Bushfires and Knowledge

Forest, Fire and Regions Group
Science Catalogue 2019–20

VICTORIA State Government | Environment, Land, Water and Planning

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Foreword

Now in its fifth iteration, the annual Forest, Fire and Regions Group (FFR) Science Catalogue provides an overview of our current science research program.

The catalogue showcases projects by theme, enabling us to share knowledge, encourage conversations to support management decision-making and highlight the innovative ways in which our science has been integrated into policy and operational management practices.

With investment or leverage in scientific research valued at more than $5 million a year, our program includes projects in forests and bushfire, as well as environmental compliance and the modernisation of Victoria's Regional Forest Agreements.

The 2019–20 fire season has been significant and the collaboration and partnerships formed through FFR's research program have been instrumental in providing up-to-date and timely access to information and modelling, data and maps, and real-time support. These partnerships and the way in which science and innovation have been integrated into our policy and operational practices are highlighted through case studies.

These case studies remind us that ongoing investment in science is pivotal in ensuring we continue to improve our understanding of forest management on public land in Victoria.

CREDIT: **Salahuddin Ahmad.** DELWP.

SECTION 1

The Forest, Fire and Regions Group Science Catalogue 2019–20

CREDIT: **Gary Sheridan.** University of Melbourne.

Integrating science with policy and operations

The Integrated Forest Ecosystem Research (IFER) Agreement is a long-term research agreement between FFR and the University of Melbourne. Since 2010 this collaboration has made a significant contribution of evidence to shape a range of contemporary FFR policies and management practices.

Today we are better informed about the design of planned burning regimes to benefit biodiversity and minimise carbon loss. We have improved the predictability of bushfire behaviour so that suppression is better targeted to minimise environmental, social and economic damage; and we have developed risk assessment tools that enable better prediction of post-fire water hazards, such as contamination, debris flows and flooding.

Robust science, models and datasets provided a unique opportunity for the University of Melbourne and FFR to build an integrative approach to landscape scale, land-management decision-making. The Landscape Decision Support System (DSS) outlined below was initiated in 2017 and is now firmly embedded in each IFER project.

The IFER program is committed to providing an integrated and cohesive evidence base for forest science and management to support: comparisons of multiple forest values, spatially based decisions, forward-looking decisions and quantification of uncertainties.

CREDIT: **Salahuddin Ahmad.** DELWP.

Table 1. **Integrating science with policy and operations – current projects**

Project title	Description	Management outcome
Landscape Decision Support System (DSS) 	The DSS recognises and emulates the drivers of change in Victoria's forested landscape and brings world-class science into a scenario-modelling framework. The framework enables land managers and communities to interactively explore potential changes in multiple forest values arising from policy interventions and key external drivers at landscape, regional and state-wide scales. These interventions include the use of fire, extraction of forest products, management of pests and weeds, habitat maintenance and restoration, other land-use practices and engagement with communities. The DSS prototype is due early 2020 and will be refined and expanded over the next three years by: • extending its focus from the Central Highlands of Victoria to other forest landscapes • developing and integrating a broader set of scenarios based on community and stakeholder consultation • examining and recommending ways to present multiple risk metrics to stakeholders and communities • improving the useability of the DSS interface in response to feedback from FFR users.	The DSS provides an interface for land managers to explore the impacts of natural drivers and policy interventions on multiple forest values. It supports FFR to identify the best policy interventions to achieve outcomes for Victoria's forests that are environmentally sound and publicly acceptable. The DSS will: • inform decision-making processes • incorporate values of a broad range of stakeholders • provide scenarios to reflect alternative management objectives and/or actions • deliver forecasting of biophysical, social and economic values over tactical and strategic time periods • enable transparent communication of modelling output alternatives • provide for the exploration of adaptive management within the decision-making process • have a user-friendly interface. **Completion date:** June 2022

CASE STUDY:
LEVERAGING OUR RESEARCH

More than just research

A critical component for any research program is the add-on value to Victorian communities for government investment. This "leverage" is where cost-free additional resources, services or other contributions are provided to Department of Environment, Land, Water and Planning (DELWP) research to supplement and strengthen our science.

Leverage can include:

- expert advice and elicitation – professional advice in response to a request from DELWP for science evidence on an emerging issue
- grants and co-funding – where DELWP funds are used to support a grant proposal, such as an Australian Research Council (ARC) Linkage program, which if successful, provides additional funds of at least the same amount as DELWP contributes
- partnerships, consortium approaches and links to other research – delivers extended expertise, connections to other research work, and other relationship benefits; represents a greater opportunity for high value science and benefits DELWP by bringing all the available expertise in a field together, building on existing quality science or the potential to quickly access expert review of research work
- student participation – postgraduate students on a research project develop expertise, increase operational capability and provide diversity. In most instances they are supported by stipends from the Commonwealth, universities or AusAid. In some instances, they are training for future DELWP employment, bringing skilled workers into the Victorian Government
- in-kind staff and operating – services provided to the research by the institution at no cost to DELWP, including staff, operating and/or resources and administrative overhead reductions.

Real value

In real terms, leverage provides a direct benefit to DELWP's research program and demonstrates our research partners' commitment to delivering world-class evidence to support our decision-making.

In 2012, DELWP formally established the Integrated Forest Ecosystem Research agreement with the University of Melbourne (although it has been operating in principle since 2010). Over its lifespan, this program has delivered research that has helped to shape a range of DELWP policies and management practices. We are now better informed about the design of planned burning regimes to benefit biodiversity and minimise carbon loss; we have improved the predictability of bushfire behaviour; and we have risk assessment tools that enable better prediction of post-fire water hazards, such as contamination, debris flows and flooding.

In 2019, DELWP and the University of Melbourne conducted a review of the program to ensure it remains targeted and effective at delivering science that enables better decision-making. As part of this review, we looked at the leverage provided by the program and identified that over ten years an additional $15 million in resources, not funded by DELWP, had been provided to the program:

- ARC Linkage Program (seven projects) $3 million
- other grants (22 projects) $8.1 million
- PhD student funding $3.9 million.

