NATIONAL BURNING PROJECT

Australasian Fire and Emergency Service Authorities Council (AFAC)
and Forest Fire Management Group (FFMG)

A Risk Framework for Ecological Risks Associated with Prescribed Burning

National Burning Project: Sub-Project 3

MAY 2016

afac
Australasian Fire and Emergency Service Authorities Council

An Australian Government Initiative

FFMG

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Abbreviations

Abbreviation	Description
AGD	Attorney-General's Department
AFAC	Australasian Fire and Emergency Service Authorities Council
DELWP	Department of Environment, Land, Water & Planning, Victoria
DEWNR	Department of Environment, Water and Natural Resources, South Australia
DPaW	Department of Parks and Wildlife Western Australia
ELA	Eco Logical Australia
ESDD	Environment and Sustainable Development Directorate, Australian Capital Territory
FFMG	Forest Fire Management Group
NBP	National Burning Project
SEQFBC	Southeast Queensland Fire & Biodiversity Consortium

(Source: Department of Environment, Water and Natural Resources, South Australia)

1. INTRODUCTION

The National Burning Project (NBP) is a multi-year project jointly commissioned by the Australasian Fire and Emergency Service Authorities Council (AFAC) and Forest Fire Management Group (FFMG), with the overarching objective:

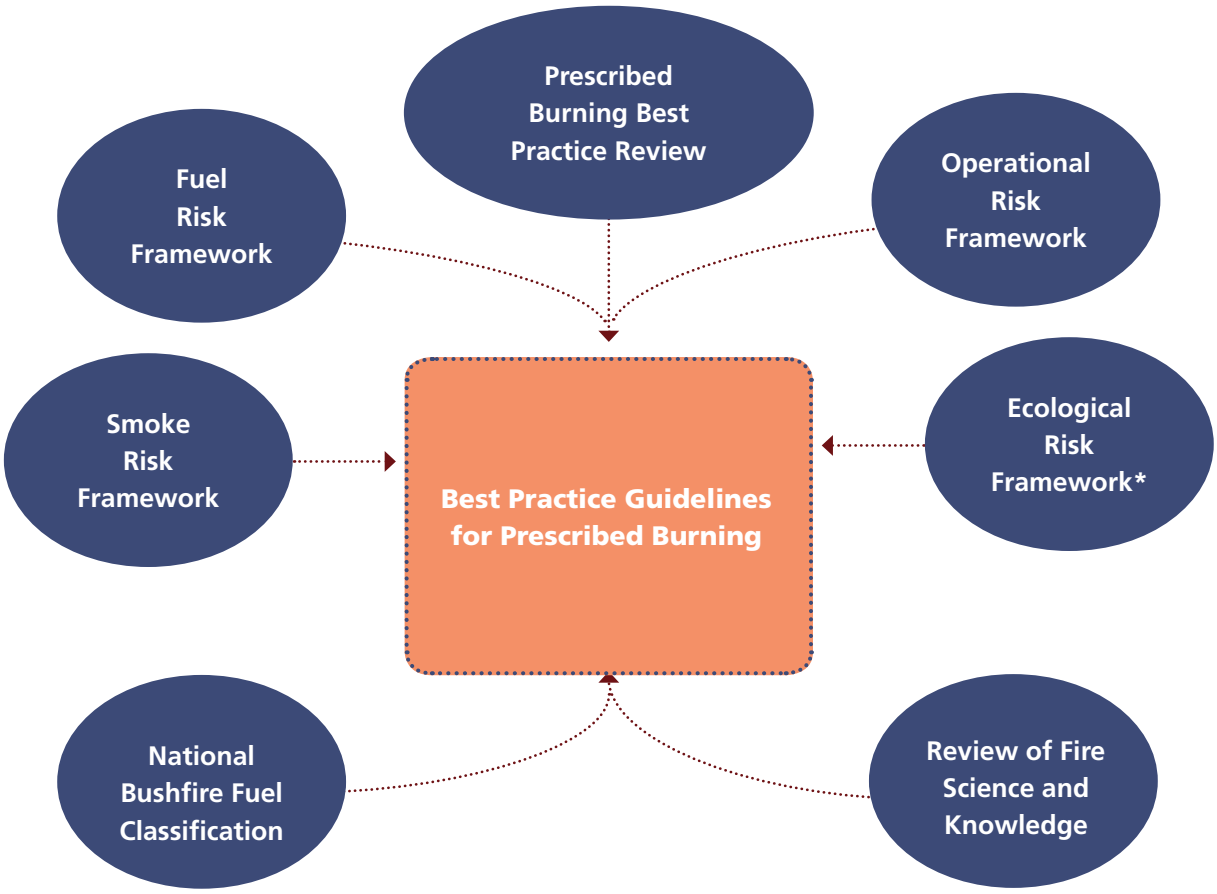
To use a national approach to reduce the bushfire risk to the Australian and New Zealand communities by the comprehensive management of prescribed burning at a landscape level that balances operational, ecological and community health risks (AFAC 2015).

A number of sub-projects are to be implemented under the NBP to develop national guidelines for:

- Best practice prescribed burning; and
- Ensuring greater interoperability between fire management agencies through developing common standards and approaches to prescribed burning (AFAC 2015a, AFAC 2015b).

This sub-project for a risk framework for ecological risks associated with prescribed burning is one of the projects that contribute to the compilation of national guidelines, as depicted in Figure 1 below. These include risk frameworks for fuel, smoke, ecological (this document*) and operational risks, and each have similar objectives, methods and are presented with a similar layout.

Figure 1 *National Burning Project – related sub-projects (AFAC 2015a, AFAC 2015b)*



1. INTRODUCTION

(Source: Office of Bushfire Risk Management Western Australia)

1.1 Development of a risk framework for ecological risks associated with prescribed burning

1.1.1 Prescribed burning background

Prescribed burning is an integral part of managing natural landscapes in all parts of Australia, however, the objectives for burning vary. In many circumstances prescribed fire is used primarily to reduce fuel hazard to aid in the suppression of and limit the damage from bushfires. In other areas prescribed fire is used to maintain healthy natural environments, maintain biodiversity or to benefit individual native species. In yet other areas the objective may be to gain economic or social benefit from landscapes. In some areas prescribed burning is utilised to achieve Traditional Owner cultural requirements. In many situations a combination of objectives identified for fire programs and individual burns can be achieved simultaneously, but it is common that the achievement of one objective will provide collateral outcomes for other objectives.

Underpinning all prescribed burning are varying levels of understanding about the role of fire in the environment and how ecosystems and their component biota respond to fire. Most of Australia's biota is adapted to fire and the maintenance of ecosystems and biodiversity is strongly influenced by fire. The right kind of fire in the right place, at the right time and applied in the right way is good for the natural environment. Prescribed fire can, however, produce undesirable ecological outcomes if applied inappropriately. Likewise unplanned fire can also have negative ecological consequences.

Land managers applying fire in the landscape are diverse and include: Traditional Owners, farmers, graziers, and managers of public lands (national parks, forests and other land), private conservation reserves, private forests, production forest, local government areas, mining leases and defence lands. They manage land to achieve a wide range of objectives. They possess a variety of skills and knowledge and hold a variety of views on the value of ecological assets. They manage fire in the landscape using management systems that vary in maturity and sophistication.

1.1.2 Project objective and scope

The objective and scope of this project was set by AFAC as follows:

To consider the ways of measuring and managing ecological risks to biodiversity through inappropriate fire regimes and use of fire by collating and analysing the current risk frameworks used in each jurisdiction (Australian states and territories and New Zealand) and recommend a potential national framework for describing ecological risk, how it changes with circumstance and how it is affected by management interventions and legislation.

Analyse and review existing ecological risk management frameworks and then work with agencies to propose a nationally-agreed framework. Risk management frameworks tailored to meet specific needs are already being used by individual fire agencies. It is envisaged that a single national framework will meet all pre-existing specific needs.

Risks to environmental values associated with individual burns, inappropriate fire regimes, and the cumulative impacts of programmed and unplanned fires will continue to occur. Ecological impacts that can occur include loss of biodiversity as measured by threatened species populations, disturbance to individuals, species, habitats and ecological processes, and changes to pest and weed populations. Inappropriate fire regimes may be recognised as a threatening process.

The completed framework will enable analysis of the risks, the setting of programs, and the monitoring and measurement of outcomes with provision for feedback in the ecological risk category.

This framework for managing ecological risks brings together the diverse views of scientists, land managers and Traditional Owners across the continent, ranging from the theoretical to the practical need to conduct burning. At one end of the spectrum, the complexity of ecosystems, their components and fire responses are analysed in sophisticated ways, while at the other end, burning is a skilful and practical art that must occur irrespective of incomplete scientific knowledge, as the consequences of not burning can be devastating for the community and for the environment.

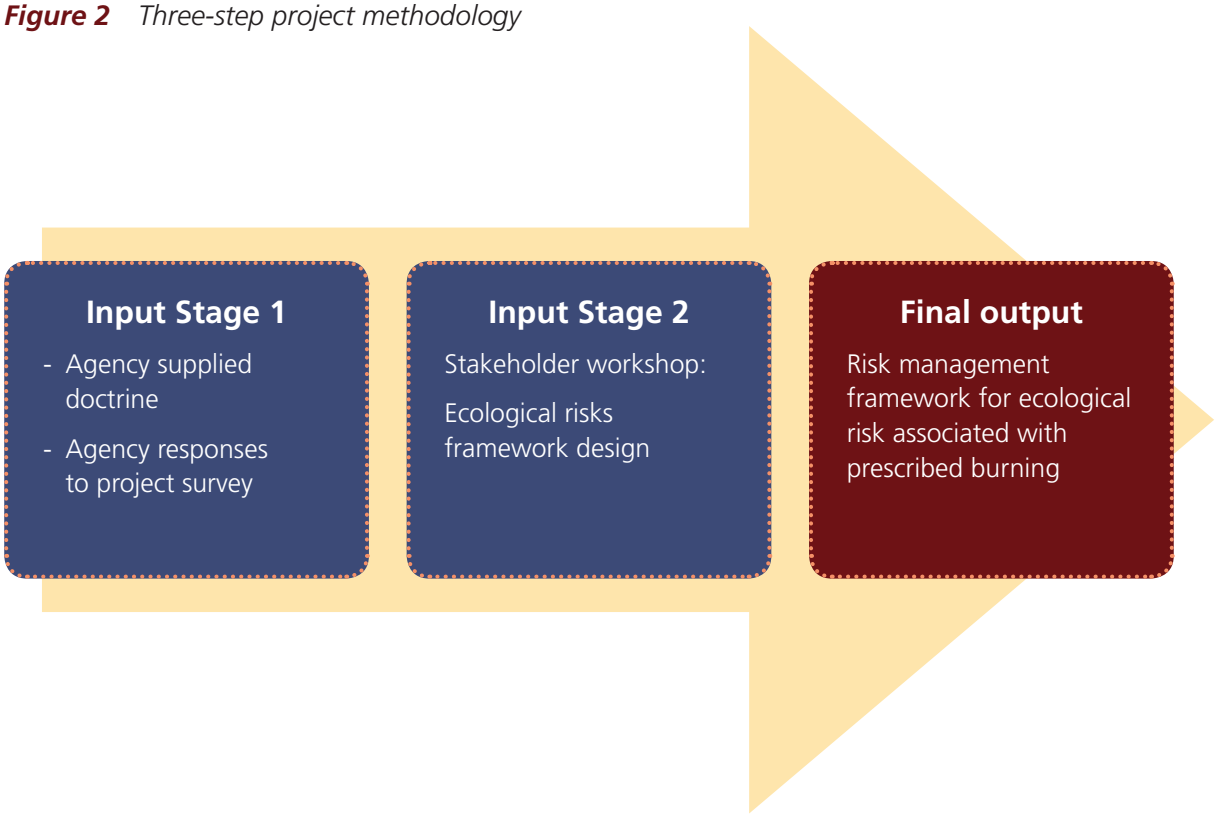
The challenge for land managers is to understand and apply the right kind of fire with the right techniques at the right times and places to provide the best possible ecological outcomes, while resolving competing objectives of burning and other constraints. This risk management framework for ecological risks associated with prescribed burning provides a way to consider the steps and processes that all land managers can take when seeking the best ecological outcomes.

Organisations implementing prescribed burning vary considerably in size and budgets. Most of the issues presented in the framework will be relevant to, and form part of prescribed burning considerations, for most organisations. The extent to which each element of the framework is addressed formally in organisation's policy and procedures will vary however. Notwithstanding, this framework is presented as a yardstick for best practice considerations as agencies review their systems, policies and procedures.

