Burning for a healthy future: People and their environments

NSW Bushfire Risk Management Research Hub

Final Report

WESTERN SYDNEY UNIVERSITY
UNSW SYDNEY
UNIVERSITY of TASMANIA AUSTRALIA
UNIVERSITY OF WOLLONGONG AUSTRALIA
NSW GOVERNMENT

Acknowledgement of Country

We acknowledge the traditional custodians and knowledge holders of the Country where we conduct our research, walk and live. We pay our respects to Elders past, present and emerging.

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NSW Bushfire Risk Management Hub Report

Summary

Note to readers: Detailed descriptions of the background, aims, main findings, and outcomes of the individual Work Packages are found in the *NSW Bushfire Risk Management Research Hub – Final Report*. This 'Summary Report' forms the first chapter of the Final Report.

Contents

Abbreviations

CWD	coarse woody debris
DPE	Department of Planning and Environment
GEDI	global ecosystem dynamics investigation
GIS	geographic information system
Ha	hectare
HRB	hazard reduction burn
Km	kilometre
LFMC	live fuel moisture content
LiDAR	Light detection and ranging
Mm	millimetre
NSW	New South Wales
NSWFRDB	NSW Fire Response Database
OH&S	occupational health and safety
PM	particulate matter
TPC	threshold of potential concern
SDC	science data compute
WP	work package

1. Context

1.1. The Challenge

Adapting to an increase in bushfire frequency and severity is a significant, climate-induced challenge for NSW and much of Australia.

The NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW, formerly the NSW Department of Planning and Environment [DPE]) through its Environment and Heritage group, including the National Parks and Wildlife Service (NPWS), have statutory land management responsibilities for bushfires in NSW under the Rural Fires Act 1997. The Department is expected to: *"... reduce or mitigate the risk from bushfire to life, property, and cultural and natural heritage."*

Significant gaps in knowledge have been major impediments in meeting this responsibility effectively. Although prescribed burning has long been one of the central strategies in fire management, effective fire management relies on knowing how much these interventions mitigate risk to human life and property and how much they potentially increase the risk to human health, environmental values, and ecosystem services.

1.2. Bushfire Risk Management Research Hub

To address the gaps in knowledge, the Department established the NSW Bushfire Risk Management Research Hub in 2018. Its overall aim was to develop the new knowledge needed to underpin cost-effective strategies that would improve fire management and reduce the risks bushfire poses to people, property, and the environment. It also sought to guide effective communication and dissemination of knowledge to the people and agencies who need it to inform policy and management decisions.

The Hub was a state-focused collaboration between the NSW Government (through DCCEEW), research institutions, fire management agencies, bushfire experts and Indigenous knowledge holders. It thus brought together researchers, fire agencies, policy makers, and public land managers in a collaborative research effort. The Hub was hosted by the University of Wollongong (UOW), and other principal research partners included the University of Tasmania (UTAS), University of New South Wales (UNSW) and Western Sydney University (WSU).

Using a risk-based approach to prescribed burning that recognised the need to address 'trade-offs' between the protection of assets ranging from houses and human health to ecosystems and threatened species, the Hub's work was designed around four guiding principles:

- Enhance bushfire research that informs the Department's strategic knowledge needs and helps it to improve fire management
- Work closely with the Department to deliver a cost-effective research program, which leverages greater investment for fire research
- Ensure research information is relevant, is based on the best available evidence, and is

made readily available in forms that end users can access, understand and apply

- Foster transfer and integration of skills and knowledge to the Department and also between research institutions, other government agencies, Aboriginal co-management partners, and the communities that the Department serves.

1.3. Work Packages

The Hub organized its research through six distinct, but linked, work packages. Each had a specific focus and was led by globally renowned researchers in that field.

Work Package 1:	Dynamic mapping and analysis of NSW fire regimes
Work Package 2:	Fuel, flammability, and carbon dynamics
Work Package 3:	Greenhouse gasses and air quality
Work Package 4:	Fire regime thresholds of potential concern for threatened biodiversity
Work Package 5:	Exploring the wellbeing benefits from engaging in cultural burning
Work Package 6:	Optimising cost-effective fire management

A summary of the findings of each work package is presented below. More detailed treatments of each work package are presented in subsequent chapters of this report.

2. Summary of Findings

2.1. Mapping (Work Package 1)

Aims

Mapping and spatial analysis is at the heart of good fire management. They allow objective assessment of landscape patterns such as how vegetation is connected, or specific locations where it is near residences. It can also reveal patterns related to plant interactions with fire that can help prioritise prescribed burning or protection from fire.

The aims of this work package were (i) to modernise a GIS mapping tool to enable more powerful spatial analysis, allowing better planning of hazard reduction burns, and (ii) to identify areas where vegetation is vulnerable to damage by future wildfires or hazard reduction burning programs.

Team leaders: David Bowman, Grant Williamson, University of Tasmania

Key Findings, Applications and Impacts

This team modernised *FireTools*, a tool used by NSW Parks and Wildlife to map which parts of the landscape have had too many, too few, or the right amount of fire for the vegetation types that live there (Figure 1). They then created a faster, more powerful cloud-based version, *FireTools Cloud*, which can process data 50- to 100-times faster.