At the same time, DELWP accessed real-time scientific advice to support emergency response to bushfires, answered questions about carbon accounting, responded to emerging biodiversity threats from bushfire and a suite of other issues.

What projects did the ARC help us fund?

Using fire to manage biodiversity in fragmented landscapes (Professor Alan York lead)

New methods for mapping variation in forest water use in time and space (Professor Pat Lane lead)

Predicting extreme erosion and sediment delivery from upland forests (Professor Pat Lane lead)

Remotely sensed forest water uses in space and time (Professor Pat Lane lead)

Defining the intangible: incorporating contested social values into native forest management (Professor Kathryn Williams lead)

Incendiary cultures: co-constructing resilience to engage with fire and risk in landscape management (Dr Ruth Beilin lead)

Reversing the loss of Leadbeater's Possum habitat (Associate Professor Craig Nitschke lead)

Working in partnership with communities

FFR investment in research to better understand the values, perceptions or risk, and tools for improving interactions in Victorian communities has been pivotal to us understanding and improving how the sector interacts with communities. Independently and in collaboration with Victorian emergency sector partners, FFR has invested in research with the University of Melbourne, LaTrobe University and Risk Frontiers.

For example, a group of projects with the University of Melbourne have built on each other to develop concepts and approaches for measuring values in different contexts, and strategies and guidance for incorporating these values in decision-making. This program of research now enables FFR to seek practical ways to apply our understanding of values to decision making, and to evaluate how this might support elements such as objective-setting, analysis of impacts, community engagement and moving towards decisions.

Table 2. **Working in partnership with communities – current projects**

Project title	Description	Management outcome
Understanding social licence for forest management in Victoria	This research will focus on addressing two barriers: the lack of scientific knowledge around the impact of forest management on key social values, especially fewer tangible values; and challenges with integrating diverse forms of knowledge in fire and forest decision making. The project will research: • the impacts of changing forests and adaptive forest management on public values • community perspectives on adaptative forest management strategies • knowledge cultures, expectations and relationships that shape social licence.	Through this project FFR will have: • data on impacts that can inform future forest policy and strategic planning for climate adaptation • data that will improve models of experiential values underpinning the IFER DSS • an understanding of relational factors influencing social licence to strengthen DELWP's community charter and the *Engage@DELWP* framework • improved capability to plan and engage staff in appreciating and incorporating diverse forms of knowledge in decision making. **Completion date:** June 2022

CASE STUDY:
SMOKE MODELLING

Collaborating on a complex problem

Driven by DELWP's responsibility to deliver a planned burning program for bushfire risk mitigation – in a manner which also minimises risk to the population from smoke exposure – FFR started investing in research and model development for smoke emission and transport in 2012.

Although smoke management research programs began in the early 2000s, a 2008 survey of smoke system users highlighted the value of a more detailed and quantitative smoke forecast model, laying the foreground for a smoke emission and transport model, the Air Quality Forecasting System (AFQx).

Planned burn windows can coincide with poor smoke dispersal conditions and the potential for microscopic airborne particles to persist in the air for an extended period, reducing air quality. Therefore, better understanding of smoke emissions and particle transportation can be used to reduce community impact and improve management practices such as the scheduling of planned burns and issue of community health warnings.

Established with funding from DELWP, which also committed relationship support and sector technical expertise, the research delivery was led by Commonwealth Science and Industrial Research Organisation (CSIRO) in partnership with the Bureau of Meteorology (BoM). The University of Melbourne, Monash University, Macquarie University and Wollongong University also contributed to the project.

Throughout the development phase stakeholder involvement included the:

- Environment Protection Authority (EPA)
- Department of Health and Human Services (DHHS)
- Australasian Fire Authorities Council (AFAC).

The AFQx model was supported by DELWP, CSIRO, BoM and AFAC throughout its development, use and hosting, and as it transitioned to operational use.

While FFR identified the drivers for the research, it was through the input of stakeholders from across emergency sector agencies and research organisations that the full needs of the system's design were identified, and the work scoped.

Through workshops and interviews, an understanding of operational procedures for planned burning was used as the foundation to identify where contemporary science and modelling systems could be used to improve the program. At the same time, knowledge gaps were identified that could be addressed during project planning.

Accountability to government and community

Although newly established, this research provided advice and direction for improvement following the Hazelwood mine fire in 2014 and subsequent Inquiry. Project fact sheets, briefings and reports to Inspector-General for Emergency Management, helped answer community and government concerns and ensured learning and improvement followed. Through model demonstrations and meetings about the needs of the sector, stakeholders had the opportunity to interact with the model, comment on its development and be included in a trial of the model.

In 2018, DELWP, CSIRO, BoM, the Victorian Predictive Services Board and AFAC began using AFQx, which provided the emergency sector with capacity to model the spread and accumulation or dispersal of smoke for planned and unplanned fire.

Evaluation of smoke forecasts during periods of heavy burning shows AQFx is useful for predicting the spatial and temporal variation of smoke and air pollution. The model is now fully operational in Victoria and is being rolled out nationally by AFAC and BoM.

Research making a difference

Without AQFx, Victoria would not have the knowledge required to make informed decisions about managing smoke from planned burning operations. It has provided planned burn coordinators with predictions of smoke dispersion that enables state wide management of both planned burn numbers and timing of ignition to manage air quality.

FFR and the CFA are now collaborating to investigate using AQFx to manage smoke impacts from all forest and agricultural burning in Victoria. FFR is also developing more robust procedures and guidelines for practitioners with regards to smoke management. AQFx is a crucial product in the suite of tools available.