2. METHODOLOGY

Eco Logical Australia (ELA) were engaged by AFAC to undertake the project and provided a methodology and timeline for its completion. The project methodology was agreed to at an inception meeting and timelines developed for its implementation. An overview of the three stage methodology is provided in Figure 2. This methodology was originally devised by GHD and AFAC for use in previous prescribed burning risk frameworks.

Figure 2 *Three-step project methodology*



2.1 Call for agency doctrine and project survey distribution

In July 2015, AFAC and FFMG member agencies and other interested parties were invited to forward relevant doctrine relating to the management and monitoring of ecological risks associated with prescribed burning and asked to participate in a developed a survey for. ELA undertook web-searches to further expand the answers to the survey questions and doctrine provided by each jurisdiction and organisation. The survey questions are included in Appendix B.

2.2 Project workshops

In July and August 2015, ELA and AFAC facilitated four workshops to explore in more detail the issues, approaches and practices used by different agencies and organisations for the management of ecological risks associated with prescribed burning. These workshops were held in Darwin, Perth, Nerang (Gold Coast) and Melbourne. All AFAC and FFMG member agencies, along with other organisations and individuals, were invited to attend the workshop with invitations distributed through agency points of contact nominated by AFAC's project manager.

2.3 Information analysis and project report

Following the agreed project methodology, input from workshops, agency doctrine and surveys was synthesised to develop the risk framework within a hierarchical structure of phases of prescribed burn planning.

These phases are:

- **strategic planning** for prescribed burning (addressed in section 4 of this report);
- **program planning** for prescribed burning (addressed in section 5 of this report);
- **operational planning** for individual prescribed burn (addressed in section 6 of this report);
- **burn implementation** of prescribed burns (addressed in section 7 of this report); and
- **post-burn monitoring and evaluation** of ecological risks (addressed in section 8 of this report).

Section 3 of this report discusses some general concepts of risks, and the nature of risk management frameworks as applied to ecological risks associated with prescribed burning. Specific consideration is given to the subtle changes introduced with the transition from AS 4360:2004 Risk Management to ISO 31000:2009 Risk Management – Principles and Guidelines.

Section 9 of this report proposes a risk management and monitoring framework for ecological risks associated with prescribed burning.

3. RISK MANAGEMENT FRAMEWORKS

In this section, some general concepts of ecological risk are outlined to provide a frame of reference and context for subsequent sections. The below material has been reproduced from the Operations risk framework (AFAC 2016) as updated from the previous frameworks for Fuel and Smoke management.

3.1 Risk management frameworks – the shift from AS/NZS 4360 to ISO 31000

In 2009 the international ISO 31000:2009 *Risk Management – Principles and Guidelines* superseded AS/NZS 4360:2004 *Risk Management* as the primary standard on risk management in Australia and New Zealand. While the risk management process incorporated in ISO 31000 is virtually identical to the prior standard, there have been some subtle changes in the main points of emphasis between the two standards. Three in particular are worth highlighting, and are listed with some commentary on the implications for developing a national risk-based framework for managing ecological risks from prescribed burns:

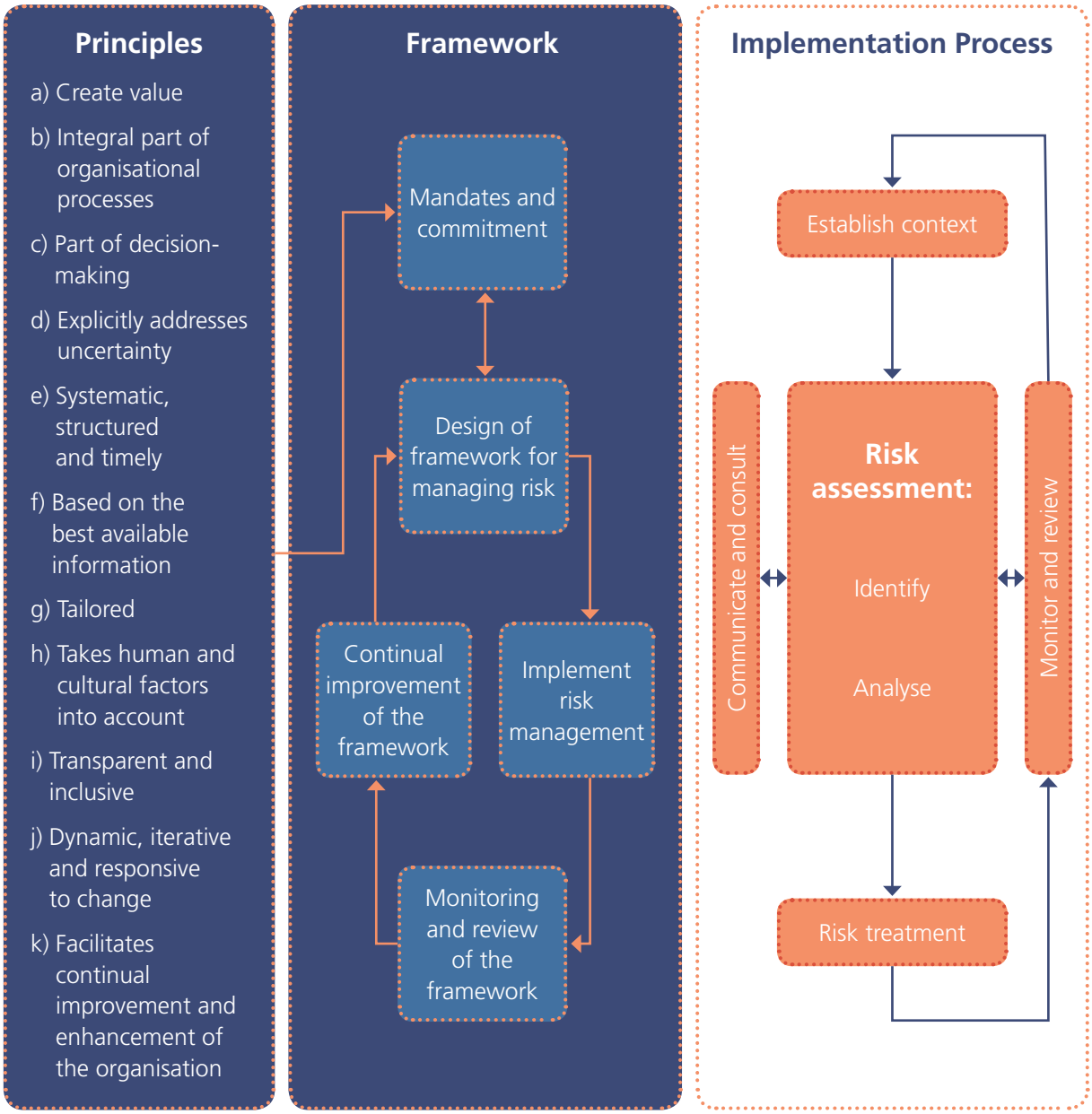
1. ***Risks are about uncertainties and relate to objectives.*** The definition of risk has changed from 'the chance of something happening that will have an impact on objectives' (old definition in AS 4360:2004) to 'the effect of uncertainty on objectives' (current definition in ISO 31000:2009). This subtle definitional change is intended to redefine the main focus of risk management to considering the effect that uncertainties can have on achieving objectives (understanding how risk arises), changing from the previous emphasis on considering the chance of an event occurring and its consequences. Further, *risk management is "a coordinated set of activities and methods… used to direct an organisation and to control the many risks that can affect its ability to achieve objectives."*

   Thus mitigating the risks associated with prescribed burning is achieved by explicitly attempting to identify and manage the uncertainties associated with the activity. Except perhaps in the very simplest of circumstances, prescribed burning risks cannot be eliminated. Thus prescribed burning risk management is about reducing risk to acceptable or tolerable levels.

2. ***There are a variety of tools and methods available to perform risk assessments and inform management priorities.*** The AS/NZS 4360 standard included strong references to the use of risk assessment 'matrices' whereby qualitative descriptors of an event's 'likelihood' and 'consequences' of occurring were used to develop a risk rating of, typically, 'low', 'medium', 'high', 'very high', extreme' or some similar descriptors. In the bushfire risk management context, problems can arise trying to adopt the 'matrices' as an assessment tool, due to the complex and wide range of fire behaviour variability and uncertainty that can exist, and that is difficult to capture in such a way. While these types of matrices can be very useful in some situations to assist with risk assessment and recording, under AS/NZS 4360 it had become the mainstream standard approach for risk assessment, which was never the intention of the AS/NZS 4360 standard. To address this, reference to the risk matrices has been removed from the ISO 31000 standard and an accompanying document ISO 31010:2009 *Risk Assessment Techniques* has been created. While the risk matrices do appear in ISO 31010 as one type of tool that may be useful in risk assessment (among a list of over 30 techniques), it is emphasised that the appropriate risk assessment and communication tools should be developed with the specific context, in this case ecological risk management, in mind.

3. ***ISO 31000 introduced 11 risk management principles to provide more explicit guidance as to how risk management is best implemented.*** The ISO 31000 generic framework for risk assessment and management is shown in Figure 3. It contains a set of principles, a risk management framework, and a risk management implementation process, and how they inter-relate. The 'risk assessment' activities, sit within the overall risk management process. The addition of the 11 principles is an important enhancement of the superseded AS/NSZ 4360 risk management process model, and highly relevant to managing prescribed burning ecological risks.

Figure 3 *The ISO31000 risk management principles, process and framework (ISO31000,2009)*



3. RISK MANAGEMENT FRAMEWORKS

Some further explanation of the risk management principles is provided below. The application of sound risk management should:

1. ***Create and protect value***

Good risk management contributes to the successful achievement of an agency's prescribed burning program and objectives (e.g. objectives relating to employee and public safety, operational effectiveness, financial efficiency/loss minimisation, agency reputation/social licence, environmental protection, legal compliance and meeting political imperatives) through the continuous review of its processes and systems.

2. ***Be an integral part of organisational processes***

Risk management needs to be integrated with an agency's governance framework and become an embedded part of its planning processes, through all phases of the prescribed burning process from strategic planning, through program and operational planning phases, to implementation.

3. ***Be part of decision making***

The process of risk management assists decision makers to make informed choices, identify priorities and select the most appropriate action. This applies through all the phases of prescribed burning.

4. ***Explicitly address uncertainty***

Identifying uncertainties is a necessary part of identifying potential risks - agencies can implement controls and treatments to optimise the chance of success while reducing (but not necessarily eliminating) the chance of failure/loss.

5. ***Be systematic, structured and timely***

The process of risk management should be consistent across an agency to ensure efficiency, consistency and the reliability of results. It should recognise that risks can change over time and be sufficiently flexible to adjust to temporal changes.

6. ***Based on the best available information***

To effectively manage risk it is important to understand and consider all available information relevant to a prescribed burning activity and to be aware that there may be limitations on that information potentially creating uncertainties. It is then important to understand how all this information informs the risk management process, and to adjust risk management as new/improved information becomes available (as commonly occurs during the burn implementation process).

7. ***Be tailored***

An agency's risk management framework needs to include its risk profile, as well as take into consideration its internal and external operating environment.

8. ***Take into account human and cultural factors***

Risk management needs to recognise the contribution that people and culture have on achieving an agency's objectives (because prescribed burning is implemented by people who are influenced by their organisational culture).

(Department of Land and Resource Management Northern Territory)

9. ***Be transparent and inclusive***

Engaging stakeholders, both internal and external, throughout the risk management process recognises that communication and consultation is key to identifying, analysing and monitoring risk. External stakeholders may have key information or insights relevant to managing prescribed burning risks, and in many cases may be able to contribute to controlling risks.

10. ***Be dynamic, iterative and responsive to change***

The process of managing risk needs to be flexible. The challenging and dynamic environment we operate in requires agencies to consider the context for managing risk as well as continuing to identify new risks that emerge during the end-to-end planning-implementation process, and make allowances for those risks that no longer exist or which change.

11. ***Facilitate continual improvement***

Agencies with a mature risk management culture are those that have invested resources in review and evaluation processes over time, and are able to demonstrate the continual achievement of their objectives.

3.2 Risk management contextualised for ecological risks associated with prescribed burning

The National Bushfire Management Policy Statement for Forests and Rangelands (FFMG 2014) provides an agreed vision and principles for bushfire management. It also provides strategic objectives and national goals in order to achieve the vision. Several of the strategic objectives and national goals from this policy statement provide a good context and guidance for this risk framework (see Figure 4).

Figure 4 *National Bushfire Management Policy Statement for Forests and Rangelands (FFMG 2014)*

A. Effectively managing the land with fire

1. Maintain appropriate fire regimes in Australia's forests and rangelands

Manage planned and unplanned fire (where appropriate), to reduce the risk of severe bushfires impacting on communities, and enhance the health, biodiversity and resilience of Australia's forests and rangelands. Underpinning this goal is an understanding that planned and managed fire can play a positive role in reducing the scale and magnitude of bushfires, and promote more healthy and productive forest and rangeland ecosystems.