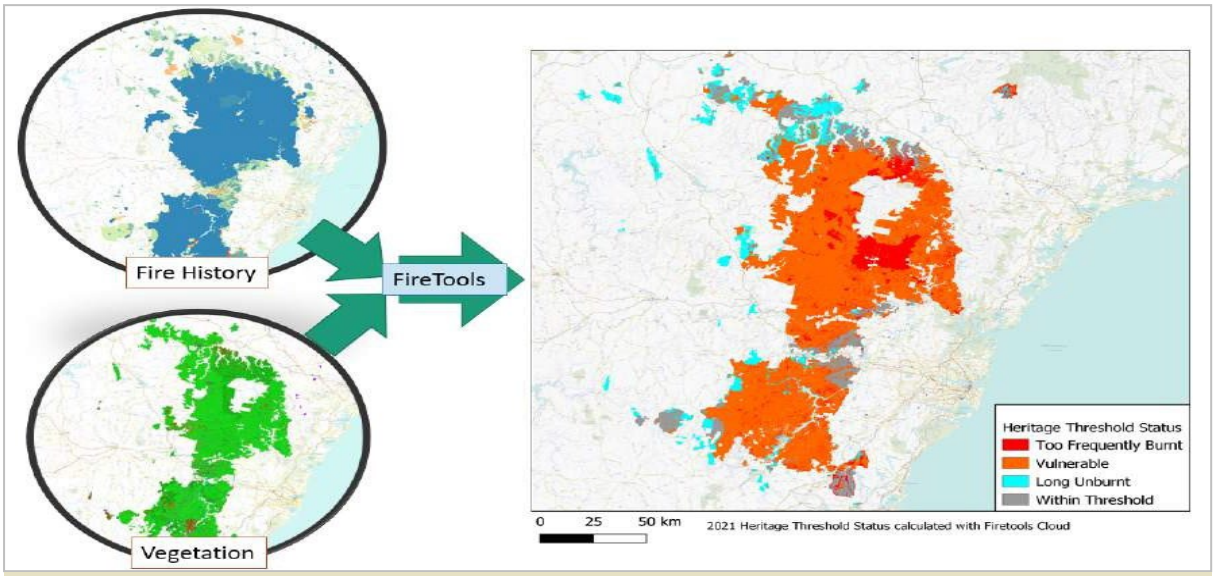

Figure 1. FireTools uses vegetation maps combined with fire history data to classify landscape threshold status.

Using the tool on data from dry sclerophyll forests in the Blue Mountains after the 2019/2020 fires, the team highlighted the dramatic rise in the proportion of forest area that is now in a vulnerable state because consecutive fires have followed too soon after each other (Figure 2).

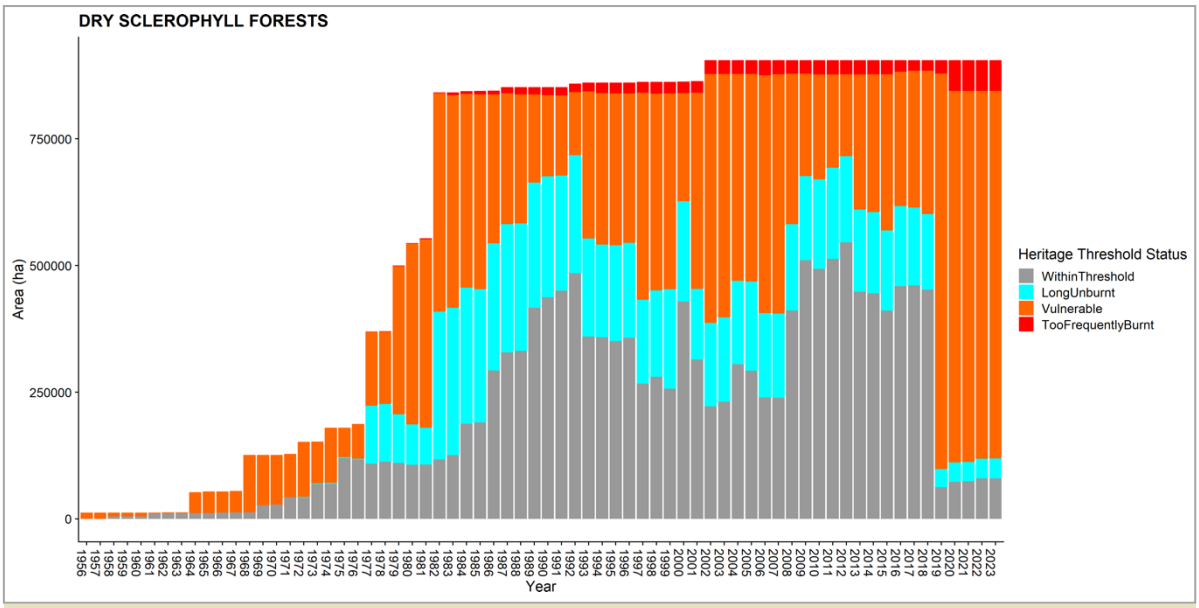

Figure 2. FireTools SDC time series analysis of vegetation status in dry sclerophyll forests in the Blue Mountains from 1956 to 2023.