Smoke modelling

The smoke emission and transportation model, Air Quality Forecasting System (AFQx) developed by CSIRO, BoM and other institutions in partnership with DELWP has enabled emergency sector partners to better understand smoke impact on communities and industries. Building on AFQx, the current suite of research projects will work on validating and calibrating the models and continue to improve DELWP's understanding of community health impacts and thresholds for smoke.

Table 3. Smoke modelling – current projects

Project title	Description	Management outcome
Smouldering: Improved quantification of emissions and plume rise to improve the forecasting of smoke levels and better provide health protection messaging (ERP 20)	This project will improve AFQx by improving planned burn emissions and plume rise data inputs during the smouldering phase. This will result in more robust and accurate smoke forecasting and assist in health protection messaging.	Improving AFQx will help support decisions around whether and where to conduct planned burns, reducing the risk of bushfires and planned burns, which can negatively impact communities through smoke emissions. : **Completion date:** December 2020
ARGOS plume model review of South West fires (ERP 21)	This project will reconstruct the emissions and downwind concentrations of PM2.5 from the March 2018 Cobden peat fires to determine the level of accuracy from the plume modelling and air quality forecasting systems during the incident. The reconstruction will identify areas of improvement for algorithm and input data in the models.	Identifying areas of improvement to the AFQx model following the Peat fires at Cobden, Victoria in March 2018. **Completion date:** May 2020

Bushfire prediction research

FFR has a strong commitment to better understanding and predicting bushfire. Our investment in the Phoenix RapidFire fire behaviour and simulation model has transformed bushfire management decision-making in Victoria. Phoenix makes a direct and ongoing contribution to bushfire management policy and operations, including community warnings and engagement, and resource allocation and planning both before and during bushfires. Improving this model and increasing the accuracy of its modules will improve predictions of individual fires; have flow on effects in improved operations, including community warnings; and improve the efficacy of the many tools that use Phoenix RapidFire as inputs.

By improving Phoenix RapidFire and developing new and innovative modelling capacity, DELWP's commitment to investment in bushfire prediction modelling continues.

Table 4. **Bushfire prediction research – current projects**

Project title	Description	Management outcome
Identifying planned burn windows (ERP 9)	Planned burning, as one mechanism for fuel management on public and private land, is an important way to protect communities and natural environments in Victoria from the negative impacts of bushfire. This project will analyse data collected since 1972 to optimise the planning and delivery of the planned burning program and provide greater understanding of planned burning windows available on a daily and seasonal basis.	Evidence to enhance delivery and broader seasonal planning of planned burn operations, through: • greater understanding of trends and variability in burn window availability, interactions • planned burn prescriptions and evidence for seasonal planning. **Completion date:** September 2019 *This project is funded under Safer Together, supported by FFR and led by both FFR and the CFA.*

Project title	Description	Management outcome
Effectiveness of resources to suppress bushfire: Aerial and ground based (ERP 12)	This project will evaluate the effectiveness of a wide suite of fire suppression techniques and practices, such as aerial and ground-based techniques, and the development of a conceptual suppression effectiveness management tool. It will identify the knowledge, methods and data requirements currently used, or under consideration, internationally, nationally, and within Victorian fire agencies. Recommended data requirements will help to ensure this tool is statistically robust, as will testing and evaluating the tool over a fire season.	Improved evidence and understanding of how effective fire management agencies are at suppressing fire will enable more effective fire management responses and reduce the impact of fire on communities and the environment. By exploring the effectiveness of resources to suppress bushfires from both the air and the ground, Victorian bushfire management agencies will be able to identify potential inefficiencies and make recommendations to improve efficiencies. **Completion date:** December 2020 *This project is funded under Safer Together, supported by FFR and led by both the CFA and DELWP.*

CREDIT: **Amy Smith.** University of Melbourne.

Project title	Description	Management outcome
Development of seasonal fire prediction tools (ERP 14)	The tools currently used to produce the seasonal fire forecast *Southern Australia Seasonal Bushfire Outlook*, limit its ability to be: • both readily updated and verified through the fire season, and • able to meet decision-making needs of fire agencies and communities. This project will review, and clearly define, the needs of fire agencies in Victoria for the development of new seasonal fire forecasting products, which will be used for a variety of strategic decision making and risk assessment functions.	A clearly defined needs analysis that enables Victoria to: • direction set the development of seasonal fire forecast products • answer key questions on the frequency, visualisation and acceptable levels of uncertainty of the seasonal fire forecasts. **Completion date:** October 2020 *This project is funded under Safer Together, supported by FFR and led by both the CFA and DELWP.*
Cropland fire behaviour (ERP 15)	Crop fires cause significant losses each year – yet their spread is not clearly understood and current fire modelling tools aren't accurate in predicting crop fire behaviour. This project will: • conduct experimental burns to develop a baseline for measuring fire spread on cropland • consider a variety of factors, including whether harvesting has occurred and crop row orientation in relation to the wind.	Through the development of a cropland fire behaviour model, this project will: • provide improvements in predicting and modelling cropland fire behaviour, which will • provide a basis for improved community risk communication and cropland fire response by agencies. **Completion date:** June 2020 *This project is funded under Safer Together, supported by FFR and led by both the CFA and DELWP.*

CASE STUDY: HYDROFIRE – ASSESSING POST-FIRE WATER RISKS

In Victoria's unique natural environment, the impact of bushfire can be significant, especially on water.

Post-fire debris flows, the most common cause of major water contamination events after bushfire and flash flooding are common for several years after a bushfire in Victoria. They can be extremely destructive – damaging infrastructure such as buildings, roads and bridges, and in the worst cases, lead to loss of human life. This was evident in 2003 when a post-bushfire fire debris flow in the Buckland Valley in Victoria's North East (>1.2 million ha) resulted in a person dying. Montecito, California has similar post fire conditions to Victoria. In 2018, 25 people died as a result of post-fire flash flooding and debris flows in Montecito -– more fatalities than the direct impact of the fire itself.