2. Balance the environmental impacts of fire

Maximise the environmental benefits through use of appropriate fire regimes, while minimising the adverse environmental effects of fire on environmental assets or services such as water, timber, carbon and air sheds.

3. Promote indigenous Australians' use of fire

Where relevant to further integrate traditional burning practices and fire regimes with current practices and technologies to enhance bushfire mitigation and management in Australian landscapes.

C. Strong land, fire and emergency partnerships and capability

6. Integrated and coordinated decision making and management

Improve decision making processes through integrated strategic and operational planning between land, fire and emergency management agencies. This will include the enhancement of mutual aid and learning, and the development of good practice examples.

8. Bushfire risk mitigation

Improve the efficiency and effectiveness of programs designed to minimise the number, spread and adverse impacts of future bushfires.

D. Actively and adaptively managing risk

13. Risk management

Ensure that the management of landscape fire is based on "best practice" approaches to managing fire regimes and risk. Such approaches should be based on sound scientific information and organisational and community values and learning, and allow the efficient use of resources.

Develop risk and adaptive management systems that support the assessment and reporting of landscape and local level risks, and identify cost-effective strategies for achieving outcomes (and performance measures) that reduce the impact of severe fires and promote ecosystem resilience.

14. Investing in and managing knowledge

Bushfire management must be supported by policies, strategies and procedures based on the best available knowledge regarding the physical relationships between fire regimes and ecosystem processes, the management of risk, community values and expectations and how these interact.

More knowledge is needed to better identify the fire regimes that optimise values such as community protection, carbon sequestration, water, timber and agricultural production and biodiversity conservation amenity over whole landscapes through time. Naturally, the relative mix will vary for different regions across the continent depending on the social, economic and environmental attributes of each region and guiding cultural values and expectations. More knowledge is also needed on fire behaviour, fire weather and fire climate and how these relate to risk and its mitigation.

Land and fire managers will continue to improve links with cooperative research centres, universities and other research providers by:

- developing a comprehensive research strategy to support the implementation of this statement (this will include assessing the value of long term ecological research sites in supporting bushfire management across the landscape);
- supporting graduate development and other forms of specialised training;
- establishing a framework for integrating research and monitoring into the management of fire at the broader landscape level, and for improving and refining strategies as a result of new knowledge – adaptive management;
- incorporating community values and knowledge into planning and action through engagement, discussions and social research; and
- establishing effective means for brokering/sharing/transfer of new and existing knowledge for fire and land managers (this will be incorporated into training, planning and operations).

It will be seen that this framework is consistent with these national goals and reflects a view that prescribed fire is an inherent and essential aspect of managing Australian bush, however, there are considerations that must be made to ensure fire is used appropriately so as to maintain ecological values as far as is practical to do so.

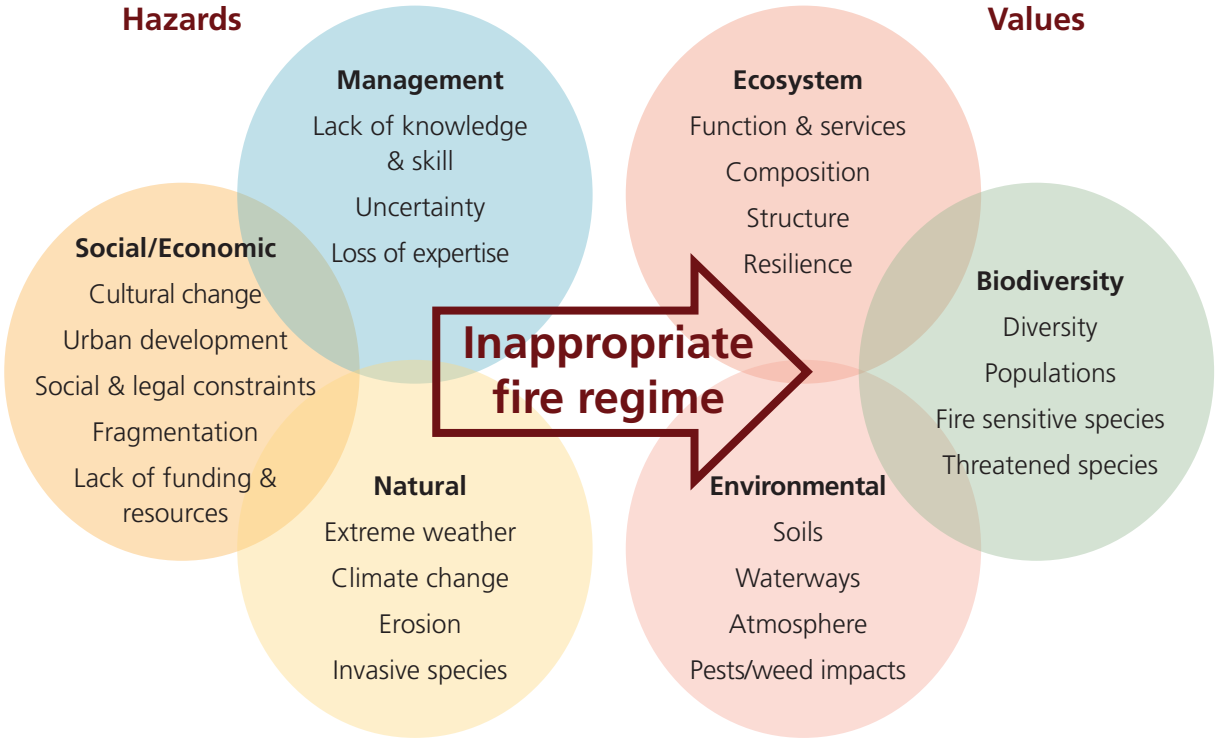
3.3 Risk assessment considerations: Inter-relationships among hazards, values and risks

Ecological risks arise from inappropriate fires, that is, fires (planned and unplanned) that burn vegetation at times, places and intensities that do not contribute to the maintenance of biodiversity and environmental values. As established in previous risks frameworks (AFAC 2015a, AFAC 2015b) it is helpful to consider this in a conceptual model where there are hazards, or sources of risk, leading to inappropriate fire and fire regimes and consequential impacts on ecological values (Figure 5). Prescribed fire can in some circumstances be part of the hazard to ecological values, while in other situations, if applied appropriately, prescribed fire can be used as a treatment to reduce risk to ecological values. Thus, the risk to natural values can arise from either a lack of prescribed fire or the application of inappropriate prescribed fire.

All attributes of the hazards and values contribute to the degree of risk. An increase in risk comes from an increase in the attribute of the hazard, and/or a higher exposure or vulnerability of the values at risk. The 'hazard' elements listed in Figure 5 are factors influencing both the need for prescribed fire and the capacity to undertake it appropriately; the 'values' elements listed broadly describe the components of the environment that make up ecological risks.

Commonly, 'risk' is considered as a combination of the likelihood of an event arising together with the consequences of the event. In this sense, values attributes may sometimes be equivalent to 'consequence' risk factors because they are factors influencing the severity of impacts arising from a fire. Hazard attributes may sometimes be referred to as 'likelihood' risk factors because they are factors influencing the likelihood of inappropriate fire. The focus in this framework, however, on hazards and values rather than likelihood and consequences, is more helpful for understanding ecological risks relating to inappropriate fire regimes and prescribed fire.

Figure 5 *Fire risk arises from the intersection of hazards with values*



3.4 Risk management considerations: Scales of assessment and prescribed burn planning phases

The sources of risk associated with prescribed burning and the management of ecological risks occur at various organisational levels, as well as spatial and temporal scales. These levels are summarised in this section and illustrated in Table 1 below.

Table 1 *Planning levels, spatial scales and temporal scales for managing ecological risks associated with prescribed burning*

Planning phase/level	Spatial scale	Temporal Scale	Monitoring, Evaluation and Reporting
Strategic planning	Jurisdiction, organisation, region	=> 5 years	
Program planning	Region, district, property	1 to 5 years	
Operational planning	Individual burn	Months/year	
Burn implementation	Individual burn	Days/month	

Organisations that may be engaged in some or all of the phases / levels for managing ecological risks associated with prescribed burning include:

- Aboriginal Land Councils and other representative bodies;
- organisations with responsibility for managing Indigenous Protected Areas;
- local, state and federal government agencies managing national parks, conservation reserves, water catchments and other public land;
- government agencies managing production forest;
- government agencies with responsibility for controlling bushfires and managing bushfire risk;
- non-government organisations managing conservation reserves;
- private companies managing forest plantations and production forests;
- pastoral companies;
- mining companies;
- individual landowners and leaseholders;
- universities; and
- organisations that facilitate collaboration and research for land management and fire (e.g. AFAC, the Bushfire and Natural Hazards CRC, the South East Queensland Fire and Biodiversity Consortium, natural resource management groups).

Most of these entities listed above, with the exception possibly of the last two, will also be responsible for delivering burning operations as well as the other levels of planning for prescribed burning described below. Individual landowners and leaseholders are less likely to be engaged at the strategic planning level.

3.4.1 Strategic planning

Prescribed burning is executed at a local scale, typically by people living in or near the burn areas, but some aspects of planning of prescribed burning take place at a much broader geographic and organisational scale, particularly in government and private organisations engaged in land management and conservation. At this level, planning focuses on developing doctrine, systems, strategies, practices and analyses that will be used at the program planning, operational planning and burn implementation levels. Written policy, mission statements, strategic plans, statements of risk appetite and other guidance documents and decision support tools are an important component at this level, but they are not the only component. Efficiencies, consistency of practice and better ecological outcomes are gained from well-developed strategic planning.

3.4.2 Program planning

A program plan identifies, usually on maps, the areas to be scheduled for treatment by prescribed burning over a specified time frame, typically from one to five years (although can be longer e.g. Tasmania 10 years). At this stage information about the burn area may be recorded (such as can be derived from quick desktop assessments and GIS) along with preliminary or broad objectives, risk and priority level, to assist with scheduling the burn. The spatial and time scales for program planning for prescribed burning reflect an organisation's operational structure and also the nature of the fire environment, such as how much planned and unplanned fire there is in the landscape each year. In some organisations, program plans may be prepared for a single land management unit, for example, a single reserve or an individual pastoral property. In other organisations, it may be a multi-year plan for a region that encompasses multiple land management areas.

Most of the organisations listed in section 3.4 will be involved in program planning for prescribed burning and in some cases assisted by external consultants. The program plan has a variety of names in different organisations; some examples include fire management plan, fire operations plan, community bushfire mitigation plan or annual burn plan. The common feature is that there are more than one burn area and that they will not all be burnt at the same time.

3.4.3 Operational planning

In many organisations, each individual prescribed burn has a written operational burn plan that provides a statement of operational intent, as well as an account of all the social, environmental and safety factors that need to be considered to execute the burn. Operational burn plans are a structured aid to minimise the chance of overlooking important issues. There are many different operational burn plan templates, but typically, a template is used consistently within an organisation. Ecological risks, while important, are just one of many issues dealt with at the operational plan level. Furthermore, the operational burn plan will only present an end point summary of the ecological risks and treatments, following a number of steps and activities applied at this level to identify ecological issues.

(Source: Department of Environment, Water and Natural Resources South Australia)

As with program planning, the terminology for this level of planning can vary between organisations and jurisdictions. For example, the Department of Environment, Land, Water & Planning from Victoria calls this level of planning the *tactical level* and the program plan level the *operational level*.

Some of the steps and activities that are described as part of the ecological risk framework at the program planning level may in some organisations occur at the individual burn plan level, or vice versa. For example, in northern Australia, operational planning and program planning tend to occur together annually because of the highly dynamic fuel and fire environment and the need to flexibly plan and respond.

3.4.4 Burn implementation

Ecological risks are considered at the time of implementing a prescribed burn, in accordance with information specified in the operational burn plan. Activities and decisions at the strategic plan level, program plan level and operational plan level will guide management of ecological risks for burn implementation, but there are assessments and decisions to be made on the day of burning that will also contribute to managing ecological risks.

4. STRATEGIC PLANNING FOR ECOLOGICAL RISKS

4.1 Identifying the potential sources of risk

4.1.1 Loss of ecosystem function due to ecologically inappropriate fire regimes

Fire management and prescribed fire play an important role in maintaining healthy functioning ecosystems, a fundamental goal for management of many natural areas.

It is well understood amongst professional fire managers that fire has been part of most Australian landscapes for a very long time and that most native plants and animals have adapted strategies for either coping with or benefiting from fire. Most prescribed fires will not, as individual events, have permanent ecological consequences. Rather, it is the fire regime – that is, the frequency, season, intensity, patchiness and size of fires, as well as the ongoing combination of these factors – that affects ecological values and which is more likely to pose an ecological risk.