This team used FireTools SDC to produce analyses for the NSW Bushfire Inquiry on fire progression and weather, and on patterns of fire severity in relation to past fire, weather, and land use. The data showed that previous hazard reduction burns in an area had limited ability to reduce the severity of fire in these bushfires. How severe past fires had been at a site did not influence the probability of severe fire in the 2019-20 season, but a fire in the past 5-10 years did reduce the probability of a severe fire, demonstrating that recent hazard reduction burning can have an impact on bushfire severity.

PhD student Todd Ellis conducted research into the fuel moisture threshold component of fire regimes using a global-scale climate reanalysis and burnt area dataset. He identified 10% as the critical threshold below which fires tend to spread, and that in all regions of the world the proportion of fire season days that are below the threshold are increasing. The trend in Australia is less severe than other world regions.

Future Research Directions

Recommendations for future research include the development of more sophisticated mapping of past fires and the response of biodiversity to fires. The current *FireTools* is a good starting point, but more nuance is needed, including:

- Incorporating the thresholds for fire season and fire severity (e.g., thresholds based on time since spring fires, or summer fires or severe fires), emerging from WP4; and
- Mapping threshold status for finer features than vegetation formations, including vegetation classes, threatened plant communities, or individual species.

2.2. Fuels (Work Package 2)

Aims

The overarching aim of this work package was to improve our understanding of the way bushfire fuels vary over time: how they are consumed by a bushfire, how they recover, and how this varies according to fire severity and vegetation type. Researchers produced a series of models, creating a biophysical framework by which to better understand and analyse fuel and carbon storage in reference to fire, especially with regard to how fuel accumulates after a fire. To achieve this they used a combination of field data, high resolution remote sensing and pre-existing models of post fire recovery. This was used to improve models for fuel dynamics that can be used for fuel mapping and bushfire operations. There are several kinds of fuel, most importantly fine fuels such as leaves and twigs that drive fire behaviour and woody fuels that comprise most of the fuel mass.

Team leaders: Matthias Boer, Rachel Nolan, Chris Gordon, Western Sydney University

Key Findings, Applications, and Impacts

The fuel consumption study established the benchmark for estimating the amount of fine and woody fuels consumed in forest fires of different type and severity. All fires consumed the vast majority of surface fine fuels, but woody consumption dominated the total consumption and was higher at higher fire severities and for wildfire > prescribe fires > cultural burns. Pre-fire fuel load was the most important predictor of post-fire fuel load. Fire severity was also associated with increased tree mortality and so transfer of carbon stocks from living to dead carbon pools. However, there were marked differences among forest types. Specifically, the driest forest type had the highest rates of canopy top-kill following high severity fire.

The project showed high severity fire had greater impacts on forest structure than low severity fire and that drought stress resulted in poor post-fire recovery. Models of shrub fine fuels developed by WP2 make estimating shrub fuel loads over large heterogeneous areas easier and more accurate. WP2 identified key drivers of bark-type distributions and produced fine-scale bark-fuel type maps which will be of use for fire behaviour prediction and prescribed fire management.

Applying all of these results to account for burn heterogeneity, and fire severity effects on bark fuels led to improved predictions in the PHOENIX fire simulator, used in NSW to predict fire spread in fire operations.

Future Research Directions

The research in this work package concluded that fuel amounts, the way fuel burns and how it builds up again are complex processes that need continuing exploration.

- A more accurate estimation of how tree mortality varies according to fire severity and species is needed, given that this is the area of most uncertainty in fuel dynamics.
  This is especially true given that trees are the main source of above-ground carbon,

and the dominant habitat in forests.

- Drought has emerged as a key driver of tree mortality and bushfire risk. More research is needed into the interaction between drought, vegetation health and flammability.

- Similarly, the research has shown that fuel moisture is a critical driver of fire behaviour and has developed promising methods to track and map moisture across the landscape. At present, none of these advances are incorporated into bushfire risk planning and response systems. There is a need to research how better to map various aspects of fuel moisture and how to operationalize them.

- Fuel recovery after fire depends on the nature of the fire, vegetation type and post-fire conditions. Research is needed to improve our ability to model these varied patterns and hence produce dynamic fuel maps across broad regions.

2.3. Smoke (Work Package 3)

Aims

Both wildfires and prescribed fires produce smoke containing particulate matter (PM – small particles that can be detrimental to humans, other animal life and plant life) as well as greenhouse gases. $PM_{2.5}$ was the particulate size of most concern – fine particulate matter with a diameter of 2.5µm or less.

This work package aimed to determine prescribed burning strategies that would result in less greenhouse gases overall and less particulates over major population centres of NSW (Figure 3). How do wildfires and prescribed fires compare and could planned fires be used to reduce overall emissions by limiting wildfire? (More smoke today for less smoke tomorrow?) The ultimate aim was to identify strategies for prescribed burning that minimise greenhouse gas emissions and exposure of humans to particulate matter.