While debris flows are mostly generated on public forested land, the impacts are distributed more broadly, affecting waterways, water supplies and communities. DELWP recognises that post-fire recovery efforts require a rapid assessment of community needs and post-fire risks. To do this requires tools to identify specific assets at risk, such as water supply reservoirs, buildings, communities, roads, or threatened aquatic species. This informs response planning, such as protection of at-risk assets, the timely provision of appropriate warning advice and the temporary provision of alternative water supplies.

Innovation that improves community outcomes

To do this DELWP has collaborated with the University of Melbourne which has brought world class science to a real-world problem, developing a user-friendly hydrogeomorphic risk model HydroFire to assess the risk of post fire flash floods, water contamination and debris flow impact.

HydroFire has been developed and deployed so that it can: easily integrate into a variety of operational environments, including strategic burn planning, broadscale post-fire risk assessment; and target impacts on high value assets such as Melbourne's water supply and community infrastructure.

HydroFire is now used routinely in operations every fire season by DELWP's Bushfire Rapid Risk Assessment Teams (BBRATs) to provide recovery advice and issue warnings.

Each time the model is used at a bushfire, information is collected to ensure we fill gaps in our knowledge and improve the model for use at the next bushfire. The latest research findings are incorporated to periodically update the risk models.

Developing HydroFire

Early research to understand the magnitude of the impact of fire on water quality in Victoria revealed enormous variability across the state; some areas experienced extreme erosion and water contamination events, while in other areas, the impacts were minor. We learned that post-fire debris flows, previously a little-known process in Victoria, were a frequent occurrence. Further investigation showed that these flows dominated post-fire impacts on water quality and were an important factor in infrastructure damage and community safety.

As a result, the University of Melbourne research team focused on this high-magnitude erosion process, asking why did debris flows occur in some places and not others, how likely were they to occur, and, how big would the erosion events be when they did occur? These questions have been answered in some parts of Victoria, however uncertainty remains for areas that have not recently been burned, and therefore where post-fire runoff and erosion has not been measured.

Critically, the research team understood that the "usability" gap between the work researchers produce and DELWP's need to inform decision making in a timely manner, needed to be closed. Complex, often highly specified research outcomes needed to be synthesised, with a broad contextual basis, in a very tight timeframe to respond to a rapidly evolving bushfire management environment.

To overcome this challenge the research team began by analysing DELWP's critical needs in delivering this risk assessment, considering the organisational and operational constraints, such as time, resources, skills and continuity.

For example, the post-fire risk models created needed to encapsulate the latest science. They also needed to be simple and robust enough to be implemented reliably in a timely way by staff with a typical level of technical skill and resources at their disposal. Incorporating this perspective early in the HydroFire model specification ensured an optimal balance between the technical detail of the science and the usability of the new knowledge. Creating a model structure within HydroFire that enables new research to be periodically integrated, without increasing the model complexity, has also assisted the rapid integration of new science into practice.

The development of long-term research relationships between the University of Melbourne and DELWP was essential to the delivery of HydroFire. It provided the stability to pursue long-term research and an environment for two-way feedback critical to understanding the operating environment and enabling the knowledge and innovation that delivered HydroFire.

The rapid integration of new science into FFR policy, planning and operations has been a highlight of this research.

Read the National Public Radio USA article on this collaboration, published February 2020. https://www.npr.org/2020/02/10/803669266/with-australia-s-hillsides-stripped-bare-by-fire-scientists-work-to-predict-mudf

Selected References

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HydroFire was developed through a research project – *Developing methods to assess post fire risks of flash flooding, water contamination and debris flow impact* delivered by the Integrated Forest Ecosystem Research (IFER) program between FFRG and the University of Melbourne.

CREDIT: **Salahuddin Ahmad.** DELWP.

Table 5. Associated fire management, predictive and behavioural research – current projects

Project title	Description	Management outcome
Planned burn mapping in Victoria using remote sensing (Sch 22)	This project will identify and develop future management options and technologies for planned burn mapping. It will capture changes in time and space, including horizontal and vertical changes in vegetation structure, using remote sensing technologies.	The severity mapping will improve DELWP's capability to repeatedly and reliably map and report on planned burning outcomes, as a critical input into a risk-based approach to strategic bushfire management planning. **Completion date:** September 2019
User interface platform for the Victoria historical fire weather-gridded dataset (ERP 10)	This project will develop a user interface to facilitate access to the historic fire weather-gridded dataset developed in collaboration between DRI and Monash University, funded by DELWP. This dataset has many applications and is currently located on a database with limited capacity to service the wide range of end-users seeking access. These include regional and district risk analysts from all agencies. The project will design and test a user-friendly data platform for the interface and develop online training for the wider user base.	The development of an easily accessible user interface platform for the Victorian historical fire weather-gridded dataset will inform risk tools for strategic, tactical and community engagement purposes and be used by Victorian bushfire management agencies. **Completion date:** December 2019 *This project is funded under Safer Together, supported by FFR and led by both FFR and the CFA.*

Project title	Description	Management outcome
Creation of a Grass Fire Danger Index (GFDI) dataset (ERP 13)	The existing fire weather-gridded dataset for Victoria includes multiple weather variables and Forest Fire Danger Index (FFDI) outputs; however, it does not provide outputs for grass fire danger. This project will develop an historical GFDI dataset to complement FFDI and to improve understanding of the entire Fire Danger Rating system. This will be achieved by combining a curing dataset derived from archived satellite data with the Victorian historical fire weather data. This will complete the fire weather-gridded dataset to allow for analysis of historic bushfire risk.	By creating a GFDI dataset, fire agencies will better understand grassland fire danger and improve their understanding of the fire danger rating system. This will complete the fire weather-gridded dataset and provide fire managers with a useful resource for research, planning and preparedness. **Completion date:** December 2019 *This project is funded under Safer Together, supported by FFR and led by both the CFA and DELWP.*

CREDIT: **Salahuddin Ahmad.** DELWP.