If an ecosystem is still healthy in terms of its function, it is more straightforward to maintain with fire, but if its function is unhealthy due to threatening processes such as inappropriate fire regime, fragmentation, weed invasion, and climate change impacts, it can be hard to return it to a healthy system – with consequences for species, habitats, tree health, ecosystem composition and bushfire risk reduction.

What constitutes an inappropriate fire regime varies considerably across the broad range of environments of Australia and the social contexts and pressures that create the risk of such inappropriate fire regimes are diverse. Some examples are illustrated in Table 2. In some areas a specific fire regime is overtly applied, while in other situations the fire regime is a default that occurs in the absence of any deliberate attempt to create a different one. In any case, most ecosystems are subject to some form of fire regime, either by totally unplanned or a mixture of both planned and unplanned fires. Even absence of fire is a fire regime. Inevitably, in most Australian landscapes, the absence of fire will exacerbate the effects of bushfire with often far more deleterious consequences for ecosystems and species. Because of the intensity and scale of bushfires, irreversible ecosystem change is a likely consequence of a prolonged absence of fire.

Despite the dependence of many ecosystems on fire for survival, fire sensitive species and vegetation types do exist in many Australian landscapes and they depend for their survival on fire exclusion, or at most, very infrequent fire. It is not uncommon for fire sensitive vegetation to be in the same landscape alongside vegetation adapted to a fire regime of more frequent burning. The risk of unplanned fires to fire sensitive vegetation is significant for various reasons and prescribed fire can be a treatment applied in the adjacent more flammable parts of the landscape to reduce that risk.

Ecologists and land managers recognise that identifying and applying ecologically appropriate fire regimes is a central tenet to managing ecological values, healthy ecosystems and natural diversity.

Table 2 *Ecologically inappropriate fire regimes*

Inappropriate fire regime	Examples of management hazards	Examples of social/economic hazards	Examples of natural hazards	Examples of impact on values
Too Frequent		• Fuel reduction burning to protect life and property		• Decline in obligate seeding understorey trees and shrubs • Change in assemblage or decline in mammal, bird and reptile diversity • Decline of fire sensitive vegetation (e.g. mulga, dry rainforest, *Callitris*) due to unplanned fire • Decline and impact on hollow trees
Too Infrequent	• Innapropriate application of inter-fire intervals/ fire regime formulas	• Perceptions that prescribed fire is bad • Lack of funds, skills or resources • Social (e.g. smoke impact) & legal constraints • Decline of Traditional Owner burning	• Reduced burning windows resulting from changes to climate	• Decline in diversity of fire dependent shrubs • Decline of herb diversity (grasslands) • Decline of shrub & herb diversity (heathlands) • Understorey thickening (Queensland) • Tree decline • Decline in habitat condition with related impacts on fauna
Too much late dry season (Northern Australia)	• Lack of early dry season burning (leading to extensive, high intensity, late dry season unplanned fire)	• Decline of Traditional Owner burning • Pastoral land constraints • Increase in arson fires		• Decline of tree diversity and cover • Decline in diversity of small mammals • Decline of fire sensitive vegetation, e.g. *Callitris*
Outside of natural fire season	• Lack of opportunity to safely or effectively burn within natural fire season	• Social/political pressure to burn when risks of fire 'escapes' are minimal		• Decline in flora with seasonally sensitive life-history phases e.g. orchids

Inappropriate fire regime	Examples of management hazards	Examples of social/economic hazards	Examples of natural hazards	Examples of impact on values
Too much in autumn (Southern Australia)		• Pressure to burn more vs. window of opportunity		• Decline of logs & hollows: decline in invertebrate & bird diversity
Too intense (Australia wide)	• Unskilled burning	• Unplanned fires dominate; insufficient prescribed burning • Pressure to burn in narrow window of suitable weather due to social constraints	• Climate change, cyclones	• Decline of fire sensitive species and vegetation, soil erosion, ecosystem function and composition • Creation of ecosystems that support only intense fires
Not intense enough		• Perceptions that prescribed fire is bad • Operational risk constraint on intensity • Pressure to burn in narrow window of suitable weather conditions • Pressure to burn when risks of fire 'escapes' are minimal		• Decline of fire dependent species (insufficient soil heating, lack of seed release from serotinous plants and reduced germination from plants requiring fire to temporarily remove resource competition) • Failure to meet rehabilitation or other objectives
Too large	• Insufficient consideration of ecological issues in burn planning	• Unplanned fires dominate; insufficient prescribed burning	• Climate change, cyclones	• Decline in fauna populations (habitat loss) • Decline in diversity • Homogenisation of fuel leading to cycle of bushfire • Impact on entire home range of threatened species

Inappropriate fire regime	Examples of management hazards	Examples of social/economic hazards	Examples of natural hazards	Examples of impact on values
Too small		• Resource or budget constraint • Social pressures to reduce burn size • Smoke management • Urban interface restrictions		• Decline in seedling recruitment (browsing pressure) • Not achieving ecological objectives
Mosaic 'grain' size too large (lack of patchiness)	• Unskilled burning	• Resource or budget constraint	• Drying of wetlands, damp lands and riparian zones	• Decline in habitat diversity and fauna populations
Lack of diversity of frequency, season and intensity	• Lack of knowledge and research • Inappropriate application of inter-fire intervals/ fire regime formulas			• Decline in biodiversity

4.1.2 Management factors

There is a substantial body of ecological knowledge from research, reports and guidelines held within land management agencies which, along with the experience of practitioners, provides guidance for determining appropriate fire regimes (Bradstock *et al.* 2012a). Incomplete knowledge and understanding of what is an appropriate fire regime is, however, a consistent situation for most if not all ecosystems of Australia. This contributes to controversy in some regions and states, and differing opinions amongst scientists and land managers. Mostly, however, the ecosystems in which prescribed fire should be applied for maintaining a healthy environment are recognised but the risk is that incomplete knowledge may lead to the application of a fire regime that is not ideal and in some cases deleterious. Not properly understanding or considering all the components that contribute to appropriate fire regimes, for example, by focusing solely on fire interval, is itself a risk that is quite wide spread.

Fire regimes that maintain a spatial and temporal diversity of functional habitats are considered desirable in maintaining ecosystem function and resilience in many Australian ecosystems. Patchy, mosaic burns are recognised as being an important component of a fire regime for ecosystem diversity and associated biotic diversity. There is, however, a gap in knowledge of what is an appropriate scale of patchiness to benefit biota and there is not a simple formula that can be applied widely.

The uncertainty that arises from incomplete knowledge must be recognised as an intrinsic factor for prescribed burning and therefore it also underpins ecological risk assessment and treatment. While our knowledge increases every year, we cannot expect to have complete knowledge when prescribing and applying fire. The complexity and diversity of ecosystems, including the many thousands of species of plants and animals that contribute to this diversity, create a daunting task for any attempt to gain a mechanistic and reductionist understanding of appropriate fire regimes. Indeed, in many ecosystems, there is no single optimal fire regime and diversity. Also, many ecosystems are in a state of change. It must be accepted that prescribed burning will take place with this uncertainty and adjustments to planned fire regimes will be made as new knowledge becomes available.

There is increasing scrutiny and pressures emerging around prescribed burns that escape. There is a risk of agencies becoming more risk averse which may limit windows of opportunity to conduct prescribed burning for ecological outcomes.

Prescribed fire was, and still is in some areas, applied by Traditional Owners skilfully and as part of everyday life. Non-Aboriginal land managers also apply prescribed fire skilfully; however, in some rural areas there has been a decline in the number of people skilled in prescribed burning as a result of changing communities and lifestyles.

The knowledge associated with fire ecology is relatively new and considerable improvement in the management of ecological risk will be achieved by increasing the scope and effectiveness of fire ecology knowledge among fire practitioners and land managers, improving their ability to 'read country' and respond effectively to the condition of individual patches of bushland. Being able to 'read country' and understand the role of fire in ecosystem function is an emerging area of knowledge. This knowledge becomes more significant when applying prescribed fire to ecosystems that are in a degraded condition and where standard fire regimes may not apply and these ecosystems may require an altered approach to fire management.

4.1.3 Social/economic factors

Some of the factors influencing a fire regime are considered natural, for example, lightning as an ignition source and the weather patterns that determine fire behaviour, but even these are influenced by human activities that contribute to climate change. More direct human influence, such as the lifestyles, behaviour and activities of people contribute significantly to moulding fire regimes and in some situations lead to inappropriate fire regimes. Prescribed fire may be a component of, or may be applied to change inappropriate fire regimes. Some examples of social factors implicated with inappropriate fire regimes are summarised here.

Urban development adjacent to bushland – Australia is a highly urbanised country. Paradoxically, many inhabitants of human settlement areas have fire prone bushland at their back door. Understandably, following the devastating bushfires that have occurred, for example, in Victoria, Western Australia, New South Wales and Tasmania, management of fuel hazard around settlement areas by prescribed burning has become a priority for governments and the area and frequency of such burning is increasing. The objective is to reduce bushfire risk to life and property but in doing so a risk to biodiversity may be created in some vegetation types by prescribed fire with intervals that are too short and patchiness too homogenous; or that facilitate other threatening processes such as weed invasion or predation by exotic predators.

As a consequence of increasing social expectation for bushfire protection, the limited resources and burning opportunities available to undertake prescribed burning may become focussed on providing a tactical defence adjacent to community assets at the expense of maintaining biodiversity across the broader landscape.

Decline in Traditional Owner burning – Traditional Owners have burnt country all over Australia for thousands of years, but in many regions this burning has declined, changed in pattern, or ceased altogether since European settlement. In many areas, the biodiversity that exists today, or did until recently, strongly reflects

the long history of Traditional Owner burning. This change in fire regimes has been documented in most Australian states and territories. In many of these areas, fire sensitive vegetation has co-existed alongside more fire adapted vegetation for millennia, but with the removal of a regular patchwork of prescribed fires, bigger, more intense fires are now burning and causing the decline of fire sensitive vegetation. Homogenisation of post-fire habitat over vast areas is a mechanism of decline, including even the fire-adapted species. Alternatively, in the absence of fire, the fire sensitive vegetation is invading fire adapted vegetation such as grasslands or open forest. Examples include rainforest in the wet tropics, Arnhem Land and Tasmania, and melaleuca in tropical savanna.

Fragmentation of landscapes – Land use change and removal of bushland is widespread and results in an increase in the boundary to area ratio of remnant areas of native vegetation. Other threatening processes can be facilitated by fire along these increased boundaries. It may be difficult or impossible to achieve the spatial diversity and fire intensity appropriate to the biota occurring in these areas by utilising prescribed fire. There is a risk in some remnants that the fire regime that contributed to the maintenance of current ecosystems and diversity can no longer be applied by prescribed burning because of practical constraints such as the need to safely contain the burn.

Many bushland remnants contain species or communities that were once more widespread. For threatened species known from only a few populations in peri-urban bushland remnants, there is a risk that the most appropriate fire regime conflicts with management of fuel hazard for protecting life and property or conflicts with being able to safely ignite and contain the burn.

Degradation of bushland – Degraded vegetation may respond to prescribed fire differently to intact vegetation. Some grassy woodlands, for example, are highly invaded by weeds and these weeds are fire responsive. Without weeds, these communities respond positively to an appropriate fire regime, but such is the competitive advantage of the weeds, these communities often decline in the extent of native cover after a fire. Areas burnt frequently for asset protection are often on the urban interface where invasive weeds and new garden escapes proliferate. Prescribed burning can provide windows of minimal competition and good nutrient levels under which existing weed infestations can spread and new ones can establish.

Lack of integration of prescribed burning across tenure – There are many situations in Australia where contiguous tracts of bushland have numerous owners with different land management objectives. Although some of these owners, particularly government agencies, are able to prepare and implement prescribed fire programs, many are poorly equipped to deal with planned or unplanned fire. There is a risk that a lack of integration of fire planning across tenure compromises achieving prescribed burn program objectives and leads to sub-optimal fire regimes in terms of ecological diversity.

In some jurisdictions there is a lack of regulated forums that enable the preparation and implementation of cooperative multi-tenure prescribed burning programs. In some jurisdictions there is also a lack of legal clarity concerning the liability held by a landowner who has a parcel of land involved in a cooperative prescribed burn. This uncertainty is a significant disincentive for land owners to participate in cross tenure burning programs.

Lack of resources and funds – Modern Australia has complex landscapes with juxtaposed urban, industrial, agricultural and bushland environments, where the operational risks and social constraints on prescribed burning are more significant than in more remote areas. The cost per hectare of burning in these more developed environments is higher compared to more remote areas and funds, resources and skill to undertake this burning can be a limiting factor. In many parts of Australia it is recognised that more prescribed burning would lead to more ecologically appropriate fire regimes, but the funding and resources to do this burning is not available when needed. Therefore there is a risk that a shortage of skills, resources and funds will cause altered and inappropriate fire regimes, including insufficient fire and fire of an inappropriate intensity or spatial scale.