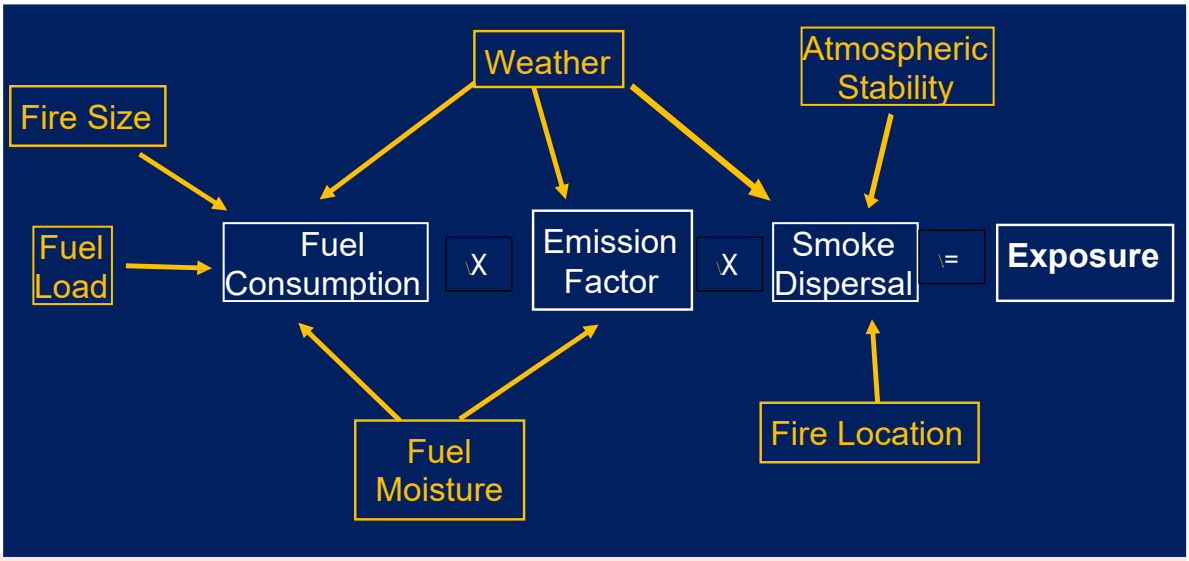

Figure 3. The information required to understand exposure from a pollutant from any particular fire is illustrated here. We must know how much fuel got consumed, how much got turned into the pollutant and where that pollutant dispersed to, in relation to where people live. Defining optimum prescribed burn programs requires integrating this equation for all the fires in a management scenarios: all the prescribed burns that are done and the bushfires that are anticipated to occur.

Team leaders: Owen Price, Michael Storey, Clare Murphy, University of Wollongong

Key Findings, Applications and Impacts

The work package showed that it was not the type of fire that had the biggest impact on $PM_{2.5}$ in Sydney but the *size* of the fire. The field work showed that prescribed produced less smoke per hectare than wildfires. However, larger fires produced less $PM_{2.5}$ per hectare. One of the analyses showed that whether a fire was a prescribed burn or a wildfire did not affect the amount of smoke that reached Sydney per hectare, but large fires produce relatively less $PM_{2.5}$ per hectare than small fires.

While larger fires caused higher pollution in Sydney, this was not a linear relationship

because large fire produce less per unit area than small ones when $PM_{2.5}$ per hectare of fire is factored in. This is thought to be for three reasons: (1) The power of fires increases with size, so that a larger fire produces a plume rising above the land surface; (2) Large fires have often occurred in wind conditions that blow smoke away from Sydney, such as easterlies that move smoke inland, or strong westerlies blowing smoke directly to sea; (3) HRBs are usually conducted in low wind for safety reasons, but wildfires are more likely to occur in windy weather. Though these conditions drive a bushfire, they also have the effect of blowing smoke through Sydney and out to sea.

Researchers concluded that increasing prescribed burning would increase the population's total exposure to landscape fire-generated particulates.

Future Research Directions

The smoke trade-off is an extremely complex issue, and the research so far has only provided the first indications of the overall impact of prescribed burning on smoke. There is still much to do. Some specific questions include:

- Identifying the best weather conditions for prescribed burns. More evidence is needed about the effect of burn size on smoke exposure. The Hub uncovered direct and indirect evidence that larger burns produce lower smoke impacts per hectare burnt, but the details and the reasons behind this effect need clarification. Also, further research is needed to balance this reduction in health risk with potential increases in risk in other areas (e.g., the possibility of such a fire escaping to other areas).
- Optimising the set of air quality measuring stations, especially to cover more rural areas (including testing a mix of reference quality stations and low-cost monitors). At present, smoky conditions in many parts of NSW go undetected.
- People's attitudes and adaptation strategies related to the smoke trade-off.
- The long-term health impacts of exposure to smoke either frequently at low levels or occasionally at high levels.