Project title	Description	Management outcome
Relationship between soil and fuel drying – flammability switch in ash forests and damper foothill forests	While Victoria's Ash and damper foothill forests are mostly too wet to sustain fire, many of Victoria's worst bushfires have occurred here. While they transition from a wet to drier state after prolonged periods of hot and dry weather, and can sustain large-scale severe fires, there is little scientific understanding as to how much drying is needed for these forests to switch from a 'dormant' state to one that promotes freely spreading fire. This research will develop a model to help predict the likelihood of a fire occurring and spreading in Victoria's ash and damper foothill forest, with a focus on factors that transition forest fuels into a flammable state.	A conceptual model of flammability in ash and damper foothill forests and an evaluation of the ability of moisture metrics to predict fire occurrence will enable fire management agencies to better prepare for and mange bushfires in ash and damper foothill forests. The project outcomes can also be incorporated into fire danger ratings, which will improve readiness levels and the communication of fire danger to communities. **Completion date:** June 2021 *This project is funded under Safer Together, supported by FFR and led by both the CFA and DELWP.*
Testing and improving mapping produced by Google Earth Engine (GEE) fire severity map tools	The validation and refinement of the GEE fire severity map tools will improve the accuracy and consistency of fire history spatial datasets generated by DELWP. This project aims to improve the quality of fire severity mapping and the capacity of FFR staff to map fire severity by: • testing and training the current GEE fire severity map tools for mapping of low severity prescribed burns • identifying new mapping approaches that overcome data gaps in severity mapping due to cloud affected imagery • building capacity within FFR to facilitate ongoing use and future refinement of the fire severity map tools.	High quality fire severity mapping will be valuable for fire management planning and refining models used to assess flora and fauna responses to fire. The project will enable FFR to understand, make management decisions and report on planned burning with a more robust evidence base. **Completion date**: February 2020

CASE STUDY: FIRE ANALYSIS MODULE FOR ECOLOGICAL VALUES (FAME)

Data for decision making

The FFR science program has provided extensive information that defines the effects of fire on environmental variables, in order to ensure that fire management meets the primary objectives for bushfire management on public land in Victoria, as outlined in the Code of Practice for Bushfire Management (the Code):

1. to minimise the impact of major bushfires on human life, communities, essential and community infrastructure, industries, the economy and the environment
2. to maintain or improve the resilience of natural ecosystems and their ability to deliver services such as biodiversity, water, carbon storage and forest products.

Focusing on the environment in the first object of the Code, DELWP assesses the impact of fire management on individual species' populations and vegetation communities. In addition, DELWP's policy position on ecosystem resilience recommends the use of three metrics that define how fire events affect ecosystem condition or 'states' over time:

- Tolerable fire interval (TFI)
- Geometric mean abundance (GMA)
- Vegetation growth stage structure (GSS)

Employing these resilience metrics, and information of effects of fires on individual species, requires accessing a vast number of files and models that delineate the diversity of plants and animals and the impacts of fire on those species as well as implementing technical computer modelling approaches. The technical and resourcing challenges associated with producing the necessary information in a timely and accessible manner presents significant challenges for their use in supporting decisions and reporting on effectiveness of fire management strategies.

Working with the Arthur Rylah Institute (ARI), FFR initiated a research project aimed at consolidating thousands of files that contain ecological data and models into a single, easily accessible and useable platform to support ecological risk assessments and evaluate the effectiveness of bushfire management strategies at achieving the objectives of The Code.

This was the key to these models being fully utilised by a wide suite of staff and for a broad set of applications, including fire management decisions and effectiveness reporting.

User-friendly development

While led by ARI the research team collaborated closely with researchers at the University of Melbourne and La Trobe University, as well as FFR staff from groups with strong stake in the outcome.

Together they delivered a framework that brings together existing ecological models into a single source and defines the criteria for how the models should be curated, used to inform decision making and updated with new monitoring and research data. The framework seeks to:

- consolidate existing ecological models
- identify current gaps in the modelling framework
- develop a conceptual framework for developing ecological models and applying them as part of ecological risk assessment and decision-making
- develop FAME to integrate analyses across ecosystem resilience metrics and threatened species
- document the process and process map for how new data collected through monitoring and research can potentially be integrated into the model updates.

A participatory approach with stakeholders throughout the project was important for finding a balance between FAME's state-wide consistency and regional flexibility.

Using structured decision-making tools and principles, this project took an iterative approach. Five workshops with key stakeholders refined the ecological objectives and ongoing regular communication with the core policy and user stakeholders reduced the ambiguity of terms and clarified the objectives for the different uses the model would have.

This process ensured that the module was fit-for-purpose and users had ownership over its development. This work was followed by presentations to a broader group of stakeholders to enable a growing understanding and use of FAME.

Structured decision-making delivers

This structured and collaborative research created an online analysis tool for FFR that considers the impacts of planned fire on biodiversity. FAME enables fire planners to evaluate the impacts of alternative fire regimes on species and vegetation, and ultimately supports explicit consideration of ecological objectives in fire management.

FAME has been used in the Strategic Bushfire Management Planning process across the state and has facilitated the evaluation of impacts on forest ecosystems from changing fire regimes under climate change.

Ecosystem modelling and resilience

Ecological research evidence provides an important role in informing a wide range of planning and operational management, including strategic fire management planning in Victoria. Recent research about fire and its relationship to ecosystem resilience, disturbance regimes and landscape heterogeneity have been used in the development of DELWP policy in defining, measuring and reporting on ecosystem resilience. This work underpins the Monitoring, Evaluation and Reporting (MER) Framework for bushfire management on public land.