While funding may be available for prescribed burning, there may be insufficient funding to remediate the negative ecological impacts of burns in degraded areas or to conduct follow-up weed or pest management work. Additionally, in some environments, weeds are the most significant fuel and, under prescribed burn conditions, fire doesn't always reduce these fuels (e.g. olives). The most effective, long term method of reducing fuel loads in these areas might require methods other than burning (e.g. manual or chemical weed control) but funding for this may not be included in prescribed burn programs, and so fire is sometimes applied instead with negative ecological consequences and marginal fuel reduction results.

Changed priorities for prescribed burning effort – The funds available for prescribed burning programs in every jurisdiction are finite. In all jurisdictions a priority is directed to protecting life and property. This can result in a large proportion of the funds available being expended in the vicinity of built assets in peri-urban areas. In some jurisdictions, funding has always been very limited for prescribed burning for ecological objectives. There is a risk that this focus of burning around settled areas limits the resources that can be dedicated to burning in other bushland for biodiversity conservation objectives.

There are limited burning opportunities each year to undertake prescribed fire operations when resources are available, and weather and fuel conditions are conducive to achieving low intensity fire behaviour. Each burn, large or small, consumes one of these burning opportunities. Optimising the consumption of these limited opportunities and funds depends on clearly defined priorities associated with prescribed fire policy and prescribed fire programs.

Yet another risk related to changed priorities comes from tropical Australia. Schemes such as the West Arnhem Land Fire Abatement Project aim to provide a more ecologically appropriate fire regime by reducing the extent of late dry season fires. One of the drivers for this prescribed burning is an economic benefit derived from the offset of the greenhouse gas emissions. Thus, while an ecologically more appropriate fire regime is one of the objectives, and indeed there is good evidence that this is being achieved, there is a risk of creating another fire regime that does not have adequate diversity.

Social constraints – In modern complex landscapes there are various social constraints on when or how much prescribed burning can be undertaken. Prescribed burning may be limited in some cases due to health and other social impacts of smoke. For example, disruption of social events, closure of highways, disruption to aircraft movements, the effect on wine grapes, apiarists and users of National Parks. These constraints, when combined with other operational constraints, reduce the 'window of opportunity' for burning.

There is a very poor understanding of fire ecology in the wider Australian community. Agencies undertaking prescribed burning in urban and peri-urban areas must invest a considerable amount of resources for community engagement (decreasing resources available for burn program output) to ensure they gain community support.

Social perceptions – There is need for improved education and awareness about the role of prescribed burning in natural ecosystems. There are still strong perceptions in certain parts of society that prescribed burning is bad for ecosystems, species and habitats despite evidence to the contrary. Or alternatively, that prescribed burning is only for asset protection or bushfire mitigation, and therefore should be limited to those outcomes. These perceptions can sometimes impose limits on prescribed burning. It can also greatly impact on community consultation processes, consume a lot of resources, delay burning or even prevent burning from occurring.

Legislative constraints – In some jurisdictions environmental/conservation legislation places a considerable administrative burden on land managers, and prescribed burning that is desirable solely for ecological objectives is in some cases avoided. These legislative constraints are commonly focussed on the protection of individual species or communities due to their rarity. Knowledge concerning the level and type of adaptation to fire associated with this biota is often incomplete. These species and communities are often embedded in or near to

fire prone landscapes. Legislation commonly assumes fire to be a potentially threatening process and is silent on fire as a naturally occurring perturbation. Gaining approval to apply prescribed fire where this type of legislation applies commonly involves long lead times and can involve a considerable amount of work.

All jurisdictions have permit systems that have the goal of preventing prescribed fires becoming damaging bushfires. These systems do not easily accommodate issuing permits for ecological burns because of perceived risks concerning burn security. These regulatory mechanisms are significantly inhibiting the amount of ecological burning that is undertaken on non-government land resulting in a decline in ecosystem health on these lands because of the absence of fire. There is a risk that as prescribed burning is avoided or constrained, the result will be fire regimes that are not optimal for maintaining ecological values.

Lack of clear supporting legislation and conflicting legislation restricts the application of ecologically appropriate fire regimes. Examples include: a lack of legislation to facilitate cross-tenure burning and provide clarity on liability; and legislation on air quality that conflicts with fire management.

4.1.4 Natural factors

Climate change, though most likely influenced by human activity, is included here as a natural factor, as it has altered weather patterns which are affecting fire behaviour, fuel type, fuel accumulation rates, fuel drying regimes and fire regimes. Post-fire growth of plants is also responding to a changing climate. It is probable in many parts of Australia that bushfires will become more frequent and more intense, while the 'window of opportunity' for safely applying prescribed fire will alter and/or reduce. Climate change presents a challenge and a risk to maintaining ecologically appropriate fire regimes.

Natural events such as droughts may restrict the opportunities to achieve ecological outcomes with prescribed burning. Storms, floods and especially cyclones can alter fuel conditions for a number of years, interfering with burn programs and creating fuel conditions that are more likely to facilitate fire spread in general, fire spread across control lines (natural or artificial), fire spread into canopy via ladder fuels, and fire impacting on already stressed ecosystems and species.

Diversity in fire regimes, and the resultant spatial and temporal diversity in functional habitats, contributes to ecosystem resilience in the face of perturbations such as climate change.

4.1.5 Competing objectives

Prescribed fire is applied to natural landscapes across Australia to achieve a number of management objectives. Common objectives include bushfire risk management, optimising productive output from natural systems (water, timber, meat and fibre etc.) and conserving biodiversity. In many cases several or all of these objectives can be achieved from the same land segment. In some situations, one or more of the objectives will require compromise to enable the achievement of others.

Prescribed burning is one of many land management activities applied to conservation reserves, production forests and other areas of natural bushland. Other activities include grazing, control of feral and native animal populations, weeds and diseases. Coordination of these various activities with prescribed burning is necessary to ensure that the risk of fire facilitating deleterious ecological outcomes between these activities is reduced.

The planning and application of prescribed fire programs across tenure boundaries, e.g. crown land, leasehold land, private land and Traditional Owner interests, is also required to optimise the achievement of objectives at a landscape and ecosystem scale. Individual landowner objectives can often accommodate the achievement (in full or in part) of the objectives of other landowners if adequate cooperation can be achieved in planning and implementing prescribed fire programs.

4.2 Analysis and evaluation of risks

4.2.1 Synthesis of ecological knowledge on appropriate fire regimes

An understanding of what is an appropriate fire regime is important to applying prescribed fire that will be most beneficial for maintaining natural diversity and ecological health. The appropriate fire regime can be defined in general terms for a vegetation complex at a regional scale, but at the local scale, the condition and state of the individual site will need to be assessed in the field and from appropriate indicators for the fire requirements to maintain healthy ecosystem function.

In a sense, the appropriate fire regime is an elusive ideal that may never be known or even exist, but the extremes of fire regime possibilities, or what is definitely not appropriate in a given vegetation type, are easier to identify. The appropriate fire regime is a range of acceptable values for parameters such as frequency, season, intensity and patchiness. Appropriate fire regimes are based on the best available knowledge from a variety of sources including:

- Research, published and unpublished;
- Local knowledge, including Traditional Owner knowledge;
- Expert opinion of biologists and fire managers;
- Monitoring data such as permanent vegetation plots and sample areas;
- Fauna and flora surveys conducted before and after burning;
- Application of knowledge from similar vegetation or ecosystems from nearby regions; and
- Computer modelling.

The more local the knowledge is, the more likely it is to assist defining an appropriate fire regime. Extrapolation of fire regime parameters from other areas is widely applied and may be the best available knowledge in many circumstances.

Tolerable fire intervals

The tolerable fire interval (TFI) concept is applied extensively for defining ecologically appropriate fire regimes in south-west Western Australia, South Australia, Queensland, Victoria and New South Wales (e.g. Cheal 2010). The terminology varies from state to state but the following terms have similar meanings:

- Tolerable fire interval (Victoria);
- Inter-fire interval (Queensland);
- Fire interval threshold (NSW); and
- Thresholds of potential concern (South Australia).

Tolerable fire intervals are based on accumulated knowledge of fire responses of individual species, most typically plants, recorded and classified in terms of vital attributes of Noble and Slatyer (1980). The guidelines from South Australia also provide a recent regional user guide to vital attributes (DEWNR 2013).

Because of the impossibility of investigating the fire responses of all species, the data collection is usually limited to the responses of strategically selected species. Some examples are as follows:

Key Fire Response Species – Those species whose life histories or vital attributes indicate that they are vulnerable to a particular fire regime (SA, in WA also called Umbrella Species). These species can be plants or animals.

Fire Adapted Species – Those species that occur commonly in fire prone portions of the landscape and are variously adapted to persist in this fire prone environment (WA).

Keystone Species – The role of these species within an ecosystem has a disproportionate effect on other organisms (WA).

Threatened Species – Species of limited range and abundance that have legislative protection and preferential status for defining an appropriate fire regime.

Some jurisdictions or organisations maintain and share databases on the fire responses of species of plants and animals, commonly using the vital attributes scheme as a basis for data collection and storage. Analysis of data from these databases contributes to identifying ecologically appropriate fire regimes.

The use of TFIs to aid decision making about appropriate fire regimes has come under criticism by researchers and practitioners and is considered far too conservative, that is, leading to fire regimes with a minimum fire interval that is too high. A review of this debate is in the *Review of Best Practice for Prescribed Burning* (AFAC 2014). Examples of the problems that occur include:

- The TFI approach often groups ecosystems into broad assemblages and then applies a minimum fire return interval to that group based on attributes of fire sensitive species. However, these species may form only a very small part of the vegetation assemblage or may even have been introduced from neighbouring areas in the absence of fire. Leaving areas unburnt for several years is risky as it may allow a bushfire to occur and homogenise the fuel landscape impacting the fire sensitive species (AFAC 2016a).
- It is becoming increasingly recognised that mosaic burning is desirable for many ecosystems. This naturally leaves many areas unburnt within the burn footprint, especially areas that are moist or somewhat sheltered by landscape features, rocky areas etc. These areas tend to be occupied by fire sensitive or less fire tolerant species or ecosystems that gain added protection from adjacent areas having been mosaic burnt. The TFI approach does not easily account for the dynamics of mosaic burning.
- Vegetation with a dominant species that out competes other species, where a minimum TFI may need to be set low enough to control the dominance of that species.
- Another reason that TFIs are often criticised is because they don't typically take into account the needs of fauna. This is usually explicitly acknowledged and is due to the difficulty/cost in collecting equivalent relevant data on fauna and their habitat. This is starting to be addressed (e.g. in Victoria) but is still challenging to practically apply.

The knowledge of the vital attributes of species can also be used to control undesirable species, such as in areas of Queensland where woody thickening is a consequence of inappropriate fire regimes; or coastal heathlands in south-east Australia where single shrub species can dominate.

With the above in mind, it should be remembered that tolerable fire intervals are just one of the tools that guide the application of prescribed fire to maintain ecosystem health and should not be used alone to determine when and how to burn in isolation from other ecosystem considerations.

Metrics for measuring ecosystem resilience

The Department of Environment, Land, Water and Planning (DELWP) in Victoria is 'testing and developing additional measures that can be used in combination with TFI to improve our understanding of ecosystem resilience' (DELWP 2015). In the context of strategic bushfire management planning, ecosystem resilience is defined as:

> An ecosystem's capacity to absorb both natural and management imposed disturbance but still retain its basic structure (in terms of species abundance and composition), function and identity (in terms of vegetation type) over space and time (DELWP 2015).

The two new metrics for measuring ecosystem resilience being developed by DELWP are:

- ***Vegetation Growth Stage Structure*** – Vegetation Growth Stage Structure (GSS) analyses are based on the premise that a mix of vegetation growth stages and habitat structures across a landscape can be derived from available models and/or data so as to potentially optimise biodiversity, and hence enhance ecosystem resilience.
- ***Geometric Mean Abundance*** – the Geometric Mean Abundance of species in a community is an index of the relative abundance of species and provides a measure correlated with community viability.

The intention is to use these metrics to guide fire management programs including prescribed burning (see also section 8.4).