2.4. Biodiversity (Work Package 4)

Aims

The concept of 'Thresholds of Potential Concern', the 'fire regime niche' that suits a species in terms of frequency of fire, has been applied across the world to manage fire for biodiversity, including in NSW. While important steps have already been made to create listings of plant species and their TPCs in NSW, important information has been lacking about responses to fire for most species; despite their importance to conservation, TPCs were known for only a few well-studied taxa. Furthermore, the concept of the TPC was limited to fire interval – the shortest and the longest interval that could be tolerated by a species. This work package built on the NSWFRDB (NSW Fire Response Database) that collated ecological and life history traits to aid understanding of species fire response. These include traits such as:

- Seed dormancy type - what does it need to break dormancy and potentially trigger germination?
- Maturation age – how many years after a fire does it take before plants of a species start flowering and bearing their own seeds?
- Regenerative organ - can it resprout from fire and/or does it regenerate from seed?
- Response to fire severity - for instance is it killed by a severe fire or is recruitment affected by fire severity?
- Response to the season of fire – are mortality or recruitment rates affected by season of burning.

This work package aimed to improve three aspects of the problem:

- Gather field data on far more species
- Consider factors other than intervals between fires, such as the severity and season of those fires
- Build a database to store these traits and thresholds for each species, and the observations from which the values are derived

The work package was particularly focused on threatened species, and how these are affected by aspects of the fire regime not previously considered, such as season or severity of fire.

Team leaders: David Keith, Mark Ooi, University of New South Wales

Key Findings, Applications and Impacts

A new structure was designed for the Fire Response Database, to align with the NSW BioNet information platform that is administered by the NSW Department of Planning and Environment. The team developed an open-source web application, added priority traits and incorporated new design principles for better consistency.

The database was also expanded to include more species, more traits, and variation within species. Several additional modules were created, in line with new design principles and to enable the standardised capture of a wider range of relevant data. One of these is a fire

event module that can be used in the field to record details at the plot scale that might influence ecological responses. Other modules are the field sample module that can be combined with the fire event module to estimate time since fire; and the taxonomic module, which defines the standard nomenclature for a group of plants. These were major advances in both the content and utility of the Fire Response Database.

Much progress was also made in moving beyond fire intervals as the sole factor in identifying *Thresholds of Potential Concern* in fire regimes for the conservation of threatened plant species, to include thresholds in factors such as fire season, severity and spatial configuration. Key processes were identified that interact with fires and govern responses at population and species levels. These were: germination, growth, survival, reproduction, dispersal, and recruitment.