Table 6. **Ecosystem modelling and resilience – current projects**

Project title	Description	Management outcome
Understanding and predicting Victoria's forest biodiversity and community dynamics THE UNIVERSITY OF MELBOURNE	Forest Biodiversity and Community Dynamics have explored the impacts of environmental variation and fire management on diversity for the past nine years. More recently they have integrated growth stage optimisation and landscape simulation models, to explore the impact of alternative scenarios of planned burning, in interaction with bushfire, on plant diversity. This project will provide a stronger empirical basis for including biodiversity and community dynamics as forest values, including in the DSS, by: • exploring the impacts of bushfire on rainforest and mixed forest communities • investigating the impact of bushfire on plant composition • using modelling to explore the potential for unburnt areas to provide long-term habitat to future fires and climate change.	The project will improve: • forest value metrics, predictors, and functions • model parameterisation • scenario development and implementation • technology transfer and community engagement. All of which will deliver improved capability of forest and fire managers to predict the consequences of alternative forest management strategies on biodiversity values and community dynamics in the context of a changing climate and altered fire regimes. **Completion date:** June 2022

Project title	Description	Management outcome
Ecosystem resilience – collection and analyses for first two of 11 priority ecological fire groups (EFGs) (ERP 2)	This project will research the effects of fire, including both bushfire and planned burning, on ecosystem resilience by: • assessing ecosystem resilience metrics across two ecosystems • measuring their effectiveness for guiding fire management • providing data for models and tools used for decision making in relation to bushfire management across the state, specifically ERP1.	This project will provide: • knowledge and evidence to support decision making for strategic bushfire management • accountability and reporting against key policy objectives for ecosystem resilience • knowledgeable conversations with communities about ecological outcomes. **Completion date:** June 2021

CREDIT: **Amy Smith.** University of Melbourne.

Project title	Description	Management outcome
Ecosystem resilience – technological advances to increase efficiency of ecosystem resilience monitoring (ERP 22)	This project focuses on developing technology to support the monitoring being undertaken in the ERP 2 project and as an input to ERP 1. It will increase the efficiency of future monitoring through development of improved field data capture, camera technology, and automated image analysis and classification.	The outputs of this research will be used to: • improve the current monitoring methodology • update the standard operating procedures (SOPs) • provide better data to support evidence-based decision making for bushfire management in Victoria. **Completion date**: June 2021
Ecosystem resilience data (ERP 6)	This project will analyse state-wide and regional monitoring data to answer key evaluation questions (KEQs) for both improvement and impact. Consolidation of this data will be used to determine the effectiveness of KEQs, as well as develop analysis protocols to answer KEQs. The project will make recommendations on necessary adjustments to the monitoring program to ensure data is adequate to answer KEQs.	This project enables FFR to critically assess and adapt its ecological monitoring KEQs. **Completion date:** September 2019
Ecosystem resilience – collection and analyses for the third of 11 priority ecological fire groups (EFGs) (ERP 24)	This project will research the effects of fire, including both bushfire and planned burning, on ecosystem resilience by: • assessing ecosystem resilience metrics across a key ecosystem • measuring effectiveness for guiding fire management • providing data for models and tools used for bushfire management decision-making across the state, specifically, ERP1.	This project will provide: • knowledge and evidence to support decision making for strategic bushfire management • accountability and reporting against key policy objectives for ecosystem resilience • knowledgeable conversations with communities about ecological outcomes. **Completion date:** June 2021

Project title	Description	Management outcome
Using fire to manage biodiversity in fragmented landscapes	FFR has adopted three broad indicators of ecosystem resilience. Developed in large continuous forests, their suitability to fragmented landscapes is unknown. As some areas of Victoria contain highly fragmented landscapes, this project aims to: • assess the effect of fire management on ecosystem resilience • build quantitative links between fire management strategies and biodiversity conservation in these environments.	These improved ecosystem resilience metrics will lead to more efficient and effective bushfire management across the diverse and fragmented Victorian landscape. They will improve FFR's capacity to quantify the effect of fire management, both planned burning and bushfires on ecosystem resilience in fragmented landscapes. **Completion date:** September 2020
Spatially explicit solutions for managing fire and biodiversity	Fire is a major driver of the structure and function of the high-conservation value and vulnerable Mallee and foothills ecosystems. A strong history of fire research in each ecosystem provides a wealth of data on its plants, birds, reptiles and mammals. This project will develop a suite of spatially explicit models and tools that enhance the capacity to design and evaluate alternative fire management strategies for biodiversity in these ecosystems.	The project will develop a framework for determining optimal fire regimes for biodiversity conservation in Mallee woodlands, shrublands and foothills forests, enabling better fire management decisions. **Completion date:** 2020

Project title	Description	Management outcome
TechEcology – evaluating the contribution of new technology and citizen science to achieving Victoria's biodiversity strategy goals 	This project will deploy video traps that constantly monitor reptiles and other small vertebrates. The cameras will provide a trial methodology that can be used more broadly to monitor the effects of fire management on reptiles. The study sites will be located within DELWP's Victorian Bushfire Monitoring Program in grassy-heathy dry forest which has been identified as a priority Ecological Fire Group.	This project aims to support integrated forest and fire management by: • testing viability of technology • improving understanding of wildlife response variables • exploring the changes resulting from citizen science. **Completion date:** May 2021
Fire and biodiversity – impacts, recovery and future planning: vegetation responses to planned fire    	This research project will address knowledge gaps relating to the relationships between fire and sensitive environments. It will improve our understanding of vegetation responses to planned fire, of fauna responses in fire-prone environments and of vulnerability of fire sensitive environments to bushfire.	The outputs of this research will: • reduce the uncertainty of the impacts of bushfire and planned burning on biodiversity and ecosystem resilience • improve the application of planned fire to enhance fire-dependent ecosystems and habitats • improve land and fire management and community understanding and confidence in bushfire management planning, delivery and recovery. **Completion date**: October 2019 *This project is funded under Safer Together and is led by Parks Victoria.*

Modernising Regional Forest Agreements

DELWP's commitment to modernising Victoria's Regional Forest Agreements (RFAs) is underpinned by a need for evidence to inform and support outcomes. FFR's research will contribute to the RFA assessment program, delivering sustainable and accountable forest management.