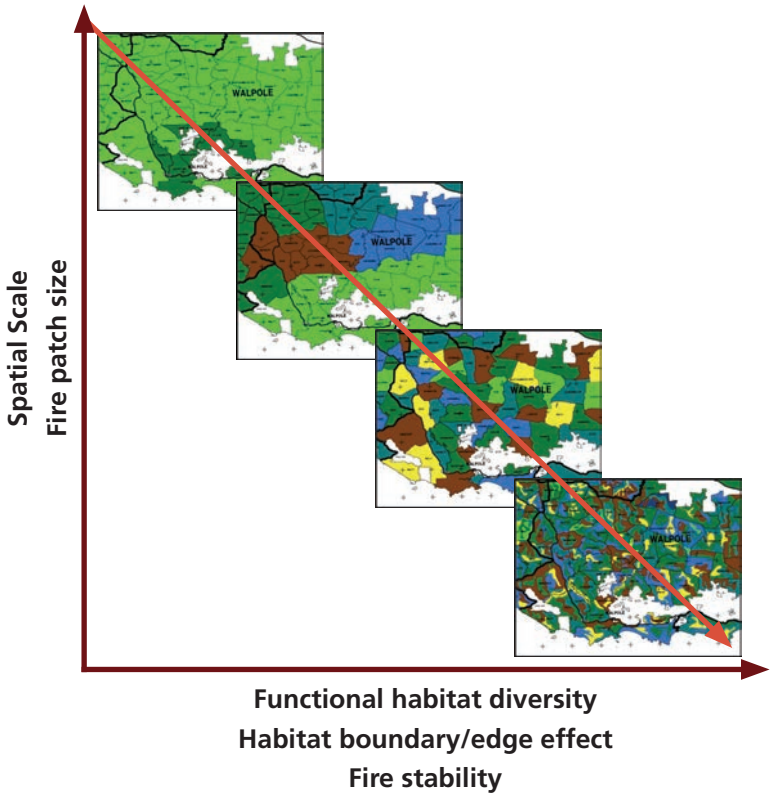
Management of functional habitat diversity and mosaic burning

Planning of fire regimes at the landscape scale may aim for some hypothetical ideal mosaic of patches of defined post-fire age classes, also known as vegetation growth stage structure. The aim is to provide diversity within the landscape of functional habitats that are associated with post-fire vegetation structure and composition as a consequence of the time since fire. A commonly used indicator of this diversity is the time since fire or fuel age class. This approach has been used in combination with knowledge of TFIs or stages in vegetation maturity and habitat structure to identify the desired program of prescribed burns in a landscape.

The appropriate scale of a mosaic is often difficult to identify and is an area of limited scientific knowledge. The scale possibilities include the size and spatial-temporal arrangement of burn units with a landscape, and then within the burn perimeter the percentage of unburnt vegetation that should remain and the size and arrangement of the burnt and unburnt patches. The appropriate mosaic may often be an estimate based on expert opinion because well documented studies of appropriate habitat mosaic scale are relatively few. Figure 6 provides an illustration of the range of mosaic possibilities from south-west Western Australia, from the least desirable to the most desirable.

Identification of an appropriate ecological scale is particularly hampered by a lack of knowledge about the dispersive abilities of fauna. While this is the case in intact landscapes it is even less clear in fragmented landscapes in which fire regime mosaics are nested within landscape mosaics of habitat patches and highly modified agricultural and urban landscapes. Mosaic burning ensures a diversity of fire regime conditions within a landscape thus providing for the different requirements of species. Maintenance of biodiversity may benefit as a result and this can be an important consideration where ecological knowledge is limited.

Figure 6 *Fire mosaic possibilities from the least desirable (top left) to the most desirable (bottom right) (Department of Parks and Wildlife, Western Australia)*



Threatened species

The ideal for a prescribed burning program is to consider the full diversity of species and fire regime requirements and not focus on a single species. A fire regime designed around one species may well cause the decline of many others. While a single species approach will be justified in some special situations as described below, the consequences of not burning at all should also be evaluated, particularly in the broader landscape context. Fire exclusion should not necessarily be considered a precautionary approach.

The fire responses of threatened species may in some circumstances be a significant consideration in determining an appropriate fire regime in a segment of the landscape; this may be a single species, a small group of species or an ecological community. The reason for giving a threatened species special consideration could be because the fire response of the species is poorly known and therefore a conservative approach to burning is considered prudent; and or the species has a very limited known range and a significant proportion of the extant total population could be burnt in a single prescribed fire. While some species are known to be fire sensitive and the appropriate fire regime is fire exclusion, lack of fire is actually a threat to some threatened species and communities, for example, they may be adapted to regular fire, or lack of fire may allow build-up of fuel across their home range which then burns with high intensity during a bushfire.

All Australian jurisdictions have legislation protecting threatened species and prescribed burning in areas where threatened species exist may require some form of legal authorisation. Therefore, knowledge on the fire response and appropriate fire regime for the species may be required prior to authorisation of burning. Some jurisdictions have lists or databases of threatened species and fire regimes considered to be appropriate.

4. STRATEGIC PLANNING FOR ECOLOGICAL RISKS

The legislation in many jurisdictions requires prescribed burning to be treated as a destructive impact comparable to developments that lead to land clearance. The latter are generally permanent losses of habitat and species, while a prescribed fire is usually a temporary disruption following which species re-establish from seed, resprouting or recolonization. Many ecologists consider the concept of managing prescribed fire as an 'impact' akin to land clearance as inappropriate. Fire is an inherently natural element of the environment unlike the urban, industrial and other developments that destroy bush. There is, however, no choice but to find the most efficient way for gaining statutory approvals and agencies have developed systems to this end.

The spatial databases of known records and distribution of threatened species are integral tools for planning a prescribed burn in many jurisdictions, often as a result of obligations under threatened species legislation. Although these databases get utilised at either the program plan level or the operational plan level, it is more likely that the management and support for the database is at a whole jurisdiction or organisation level. Development and maintenance of good quality databases on natural values such as threatened species, with data that is routinely audited, underpins so many of the critical decisions made in fire management (and in land management generally) and should be well supported.

Traditional Owner knowledge

Traditional Owners used fire extensively throughout Australia for many thousands of years and in some areas still do. The landscapes and biodiversity that exist today are strongly influenced by Traditional Owner burning. Where fire regimes are changing or have changed from an indigenous pattern to a contemporary pattern the legacy or signal of the Traditional Owner burning often remains evident in the extant vegetation and species distributions. A common 'signal' is the presence of fire sensitive vegetation that has been protected by indigenous burning carried out in a frequent, patchy, low intensity mosaic.

The burning and the fire regimes created by Traditional Owners encompassed their cultural concerns, food production needs and their understanding of environmental needs. The fire regimes that have changed from traditional indigenous patterns are more often than not considered to be less ecologically appropriate and characterised by large, high intensity bushfires:

> Frequent widespread and deliberate use of fire at a fine scale is a common observation of traditional Aboriginal fire management, from the wet tropics of North Queensland, through the western desert, and into the south-west forests of WA. A fine-grained, fire-induced mosaic provided habitat diversity and reduced the possibility of large, intense and homogenising wild fires. In the western desert, and probably in other ecosystems, it is difficult to envisage wild fires incinerating hundreds of thousands of hectares in a single event, under traditional Aboriginal fire management (Burrows 2003).

There are still many areas where Traditional Owners' knowledge is in existence and can provide insights into the identification of ecologically appropriate fire regimes. In other areas, the pattern of species and vegetation provides contemporary signals that allow reasonable estimation of what indigenous fire regimes might have been. This estimation is a reasonable starting point to enable the reconstruction of indigenous fire regimes in many parts of Australia even though Traditional Owners' knowledge and practice and its cultural context may be fragmented or lost.

(Source: Queensland Parks and Wildlife Service)

Health indicators

In the Queensland Parks and Wildlife Service there is a focus on maintaining functioning and healthy ecosystems. Thirteen bioregion-based planned burn guidelines were prepared to give specific guidance to practitioners via photographic and written indicators of ecosystem health. For each ecosystem group (Fire Vegetation Group) indicators are provided to guide practitioners in the field so that they can identify areas that are in healthy conditions, areas where application of fire might be required or areas showing a range of ecological health problems (such as weed invasion, an overabundance of a single species, rapid ecosystem change etc.). These degraded areas may require an altered approach if the management goal is to rehabilitate the system. For each management issue identified, specific fire regime guidance is offered including information on fire frequency, seasonality, intensity etc. which include but are not focused on consideration of fire tolerance intervals. Guidelines on suitable fuel, soil moisture and weather conditions that will help achieve the fire regime are also offered, as well as a range of ignition strategies that may be suitable.

This approach has elevated the role of 'reading country' and attempts to provide to practitioners the skills they need to judiciously apply fire regimes, nuanced by considerations of the need to adjust these regimes based on the condition of the land as it presents today.

4.2.2 Examine current fire regime trends

Mapping of all fires, both planned and unplanned, underpins both short and long term fire planning, analysis of fire regime trends and analysis of biodiversity characteristics associated with different fire regimes. The scale of resolution of fire mapping varies considerably around Australia, reflecting the scale of fires occurring in the landscape and the technical, financial and practical limitations to data collection and analysis. The higher the resolution and quality of data, including recording of fire patchiness and intensity, the more beneficial the mapping will be for planning, analysis and research into ecologically appropriate fire regimes. Remote sensing data and analysis tools improve every year and their availability is increasing.

Fire mapping is an important monitoring tool. Even if fire mapping is the only monitoring that is being undertaken of fire regimes, with limited or no recording of ecological responses, it will provide a basis for future analysis of appropriate fire regimes and can be a surrogate measure of ecosystem health where underpinning ecological knowledge does not exist.

The Northern Australian Fire Information system provides publically available weekly updates of fire scars at a maximum resolution of 250 metres across all of northern Australia. This mapping is widely used by a variety of land managers and has proven to be an extremely powerful tool for planning and managing fire operations and has helped change fire regimes in northern Australia. The scale and coverage reflects the significant amount of burning that occurs across tropical Australia every year. Severity mapping of fires in northern Australia has also been developed from satellite imagery enabling ecological assessment of fire regimes related to intensity and frequency of burning. The evidence indicates that the dominance of large and frequent late dry season fires is causing a significant decline of biodiversity and this fire regime was not characteristic of Traditional Owner burning (Williams *et al.* 2001). The developments in fire mapping in northern Australia are playing a central role in moving towards more ecologically sustainable fire regimes.

Fire severity mapping is being used in southern Australia to document and analyse major bushfire events. These maps provide input for research into and monitoring of post-fire recovery for high intensity fires which have a more significant ecological impact. It is desirable that severity mapping becomes more available as a routine tool for analysing fire regimes and this may happen as automated systems of capturing and analysing remotely-sensed imagery are developed. The potential exists for quantifying the patchiness and mosaic patterns of fires and thus recording a more data rich fire history than a simple fire scar map of a perimeter. Utilisation of remote sensing data by spatial analysis tools and statistics that are commonly applied in wildlife ecology may also have a role to play in describing, monitoring and reporting on fire regimes and their consequences

Where available, vegetation mapping is used in association with fire mapping to analyse fire regimes, provided that both are done at a suitable scale to identify fire regime components (i.e. frequency, intensity, season, patchiness) within different vegetation types within the burnt landscape. Vegetation maps are the basis for fire planning at the program and operation level in southern Australia, where appropriate fire regimes are defined for broad vegetation categories.

4.2.3 Identify causes and areas of inappropriate fire regimes

Understanding the causes of ecologically inappropriate fire regimes may assist in identifying ways of moving towards more appropriate fire regimes. The strategies to reduce this risk may include a combination of prescribed burning and other actions such as community education, training and fire prevention. Because this implicates changing peoples' behaviour and activities, there are challenges in finding social solutions and funding for changes.

The northern Australia carbon abatement projects are good examples of where social, economic, carbon emission and ecological benefits are linked to prescribed burning. Burning in the early dry season is undertaken to reduce the extent, frequency, intensity and ecological impact of late dry season burning; in effect moving away from an inappropriate fire regime toward a more appropriate regime by changing the proportions of late and early season burning.

4.2.4 Evaluate competing objectives

There may be situations where fire regimes necessary to achieve policy objectives are not entirely compatible with biodiversity conservation. These situations typically occur where life and property values are adjacent to, and at threat, from bushfire hazard on nearby natural lands. In this situation government policy inevitably assigns a higher priority to the protection of life and property than to the conservation of biodiversity. The management of bushfire risk by treating fuel loads utilising prescribed fire is a common strategy in these situations. Prescribed fires for this purpose are characterised by low intensity fire behaviour, a high proportion of the target area being affected by fire (commonly between 70% and 90%), the maintenance of secure burn boundaries using access tracks and the treatment of dangerous trees (commonly older trees with a high proportion of dead material and hollows etc.). To be effective in moderating bushfire risk to acceptable levels this type of fire will be applied to a reasonably high proportion of the land adjacent to the assets.

In these situations the management of bushfire risk by fuel hazard reduction may be a competing objective with ecological objectives. This is particularly the case in ecosystems where the fuels return to unacceptable risk levels before the ecologically appropriate fire interval is reached and/or the desirable level of spatial heterogeneity of fuel ages (functional habitats) cannot be maintained. Although this management option can produce a different vegetation compositions then when measured against historical data, if can still provide useful ecological outcomes, especially if the site is chosen carefully.