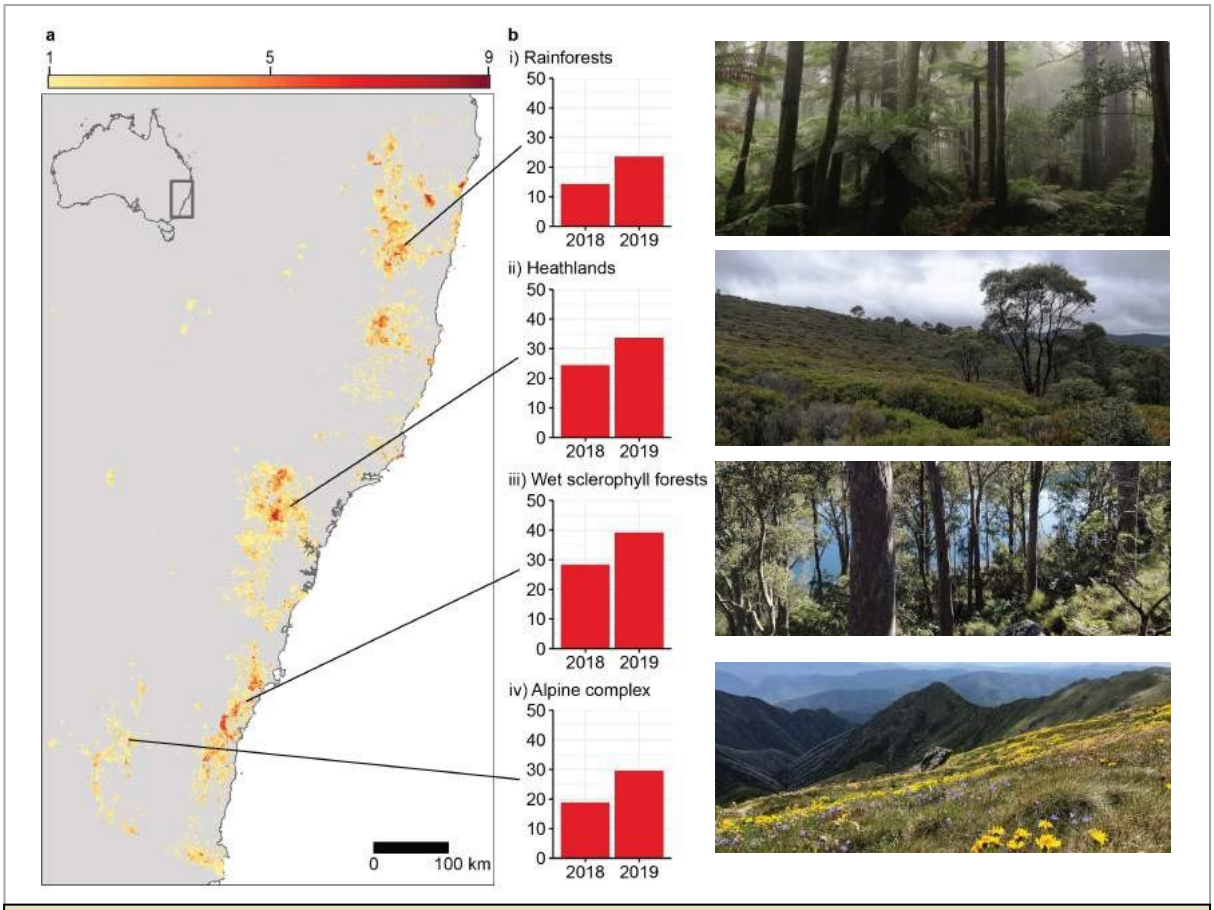

Figure 4. Fires which occurred sooner than minimal intervals from 1960 to 2020 across NSW. a) Mapped frequency of fires (1 to 9) below minimum intervals from 1960 to 2020. b) Percentage of total area (y-axis) that burned below minimum intervals at least once from 1960 to 2018-19 ('2018') and from 1960 to 2019-20 ('2019') (x-axis) for 4 vegetation formations: i) rainforests, ii) heathlands, iii) wet sclerophyll forests and iv) alpine complex.

This work package established a research program to target the question of how best to use managed fires for persistence of target species. It recommends a precautionary approach with regard to season of burn:

- Refer to season of burn response for a species, if available
- Avoid burning in the season that would cause the greatest decline in population
- Where data is not available, do not burn in the same out of season period more than twice in a row.

In response to the NSW Bushfire Inquiry, the team was asked to assess the impact of the 2019-20 bushfires, so it turned its focus to extreme fire events and how they affect biodiversity (Figure 4). It assessed 135 threatened species and eight ecological communities after the 2019-20 fires. It found that some threatened species have traits that make them more vulnerable than other species to extreme events, including, for instance, those that retain seeds in the canopy within thin-walled cones. Recommendations include prioritising such species in post fire recovery plans. Additionally, in locations where fires were severe, longer recovery periods without burning may be required for some obligate seeders with small seeds.

Future Research Directions

The fire response database will require decades of field work to complete, especially for animals for which only rudimentary data is currently available. This work will require the NSW DPE to partner with experts from around the country, in a similar model to the post-2019/20 bushfire research commissioned by the Federal Government.

This research and the NSW Bushfire Inquiry highlights the need for a comprehensive wildlife monitoring program to continually improve the TPC data for individual species.

Fire management will only work for biodiversity if it is tackled in conjunction with other threats that fire interacts with. Two that came to prominence after the 2019/20 bushfires were weed and feral animal management. There is a need to research those interactions and practical solutions to co-manage threats.

2.5. Exploring the wellbeing benefits of engaging in cultural burning (Work Package 5)

Aims

The overarching aim of this work package was to explore the wellbeing benefits of cultural land management practices, particularly cultural burning, and to identify ways to better support First Nations peoples to fulfil their aspirations to care for Country.

The approach builds on previous research that measured direct benefits for Aboriginal health and well-being by caring for Country in the Northern Territory. While that study considered this issue of re-engaging with Country in a broad sense, and analysed health markers such as BMI, blood pressure and type 2 diabetes status, the current project aimed to focus on cultural burning in a social research context, consulting with Indigenous communities through in- depth qualitative research methods to explore and document their perspectives.

The key objectives of this Work Package were to:

- Build relationships and trust with Indigenous communities
- Co-design research studies
- Document lived experiences of engaging in cultural land management
- Collect meaningful in-depth qualitative data
- Define wellbeing outcomes and indicators collaboratively
- Design and test wellbeing indicators
- Document cultural burning diversity
- Complete narratives of cultural burning

Team leaders: Kat Haynes, Vanessa Cavanagh, University of Wollongong

Cultural burning is also about cultural renewal for the teens who attended a workshop on the south coast.

Key Findings, Applications and Impacts

The work undertaken gave voice to numerous Aboriginal youth and elders and is an important step in disseminating and acting upon their perspectives. Overwhelmingly, respondents all discussed how cultural burning is a journey of healing people and the environment and is an extremely valuable pathway for connecting people back to Country. They agreed that engagement with cultural burning and connection to Country has significant benefits for spiritual, physical and mental health, increasing pride, confidence and resilience to life's knocks and stresses. Many expressed frustration and grief from the impacts of the 2019-20 fires.

Burning for resilience: A two-day workshop for Indigenous youth was held in June 2021. It was an Aboriginal-led community project in which local elders mentored emerging leaders who facilitated the workshop. The emerging leaders in turn mentored 24 Aboriginal teenagers, aged between 14 and 17. Participants were invited from four NSW South Coast schools - Batemans Bay, Nowra, Ulladulla and Bomaderry. Research data were collected through participant observation and a series of semi-structured interviews, some of which were captured as digital stories on video camera. The majority of the students had never done a cultural burn before and many discussed significant short- and long-term benefits in terms of their connection to Aboriginal culture, building identity and general wellbeing.