Table 7. Modernising Regional Forest Agreements – current projects

Project title	Description	Management outcome
Mapping high conservation value forests in Eastern Victoria 	By identifying areas of forests that are likely to contain high conservation values at a landscape-scale, this project will generate datasets that provide ecological basis for: • estimating the area of habitat of forest-dependant fauna • mapping of key growth stages and ecosystems for biodiversity management and conservation • estimates of forest biomass that can be used to predict forest carbon pools and fuel loads • predictions of forest density and diameter distributions that can inform timber harvest planning and sapwood area for water yields.	This project will provide important information for supporting decision-making during the current RFA planning process. **Completion date:** December 2020

Project title	Description	Management outcome
RFA – updated habitat distribution models for key forest species 	Habitat distribution models (HDMs) are spatially explicit models of a habitat suitability index that can be expressed individually for each species. HDMs interpolate – model the gaps – between known observations of species. The purpose of HDMs is to provide a higher level of information content to inform management than from individual observations. The development of revised HDMs for forest-dependent species can provide the basis for development of integrated data tools and frame works that consider species' distribution, forest resources, access, etc. This project will develop a series of HDMs that better reflect the current distribution of the selected forest dependent taxa, particularly with respect to an increasing interest in landscape scale threatened species management.	This project will contribute to the broader RFA assessment and Forest Protection Survey Programs ensuring that the modernised RFAs are based on the best available information. **Completion date:** June 2020
RFA –landscape scale surveys 	This project will conduct landscape scale surveys to collect new field data to improve understanding of the distribution of high priority, forest-dependent threatened species and update HDMs. The project will select sites based on sampling areas that provide the greatest information gain to models, within eastern Victoria. The sites will be tenure blind – they may include areas outside the current known distribution of the species or in marginal habitats.	This project will contribute to the broader RFA assessment and Forest Protection Survey Programs ensuring that the modernised RFAs are based on the best available information. **Completion date:** June 2020

Table 8. Building our understanding of bushfire, climate and risk – current projects

Project title	Description	Management outcome
Understanding and predicting Victoria's forest carbon and water cycles	This project has already delivered significant advances in our understanding of carbon and water processes and outputs at a range of spatial and temporal scales. Integration of these values was initiated for the IFER Decision Support System (DSS), making it clear that many of the remaining questions have vegetation structure and dynamics at the core for both carbon and water. This project will: • conceptualise the key attributes of the forest state crucial to robust accounting of carbon and water • investigate and improve the quantitative relationships driving the forest system and allow for prediction of system dynamics, including examining how risk concepts can be better integrated into forest carbon and water accounting • develop models and modelled scenarios that allow evaluation of system responses to environmental forcing (e.g. climate and fire) and management practices.	This project will close fundamental knowledge gaps in both carbon and water responses to climate, bushfire and management practices. It will also examine how risk concepts can be better integrated into forest carbon and water accounting, and provide a stronger integration of carbon and water as forest values. Specifically, this project will: • improve understanding of the likely impacts of drying landscapes • provide a stronger basis for evaluating the impacts of high-severity fires and compounded disturbances on forest carbon and water outcomes • improve capacity to model the interactions between forest carbon and water at landscape scales, including the prediction of trade-offs and potentially perverse outcomes • provide a stronger basis for quantifying, representing and communicating effectiveness of mitigation and adaptation policies and practices to provide positive outcomes and to reduce risks to forest carbon and water. **Completion date:** June 2022

Environmental compliance

Environmental compliance is a dynamic field requiring up-to-date information to meet regulatory responsibilities, educate and enforce legislation. This research focuses on using improved technologies to strengthen datasets, enhancing guidelines for protecting and managing wildlife, developing metrics to measure the effectiveness of compliance activities on reducing environmental crime and understanding whether compliance objectives align with community expectations.