It is important to have as good an understanding as possible of the competing objectives, by quantifying the benefit in terms of reduction of bushfire risk and the cost in terms of ecologically inappropriate fire regime whilst considering various options of spatial and temporal patterns. The solution would be to find an optimum prescribed burning regime that manages fuel loads in temporal and spatial patterns that are ecologically sustainable, but this win-win situation will not be achievable in all circumstances.

In many jurisdictions, trade-offs are prioritised by restricting ecological compromise to certain parts of the landscape and identifying these in zones, for example, asset protection zones neighbouring towns (provided the ecosystem is suitable to withstand the trade-off and not likely to move to a system with a more woody state). The best possible ecological outcome should be informed by an explicit understanding of the benefit for other objectives where it is possible to quantify these. These outcomes should consider whether these benefits can be achieved as, or more, efficiently by other means (e.g. improving urban planning, community bushfire preparedness, bushfire response capabilities etc.).

Ecosystems in asset protection zones can be manipulated by frequent fire as one of the fuel reduction strategies. This may be an acceptable solution if the risk to lives is reduced. There is a risk however that some ecosystems will respond by forming fuel complexes that are more fire prone and lead to higher risk fires. For example if fire tolerant shrubby understoreys, rather than grasses, are formed and canopy cover is reduced then bushfires will burn faster, hotter and generate more embers. This must be taken into account when planning the location of asset protection zones.

Beyond asset protection zones, it is usual to identify bushfire mitigation zones which aim to achieve a compromise between ecological outcomes and reduced fuel hazards. The remaining areas are usually zoned for land management purposes where ecological outcomes are the highest priority. In this way, fire management zones are a very common tool to achieve and specify fire regimes for different objectives.

Another approach is use of fire simulation models. These are used to test different prescribed burning scenarios as part of bushfire risk assessment and the benefit can be quantified by indices of ‘leverage’ or ‘residual bushfire risk’. The evaluation of prescribed burning scenarios against bushfire risk reduction benefit is becoming more common as more simulation tools are being developed and research papers and reports utilising these tools are published.

4.3 Treatment of ecological risks

The treatment of ecological risks at the strategic level involves a variety of organisational or regional level activities that provide the rationale for why the use of prescribed fire is required and will support making the best possible decisions on where, when and how to undertake prescribed burning that is considered most ecologically appropriate based on current knowledge. Organisations need:

- Clear documentation of organisational level objectives in relation to fire and biodiversity
- Clear statement on level of acceptance of risk in terms of fire and biodiversity
- Clear documentation of an organisation's systems, training and procedures in relation to fire and biodiversity along with its commitment to training, knowledge management, research and community engagement.

4.3.1 Information and knowledge management

The latest available knowledge should be collated, analysed and made readily accessible for program planning and operational planning. This involves developing and continually updating mapping of fire history, vegetation, threatened species (and/or their habitat); and databases on species distribution and fire responses. Fire regime ideals are summarised in strategic plans, reserve plans, guidelines or other supporting documents. Accessibility can be enhanced by provision of tailor made tools in GIS to generate standard reports, summarise past fire regimes, and project future prescribed fire needs. Consistency and efficiencies are gained by continually developing systems within organisations. Programs to train and mentor practitioners in ecological knowledge are an important factor in ensuring ecological knowledge becomes embedded in work practices.

4.3.2 Targeted research

Where resources permit, support is given either internally within prescribed burning organisations or for external researchers to provide targeted research relating to key questions on aspects of fire ecology, fire regimes, fire risk, social research and the operational application of fire (e.g. fire behaviour, fuels).

Partnerships and collaboration between prescribed burning organisations, universities and other research institutions are important to ensure research is undertaken that will improve prescribed burning programs and address ecological risks. In many cases, the research depends on the combination of skills and resources from both prescribed burning and research organisations. For example, universities do not usually have the capacity to undertake prescribed burning and agencies have limited research resources. This collaboration includes identifying knowledge gaps, developing research programs that address the practical needs of fire managers and funding researchers for specific projects.

The Bushfire and Natural Hazards Cooperative Research Centre and previously the Bushfire Cooperative Research Centre play an important role in supporting research partnerships. Many research questions are of common interest to organisations involved in delivering prescribed burning across jurisdictions so the efficiency gained by collaboration at a national level is significant. Examples of research completed to date include questions relating to fire ecology and biodiversity, soil erosion, water and catchment management, bushfire risk management modelling and mapping fire in northern Australia.

(Source: Department of Environment, Land, Water and Planning Victoria)

4.3.3 Natural value monitoring

A strategically designed program of monitoring of natural values will support the evaluation of prescribed burning outcomes and identify or clarify the effects of prescribed burning to address specific flora and fauna knowledge gaps. Design needs to recognise the budget constraints of the organisation and therefore be realistic and practical. There are many biological attributes that can be monitored; however, monitoring will only ever be undertaken of a sub-set of attributes because of limited capacity. Therefore strategic level guidance should be provided on how to select and prioritise the attributes to focus on and the most useful monitoring techniques (see section 8).

It is recognised in all jurisdictions that more monitoring should be undertaken to advance the development of ecologically appropriate prescribed burning than is currently occurring and that more investment is required. Individual organisations and jurisdictions do not necessarily know about the techniques and investment made by others. As with targeted research, collaborative development across jurisdictions should be pursued for monitoring techniques, data and development of tools to ensure efficiency and better outcomes for all.

4.3.4 Guidelines for practitioners

Ultimately prescribed burning is a practical skill delivered by people in the bush. The publication of high quality supporting guidelines assists land managers to make informed decisions on prescribed burning.

Ultimately prescribed burning is developed and delivered utilising the combined inputs of a wide variety or people, skills and experience. The publication of supporting guidelines assists land managers and fire practitioners to make informed decisions on prescribed burning (e.g. ESDD 2012; DNPRSR 2013). The guidelines can provide direction on:

- ***why to burn:*** bushfire risk management, productive land uses, biodiversity conservation, burn program objectives, burn objectives;
- ***when to burn:*** ecosystem health, fire regimes, tolerable fire intervals, risk management, achievement of burn program objectives;
- ***where to burn:*** priorities and principles, strategic bushfire risk management, strategic biodiversity conservation, achieving burn program objectives; and
- ***how to burn:*** burning prescriptions, fire behaviour and techniques.

Key principles relating to fire ecology, fire regimes and knowledge management have been incorporated into guiding publications in several jurisdictions. Some good examples of these are given in Figure 7 and Figure 8.

Figure 7 *Scientific principles to guide fire management in south-west Western Australia (Burrows and Abbott 2003)*

Principle 1

The vegetation and climate of south-west WA make it highly prone to bushfire. Fire should be regarded as an environmental factor that has and will continue to influence the nature of south-west landscapes and biodiversity and is integral to conservation and land management.

Principle 2

Species and communities vary in their adaptations to, and reliance on, fire. Knowledge of the temporal and spatial scales of fires in relation to the life-histories of organisms or communities involved underpins the use of fire in natural resource management.

Principle 3

Following fire, environmental factors such as landform, topography and species' life history attributes, and random events such as climatic events, often drive ecosystems towards a new transient state with respect to species composition and structure. This may preclude the identification of changes specifically attributable to fire.

Principle 4

Fire management is required for two primary reasons, which are not necessarily mutually exclusive: a) to protect and conserve the biota; and b) to reduce the occurrence of large, damaging wildfires. The biological impact (killing power) of a single fire event and the rate of recovery are directly proportional to the intensity and size of the fire.

Principle 5

Fire management should be both precautionary and adaptive, considering ecological and protection objectives in order to optimise outcomes.

Principle 6

Fire diversity promotes biodiversity at both the landscape scale and the local scale. At the landscape scale, an interlocking mosaic of patches of vegetation representing a range of biologically-derived fire frequencies, intervals, seasons, intensities and scales will provide diversity of habitats for organisms that are mobile and can move through the landscape. At the local scale, appropriate fire regimes based on biological attributes are necessary to ensure the persistence of sessile organisms and structures.

Principle 7

Avoid applying the same fire regime over large areas for long periods of time and minimize seral and structural homogenization by not treating large areas with extreme regimes such as very frequent or very infrequent fire intervals.

Principle 8

The scale, or grain-size, of the mosaic should: a) enable natal [new born] dispersal; b) optimise boundary habitat (interface between two or more seral states); and e) optimise connectivity (ability of fauna to cross between seral states).

Principle 9

All available knowledge, including life histories, vital attributes of the flora and fauna and knowledge of Noongar [Traditional Owner] fire regimes should be utilized to develop ecologically-based fire regimes for a landscape unit or a vegetation complex.

Principle 10

Fire history, vegetation complexes and landscape units should be used to develop known and ideal fire age class distributions.

Principle 11

Wildfire can damage and destroy both conservation and societal values, hence risk management must be based on a systematic and structured approach to identifying and managing the consequences of such an event.

Principle 12

Fire management should adapt to changing community expectations and to new knowledge gained through research, monitoring and experience.

4.3.5 Community engagement

Applying prescribed fire effectively and at appropriate scales requires the knowledgeable support of the general public, politicians and communities of interest. A tolerance of the inconveniences associated with the application of prescribed fire such as smoke impacts, disruption to transport and industry is necessary. Targeted, persistent programs of engagement to garner this community support are essential to the success of prescribed burning programs. Social research, professional extension services and effective means of monitoring social values and perceptions are required. A standardised lexicon of prescribed burning terminology would assist in creating this national level of social acceptance.

4.3.6 Practitioner training and support

Prescribed burning requires considerable skill and knowledge to apply appropriately and to achieve the best possible outcomes. Adequate training, mentoring and support for the people undertaking the operational planning and execution of prescribed burning are essential. The training should include learning about ecological principles and objectives as well as the practical application of fire. It is recognised across jurisdictions

Figure 8 *The key principles advocated to guide the conservation of biodiversity in South Australia which relate to fire management (DEWNR 2013)*

1. In-situ conservation – Biodiversity is best conserved in-situ where landscapes, ecosystems and ecological processes maintain species in their natural habitats. Complementary ex-situ conservation activities should support in-situ conservation if required.

2. Appropriate planning – Biodiversity conservation activities are planned at the appropriate biological, spatial and temporal scales in consultation with government, industries, and urban, rural and Aboriginal communities.

3. Managing the cause – It is essential to prevent the introduction of new threats and deal with existing threats at their root cause.

4. Prevention – Preventing the loss of biodiversity by dealing with existing threats is preferable to reconstruction and treating symptoms.

5. Precautionary – Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

6. Developing knowledge – It is essential to develop and share knowledge, and seek and value the wisdom of government, industries, and urban, rural and Aboriginal communities.

7. Best available knowledge – The best available biodiversity knowledge should be used in a precautionary way as part of a risk management approach to informed decision making.

8. Adaptive management – Biodiversity management must incorporate an adaptive approach that is flexible and inclusive, continually improves by testing and learning, and is based on science where appropriate.

9. Ecosystem approach – Biodiversity management will be most effective when we adopt an ecosystem approach that recognises and integrates all components (genes, species, ecosystems) and attributes (components, patterns, processes) of the biodiversity hierarchy, and manages these at appropriate spatial and temporal scales.

In seeking to optimise the management of fire for biodiversity outcomes, the best elements of these different approaches need to be used to develop and implement ecological fire regimes. This will require careful planning (Fire Management Plans), expert advice (ecologists, fire specialists, and others with specific or local knowledge), and ultimately a land management decision (landowner, land manager or land management agency staff).

that training for fire practitioners on ecology needs to be increased quite significantly, particularly to support understanding of ecosystem function and practical interpretation of management requirements at the local level. Support should include regular forums to review past operations, lessons learnt and recent developments in techniques and ecological knowledge.

4.3.7 Integrated planning across tenure

The management of prescribed fire at a regional level, to be strategic and effective, may need to cross tenure boundaries to achieve the objectives of multiple stakeholders. Integration of burning programs at a larger landscape level enables better coordination of burning for multiple objectives and may reduce the need to implement inappropriate fire regimes (for fuel management purposes) in some areas of public land. Opportunities to integrate burning programs at a larger landscape level should be explored.

4.3.8 Streamlined approvals for prescribed burns

There is a need in some jurisdictions for reform in the regulatory processes imposed upon ecological burning to ensure that burning can be better recognised as a responsible land management activity to maintain ecosystem health and not just a threat to community and environmental values. These reforms may require changes at both federal and state levels. The aim is to ensure that approval processes provide a realistic opportunity for prescribed burning to be undertaken where and when it is needed for ecological health.

4.3.9 Strategic plans and zoning format

Strategic plans given guidance on higher level objectives, strategic direction and priorities. At the strategic level, definition of zones and associated objectives is stated to provide consistent understanding and terminology between land managers and stakeholders. An illustration of how ecological values are treated within a zoning scheme is given in Figure 9 from the Victorian Code of Practice for Bushfire Management on Public Land (DSE 2012).