Links to wellbeing: From the analysis of over 20 in-depth qualitative interviews conducted by the team they designed a survey tool that can be used to measure long-term changes in wellbeing and connection to Country. It consists of two sets of questions, one to measure baseline wellbeing data before engaging in cultural activities and a second set to be used after a single event, or many times to measure longitudinal change in wellbeing from ongoing engagement with on-Country activities. Data from these surveys can be used to inform policy and practice to better support Aboriginal-led cultural land management.

LISTEN, BECAUSE COUNTRY IS SPEAKING: Thirteen key First Nations cultural burning practitioners/key stakeholders were interviewed in a semi-structured style, centred on Country. This project was a collaboration between the Work Package team and staff from the Cultural Fire Management Unit, DPE and its aim was to capture the views of key First Nations stakeholders to inform the development of the new cultural fire management unit within DPE.

Future Research Directions

Significant advances in understanding the wellbeing benefits have been made through this work package. Unfortunately, significant barriers still exist that continue to erode wellbeing and prevent First Nations people fulfilling their obligations to care for Country. As documented in the report completed for the Cultural Fire Management Unit, significant structural barriers remain that restrict access to Country, the repatriation of knowledge, and the building of real capacity.

2.6. Synthesis (Work Package 6)

Aims

The principal aim of this final work package was to integrate findings from the different themes of the Hub to produce models and frameworks that land managers can use in designing fire management. These models needed to consider the trade-offs between risks to life and property, a healthy environment, and the need to protect key values such as biodiversity and conservation.

Team leaders: Hamish Clarke, University of Wollongong, Trent Penman, University of Melbourne

Key Findings, Applications and Impacts

The team used 13 different landscapes as case studies and created virtual representations of these that could then be used in simulations (virtual experiments) centering on the amount of prescribed burning and in what landscape patterns.

The landscapes, each of around 200,000 hectares represented a range of vegetation types, climate zones, land use types, settlement patterns and fire regimes. They stretched from Casino in northern NSW to the southeast corner of NSW, and from the coast (such as Jervis Bay) inland to Broken Hill.

Researchers used the model, PHOENIX RapidFire, to simulate fire behaviour. Thousands of simulations for each landscape were run to show what could happen under different prescribed burning scenarios in terms of loss of human life, house loss, damage to infrastructure and to the environment. The models were also able to explore the financial implications of different strategies.

Simulations varied according to two measures: (i) the total area of prescribed burning in the landscape, and (ii) what proportion of that was allocated to blocks of land that were ‘edge’ (near houses) or ‘landscape’ (away from houses).

The researchers trialled a method to incorporate the effect of season of the prescribed burn into the trade-off analysis. To do that, the simulation output was reanalysed with longer tolerable fire thresholds to capture the effect that it takes longer to recover from a fire occurring at the worst time of year for any species.

The researchers trialled approaches to incorporate results from other work packages into the trade-off analysis. For instance, if prescribed burning is limited only to the season (time of year) with the least impact on sensitive species, there are complex and non-linear changes in the places with environmental impact. Incorporating the health costs of smoke leads to much higher total costs from prescribed burning.

Simulation outputs from four case studies were also reanalysed in light of the huge burn footprints of the 2019/20 bushfires to estimate the level of risk reduction those fires created and how rapidly risk will rise again. In Jervis Bay (south coast) bushfire risk was 25% of the pre-2019 level, rising to 40% by 2025, while in Casino (sub-tropical north), risk was 75%, rising to 80% by 2025.

In summary, the key findings are that optimal management needs a case-by-case approach

and that prescribed burning mitigates risk of fire but cannot eliminate it. In addition, there is a need to recognise that trade-offs in fire management cannot be avoided, since in some cases reducing the risk to one kind of asset (for instance property and infrastructure) may increase the level or risk to others (such as biodiversity, human health, and ecosystem services).

- There is no 'one size fits all' when it comes to prescribed burning – tailoring solutions is needed.
- The effectiveness of prescribed burning in altering the severity and behaviour of a future bushfire is influenced by weather, fuel moisture, drought, vegetation type, topography, time since the prescribed burn, and how much fuel was removed or modified. Effectiveness may also vary from region to region.
- Prescribed burning may have little or even no effect when weather conditions are extreme.
- When planning prescribed burning, all 'assets' (often referred to as 'the things we care about') need to be explicitly recognised and weighed up; these assets are all affected by both bushfire and prescribed fire.
- Climate change acts by many pathways to drive bushfire risk: fuel, fuel moisture, ignitions and weather, including the frequency of extreme weather conditions.
- There is a need to develop a respectful relationship with Aboriginal burning and support Aboriginal-led burning and cultural renewal.

Future Research Directions

The WP6 risk modelling provides a powerful framework for comparing different prescribed burning strategies in terms of their costs and benefits for multiple objectives and made some progress toward incorporating values determined by other work packages. This is an ongoing process and more research is needed to improve the framework and the addition of new values. Specifically:

- Biodiversity values need to be better represented by incorporating fire seasonality and severity and the fact that species with different fire niches occur at the same site.
- Smoke impacts need to be more comprehensively incorporated into the framework.
- The value and implications of cultural burning need to be incorporated into the framework.
- These improvements may best be served by developing new modelling approaches.