Table 9. Environmental compliance – current projects

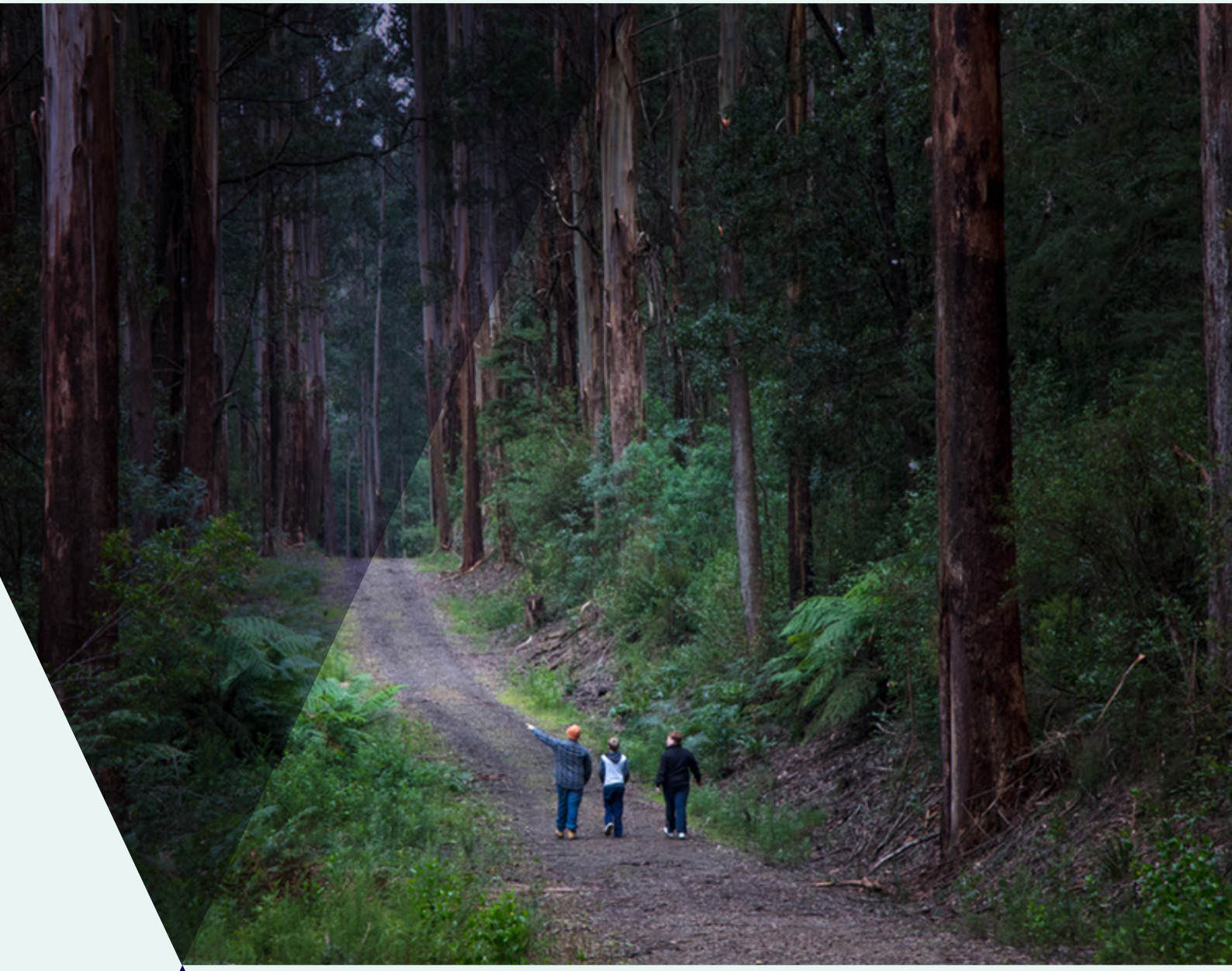
Project title	Description	Management outcome
Developing strategic intelligence for the environmental compliance regulator (ERP 7)	Strategic intelligence assists with recognising and understanding priority risks and harms in the operating environment – including new and emerging risks. It can enable more confident targeting of policies, regulatory tools and compliance efforts for the best outcomes, gauge the impacts of efforts, and adjustment of approaches accordingly. This project will develop capabilities (systems, tools and capacity) for FFR to: • capture, analyse and use data in more dynamic ways • assess the performance and functioning of its regulatory systems • better identify emerging or intensifying issues.	Generation of strategic intelligence from existing and under-utilised data as well as new and emerging technologies and datasets will: • improve DELWP's ability to undertake strategic assessments and thinking across the environmental regulatory framework – in the context of social, political and economic operating environments. **Completion date:** to be confirmed

Project title	Description	Management outcome
Use of emerging technologies for native wildlife population assessment and management (ERP 16) Research organisation to be confirmed	Accurate and timely assessments of native wildlife are needed for many purposes: • monitoring the effectiveness of management strategies • management of wildlife taken as game or reported to be damaging crops and pastures • rapidly identify and manage threats to wildlife such as disease and natural hazards. This project will collect, identify and analyse species imagery and habitat condition data, to develop algorithms and systems that enable managers to interpret population and habitat/ impact data.	The development of survey standards, systems and methods for FFR to undertake ecologically sound, repeatable and reliable assessments of wildlife populations and habitat conditions. **Completion date**: to be confirmed
National guidelines for the seizure and holding of wildlife (ERP 17) Research organisation to be confirmed	FFR and other agencies with wildlife management and compliance responsibilities require improved standards to manage the requirements and risks associated with seizing and holding wildlife. This project will develop guidelines for wildlife management and compliance agencies that outline the requirements for housing, feeding, transporting and disposing of the most commonly held and traded classes and orders of native and invasive wildlife. In addition, the project will outline the design and layout requirements for wildlife enclosures and the competencies and training curriculum for staff.	Guidelines for the seizure and holding of wildlife, including how animals are housed, fed and handled as well as infrastructure design; development of wildlife facilities and appropriate training for staff. The guidelines will assist FFR and other agencies with wildlife management and compliance responsibilities to ensure facilities, capabilities and standards are enough, in relation to the seizing and holding of wildlife. **Completion date:** to be confirmed

Project title	Description	Management outcome
Making a difference – conceptual framework to show benefits of compliance (ERP 18)	DELWP's draft Environmental Compliance Policy commits us to using a risk-based approach to resource allocation. It ensures we prioritise actions causing the most harm to the environment and the biggest impact on fair and legal access to public land and access to natural resources. To achieve this FFR requires metrics to estimate and over time measure the loss that was avoided due to compliance actions. This project will develop metrics for environmental and social uplift resulting from compliance actions.	This project will enable FFR to meet its Environmental Compliance Policy objectives to: • reduce harm to our natural and heritage values, and the environment • reduce illegal, inequitable and unsafe access to public land and use of natural resources. **Completion date:** June 2020
The human dimension of environmental crime (ERP 19)	DEWLP's draft Environmental Compliance Policy places the community at the centre. This project aims to consider compliance issues relating to social, environmental and economic values in the areas of: • native wildlife • trafficking of exotic species • licensing of the sale of native flora and fauna • rubbish dumping • recreational values and fire prevention on public land • unauthorised occupation of crown land and adherence to license, permit and lease conditions. The project will investigate and analyse community perceptions of policy options and provide staff training on how to obtain relevant information from communities.	A better understanding of community expectations of environmental compliance values and objectives will enable FFR to ensure compliance program priorities align with community priorities. A better understanding of motivations behind non-compliance will enable FFR to target compliance actions more effectively. A better understanding of community perceptions of wildlife management will enable FFR to develop new wildlife population management solutions that are acceptable to the community. **Completion date:** March 2021

SECTION 2

Appendix 1: Fire and adaptive management research reports



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For copies please go to: https://www.ffm.vic.gov.au/research-and-publications/fire-research-and-adaptive-management-publications

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