lett* **7**, 355–370.
Thom JK, Coutts AM, Broadbent AM, Tapper NJ (2016) The influence of increasing tree cover on mean radiant temperature across a mixed development suburb in Adelaide, Australia. *Urban For Urban Green* **20**, 233–242. doi:10.1016/j.ufug.2016.08.016.
Victorian State Government (2019) Strategic bushfire management planning: Engage Victoria summary - Safer Together project 2.3. (Melbourne)
Di Virgilio G, Evans JP, Blake SAP, Armstrong M, Dowdy AJ, Sharples J, McRae R (2019) Climate change increases the potential for extreme wildfires. *Geophys Res Lett* **46**(14), 8517–8526. doi:10.1029/2019GL083699.
Volkova L, Bi H, Hilton J, Weston CJ (2017) Impact of mechanical thinning on forest carbon, fuel hazard and simulated fire behaviour in Eucalyptus delegatensis forest of south-eastern Australia. *For Ecol Manage* **405**(September), 92–100. doi:10.1016/j.foreco.2017.09.032.
Volkova L, Weston CJ (2019) Effect of thinning and burning fuel reduction treatments on forest carbon and bushfire fuel hazard in Eucalyptus sieberi forests of South-Eastern Australia. *Sci Total Environ* **694**, 133708. doi:10.1016/j.scitotenv.2019.133708.
Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DMJS, Clarke PJ, Cook GD, Hennessy KJ, York A (2009) Interactions between climate change, fire regimes and biodiversity in Australia: a preliminary assessment. (Canberra) http://climatechange.gov.au/~/media/publications/adaptation/fire-report.pdf.
Wilson N, Cary GJ, Gibbons P (2018) Relationships between mature trees and fire fuel hazard in Australian forest. *Int*

J Wildl Fire **27**(5), 353–362. doi:10.1071/WF17112.
Ximenes F, Stephens M, Brown M, Law B, Mylek M, Schirmer J, Sullivan A, McGuffog T (2017) Mechanical fuel load reduction in Australia: a potential tool for bushfire mitigation. *Aust For* **80**(2), 88–98. doi:10.1080/00049158.2017.1311200.
Zylstra P (2012) The historical influence of fire on the flammability of subalpine snowgum forest and woodland. *Vic Nat* **130**, 232–239.
Zylstra PJ (2018) Flammability dynamics in the Australian Alps. *Austral Ecol* **43**(5), 578–591. doi:10.1111/aec.12594.
Zylstra P, Bradstock RA, Bedward M, Penman TD, Doherty MD, Weber RO, Gill AM, Cary GJ (2016) Biophysical mechanistic modelling quantifies the effects of plant traits on fire severity: species, not surface fuel loads, determine flame dimensions in eucalypt forests. *PLoS One* **11**(8), e0160715. doi:10.1371/journal.pone.0160715.