3. Outputs

3.1. Development of and evaluation of tools

The Hub improved several tools, creating faster, more capable versions. Stand-out examples are FireTools and FireToolsCloud for planning where and when to apply prescribed burning, and the Fire Ecology Traits for Plants database.

The Hub designed a survey tool designed to measure how wellbeing of Indigenous people benefited from engagement in on-Country cultural activities. The survey measures baseline wellbeing data before and change after the event. The intention is to use it repeatedly to measure long-term change in wellbeing from ongoing engagement with on-Country activities.

Other stand-out examples are the validation of the RFS smoke prediction system and the Global Fuel Moisture and Dry Fuel Moisture mapping tools available through the Hub website.

3.2. Summary of research outputs

The Hub communicated its research outputs in many ways. Numerous papers were published in high-ranking international journals and published as chapters in edited books and reports. Many researchers contributed to global discussions on the future of fire management, influenced strategies for managing bushfire and prescribed burning, and contributed to research on cultural burning. In summary, its outputs included the following:

- 185 refereed journal articles
- 23 conference presentations
- 5 articles for *The Conversation*
- 9 webinars
- More than 40 media interviews
- A short film, *Cultural Burning for Resilience, The Mini-Documentary*
- Four Friends of Fire comic
- Comic on fuel dryness
- Bushfire science animation
- Youth-led workshop, Cultural burning for resilience, Ulladulla
- FireNotes: 10 brochures summarising Hub findings.

3.3. Contribution to NSW Bushfire Inquiry

After the 2019-20 fires the Bushfire Hub suspended research projects for five months to prepare an analysis of the nature, causes and consequences of these fires in response to requests from the NSW Bushfire Inquiry. The value of this work was explicitly recognised

The 2019-2020 Bushfires in Summary

- 11, 744 fire incidents
- 5.5 m ha burned
- 26 lives lost
- 2476 homes destroyed
- $899m infrastructure lost
- $43m telecommunications lost
- 601, 855 ha of pasture damaged

(Source: Final Report of the NSW Bushfire Inquiry, 2020)

by the Inquiry. See https://www.nsw.gov.au/departments-and-agencies/premiers-department/access-to-information/nsw-bushfire-inquiry

The analysis of this fire event was presented to the NSW Bushfire Inquiry in various ways, covering all aspects of the Hub's expertise including human impacts, the importance of cultural burning, the effect of the fires on biodiversity, fire severity and spread, fuel dryness and future risk analysis.

- It ran a series of seminars to share and discuss research on key facts of the 2019/20 fires such as area burnt, severity, weather patterns and effects on biodiversity. The seminars explored causes, lessons learned and options for future bushfire management.
- The Hub also produced 19 reports looking at future risk, ecosystem impacts, fire threshold impacts and the impacts on plant species. All of the work package teams contributed to the series, which was comprehensive in its scope. Other subjects included fuel hazards, smoke, cultural burning, fire severity and spread and asset loss.
- An important finding was that the causes of the extent, intensity, speed and destructiveness of these unprecedented fires were record-breaking drought and extreme fire weather, not the build-up of fuel.
- Modelling from Work Package 6 showed that any reductions in future wildfire risk due to the 2019-20 fire season are partial and temporary. Even with reduced fuel loads some residual risk remains. Often this risk is substantial and over the next six years is predicted to increase, in some cases returning to or even exceeding pre- 2019-20 levels. There is a limit to the amount of prescribed burning that can be undertaken if vegetation is to remain within its tolerable ecological threshold after the 2019-20 fire season.
- The potential for risk reduction was found to vary considerably across different landscapes and case studies due to the geographic patterns of natural features such as vegetation and assets such as housing or biodiversity.
- Because such a large area was burnt, the potential to surpass ecological thresholds is heightened and the researchers recommends capping prescribed burning at 2-5% depending on the landscape.

4. Lessons learned

The Bushfire Hub produced holistic research outputs because it was clearly focused on one theme: how to use prescribed burning to achieve multiple benefits. The research output was significant, with 185 scientific papers and dozens of more public communication such as radio interviews. The practical outcomes of the research are harder to measure because recommendations take a long time to become embedded in practice. Despite this, some of the tools and recommendations are already being used by fire management agencies.

The governance structure of a steering committee consisting of representatives of the researchers, agencies and independent experts and more technical working groups for each work package operated well. This facilitated both the smooth flow of the research and the agility to change focus where needed. Professional connections among the researchers and between researchers and staff in the agencies were greatly strengthened, and these connections have carried forward to developing highly collaborative teams and projects in the successor to the Hub: the NSW Bushfire and Natural Hazards Research Centre, established in 2023.

The NSW Government commissioned an evaluation report from consultants ACIL Allen (June 2022). The report commended the Hub for:

- The wide range of high-quality research produced
- Leveraging additional funds (approximately 4:1)
- Contributions that formed the backbone of the 2019-20 Bushfire Inquiry report
- The practical tools, in particular, FireTools.

On the other hand, the report identified problems with:

- The research not being sufficiently focused on practical outputs
- Translating research into practice, and in particular, not having a clear program logic or framework for that translation
- Finishing the research projects, which was partly due to staff leaving before the end of the Hub because of career uncertainty.

The Department has taken this feedback into account in the design of the second research centre.