Zoning is not applied in all areas or by all organisations, but where it is, zoning is a tool to manage appropriate fire regimes in the landscape or minimise the areas where ecological values may need to be compromised.

Figure 9 *Fire management zones (Code of Practice for Bushfire Management on Public Land, DSE 2012)*

5. PROGRAM PLANNING FOR ECOLOGICAL RISKS

5.1 Identifying the risks

5.1.1 Inappropriate fire regimes; schedule, resource and priority risks

The aim at the program planning level is to schedule burns to operationalise strategic objectives. There is a risk that the schedule of burns in a program plan may lead to inappropriate fire regimes if adequate analysis is not undertaken of the fire history and current condition of areas. All jurisdictions undertake the process of evaluating previous fire events as compared to a recommended fire regime, in order to assist in projecting future prescribed burning needs. However, the process has a number of limitations including:

- Recording of fire scars is usually not refined enough to capture the true patchiness of a burn and variations in intensity; and
- Comparing fire history to a fire regime will give a broad indication of the need to burn, however, does not take into account the current range of conditions at the proposed burn site. The current condition of the site may require a different approach, or conversely, other sites that were not highlighted as requiring fire in the analysis may in fact require burning. Therefore local knowledge has an important role to play in interpreting the results of desktop analyses.

Where resources are limiting the capacity to undertake burns, the need to carefully consider priorities becomes very important. For good reasons, the imperative is usually directed toward achieving burns that address life and property protection. However, this carries a risk that ecological priorities for burning are not adequately identified and considered in developing a program plan to achieve the best possible ecological outcomes with the available resources. Balancing these objectives is an ongoing concern for organisations involved in prescribed burning.

From an ecological perspective, the schedule needs to identify appropriate timing at the seasonal and yearly scales to accommodate the requirements of species and the current and future condition of vegetation. Identifying ecological risks for program planning involves utilising mapping tools, databases and guidelines developed at the strategic planning level, where these are available.

5.2 Analysis and evaluation of risks

5.2.1 Strategic requirements, fire regime requirements and objectives

Relevant policies, guidelines and planning documents should ensure that the proposed burn schedule will be consistent with priorities and other land management objectives.

In many organisations a zoning map will be prepared which sets a framework for objectives and priorities for the proposed prescribed burning units within each zone category. The primary burning objective may be consistent with an ecologically appropriate fire regime in some zone categories but not others.

Many organisations have a routine schedule of consultation with stakeholders to ensure that all relevant issues are considered in the proposed burn program. This consultation may not only be about ecological issues; consideration of operational and community matters may be part of the consultation either together or separately. The range of potential stakeholders relevant to ecological issues includes Traditional Owners,

specialists (including various discipline specialists such as ecologists, botanists and zoologists), neighbours, and operations personnel (e.g. rangers or other land managers). It is important to ensure that local knowledge is considered as far as possible.

Reducing ecological risk can be effectively treated by learning from past experience and communicating the learnings to others and inculcating them into operational practice. Therefore a program review should be undertaken prior to extending or building a new program.

Some organisations have internal consultation meetings that are held annually to review a proposed program. Review of previous year or years of prescribed burning and subsequent monitoring may contribute to the decision making at the consultative meetings. The outcome will be consolidation of burn area proposals, including identification of issues to be considered for individual burn operations.

5.2.2 Fire history implications

Analysis of fire history across the landscape is required to identify which areas may be available for burning consistent with the desired fire interval thresholds, seasonality, intensity and resultant landscape diversity of functional habitats or other ecologically appropriate fire regime parameters. The quality and complexity of the spatial and temporal diversity of fire history will depend on the chronological extent of fire history data and the spatial resolution of the information. In some ecosystems, the legacy of many earlier fire events at a location will be relevant to the maintenance of ecological values. This is typical of ecosystems with complex vegetation structural forms and evidence of extended timelines for seral progression post fire event. In other ecosystems only the recent fire history will have a significant influence on continued ecosystem function. These ecosystems are typically those characterised by flammable grassland components that are adapted to frequent fire events. It is possible to examine repeated or overlapping fire records but this will require well developed GIS analysis skills and appropriate software. Analysis of fire history becomes more efficient and effective where GIS tools are developed to automate the process and present the data in a number of different ways.

5.2.3 Current fire regimes compared to targets or ideals

At the program level of planning the requirements of ecosystems rather than individual species should be considered. Consideration should be given to the spatial interaction and interdependence of fire adapted (ecosystems adapted to fire), fire sensitive (ecosystem potentially damaged by fire), fire dependent (ecosystems requiring fire) and fire independent (ecosystem neither requiring nor damaged by fire) ecosystems and their fire history. As a consequence areas that are available and unavailable for prescribed fire operations during the planned program can be determined. Collation of records of threatened species, fire sensitive species and communities, and other significant biota in proposed burn areas is undertaken from all available sources including databases and GIS. The fire regime requirements of targeted species and communities are reviewed. Vegetation maps in combination with the fire history overlay are used to identify target prescribed burning areas that are consistent with the appropriate or desired fire regimes within and across potential burn units.

The risk of bushfire should be considered as part of program planning. This is particularly the case for large areas of vegetation of the same post-fire age with fuel loads and distributions capable of sustaining the propagation of bushfires. In these situations, insufficient prescribed burning to reduce the likelihood of large, intense bushfires developing will facilitate a significant risk of ecological damage occurring as a result of bushfire events. Thus, waiting for a desired minimum post-fire age across the entire area before scheduling prescribed burns may facilitate undesirable ecological outcomes.

(Source: Parks and Wildlife Service Tasmania)

5.2.4 Competing objectives and priorities

A burning program that is primarily to reduce fuels and protect assets should also, as far as practical, consider and accommodate ecologically appropriate fire regimes. Compromises between ecological objectives and other burning objectives may need to be made in the final determination of burn areas, however, the ideal is that the compromising of ecologically appropriate fire regimes is minimised as far as possible. Zoning may be a tool to determine priority areas where maintenance of low fuel loads to achieve acceptable bushfire risk levels takes precedence over ecological fire regime outcomes and areas where achieving ecological fire regime outcomes will be more readily accommodated.

Prescribed burns may be scheduled where the primary objective is to achieve ecological outcomes either within the burn area or to provide protection to adjacent fire sensitive ecosystems such as rainforest, woodlands and rock outcrops. Identification of priorities for each burn in the burn program is important if for various operational constraints (e.g. budget, weather, resources) all burns in the program may not be completed. The prioritisation for ecological burns should consider conservation values and the relative ecological dependence on prescribed fire of significant biota.

Decisions on priorities for burns in a program may need to be made between burns for different objectives, for example, between ecological burns and fuel reduction burns. In these situations, some consideration should be given to comparative evaluation of the fuel risk reduction benefit compared to the ecological benefits for significant conservation values. Strategic selection of some areas for burning may provide a synergy of both ecological and fuel hazard reduction benefits. Prioritising burns in a program, however, has to be based on a number of criteria not just the achievement of biodiversity conservation or bushfire risk mitigation goals.

Figure 10 (page 48) is an example of prioritisation and criteria used by the Department of Parks and Wildlife in Western Australia. Although prioritising burns gives important guidance to scheduling prescribed burns, operational factors become critically important. These include windows of opportunity, operational efficiencies and available of people and equipment.

5.2.5 Timing requirements for burns

Where ecological values are evaluated, the prescribed burning program will identify burn areas and a schedule after consideration of the factors described above: fire history, natural values, ecologically appropriate fire regimes, policies and guidelines, zoning, matters identified through consultation and other burning objectives.

At the seasonal scale, appropriate timing will account for:

- fire regime requirements of significant natural values;
- avoidance of burning non-target fuels and organic soils; and
- to ensure that the desired fire behaviour, fire intensity and mosaic is achievable.

Social or economic burning objectives may also need to be considered in the seasonal timing of burning, for example, maintenance of a nectar source for bees near apiary sites; or burns which are required to precede tree harvesting operations in adjacent areas.

At the yearly scale, appropriate fire intervals for species and vegetation communities will be a consideration for scheduling; in some jurisdictions this may be obligatory. Providing an appropriate mosaic of post-fire ages across multiple burn units may also be a consideration in scheduling; or providing a spatial-temporal pattern to reduce fuel hazard risk while also maintaining ecologically appropriate fire intervals.

Integration of burn schedules across multiple tenures and land managers, where possible, provides an opportunity to better accommodate ecological fire regimes while achieving other objectives. Burning across tenure boundaries may also reduce the environmental risks associated with constructing new control lines at property boundaries (e.g. introduction of weeds, soil erosion) as well as reducing overall cost.

5.2.6 Progressive burning requirements

Progressive burning involves targeting burn units at different times, often under different conditions, to progressively build up burnt areas that provide a barrier to support later burns (often during drier conditions). The spatial and temporal pattern of burning can be planned at both the intra-annual and inter-annual scale to provide ecological and operational benefits. Progressive burning (especially in northern Australia) starting early in the burn season can provide barriers for burning later in the season when increasingly more fuels are dry enough to burn. At the inter-annual scale, previous burns both planned and unplanned, can be utilised as containment boundaries for prescribed burns. Progressive burning contributes to creating a mosaic and fire regime diversity. In some cases progressive burning that establishes low fuel conditions in the surrounding landscape, is the only safe way to burn damper vegetation types (such as karri forests in south-west WA or wet sclerophyll in the wet tropics of Queensland) that will only support fire at the driest time of the year. A related activity, often called staged-burning, involves applying sequential ignitions to a single burn unit to enable low intensity fire within each fuel type when that fuel type is ready to burn, whilst not igniting adjacent fuel types that are too wet to burn.

Figure 10 *Levels of priority and prioritisation criteria for planned burns from the Department of Parks and Wildlife (DPaW) in Western Australia.*

Priority definitions

There are three levels of priority that can be assigned to a burn purpose or to a burn as the overall priority rating:

- **Priority 1**: those burns that must be done in this season due to their importance in achieving or facilitating the future achievement of DPaWs fire management objectives.
- **Priority 2:** those burns that must be done in this season or the next season to achieve or facilitate the future achievement of DPaWs fire management objectives
- **Priority 3:** those burns that are to be done at some time to achieve or facilitate the future achievement of DPaWs fire management objectives

Prioritisation criteria for each burn purpose

There are a number of standard criteria for each of the burn purposes that have to be considered when determining the priority for a burn unit. Having considered these standard criteria a judgement is made on what priority rating is most appropriate for each burn purpose associated with the burn.

Burn Purpose	Criteria
Biodiversity	Program building Contribution to strategic protection Scheduling constraints Management constraints Species management Scheduling criticality Ecosystem management Criticality of spatial distribution or location Negative Exponential distribution of fuel ages
Bushfire risk management	Program building Scheduling constraints Management constraints Landscape fuel management – potential fire run length Scheduling criticality Potential wildfire intensity Location and value of assets Threats to assets Seasonal sensitivity
Silviculture	Program building Contribution to strategic protection Scheduling constraints Management constraints Scheduling criticality Karri regrowth aggregation Seed condition forecast

	Silvicultural prescription and timing (tops disposal, regeneration release, advanced growth protection etc.) Time since chaining Establishment program commitments Seasonal requirements Fire intensity Burnt mosaic requirements Germination requirements
Water Catchment	Program building Contribution to strategic protection Scheduling constraints Management constraints Seasonal requirements Spatial requirements Contribution to water supply policies
Research	Program building Contribution to strategic protection Scheduling constraints Management constraints Scheduling criticality Strategic protection of experimental site Seasonal requirements Fire intensity Burnt mosaic requirements Experimental design requirements Location
Vegetation Management	Program building Contribution to strategic protection Scheduling constraints Management constraints Seasonal sensitivity Spatial distribution Compliance with statutory plans
Community Interest	Program building Contribution to strategic protection Scheduling constraints Management constraints Good Neighbour policy Local fuel management/ fire impacts Developing capacity in local Brigades Capability of stakeholders to collaborate Alignment with DPaW burning approach (liability, public risk mitigation, biodiversity management)

5. PROGRAM PLANNING FOR ECOLOGICAL RISKS

(Source: Queensland Parks and Wildlife Service)

5.3 Treatment of ecological risks

Ecological risks are controlled at the program planning level by identifying:

- suitable scheduling of burning that balances competing objectives and priorities;
- suitable scheduling of burning that respects timing requirements of ecosystems and species;
- suitable scheduling of burning that respects timing constraints due to social activities (like major events) and management limitations (availability of resources); and
- a burning program that achieves good ecological value for money/resources.

Natural values evaluation, guidelines and consultation may have revealed some constraints or considerations for implementation of the burn that need to be addressed in the operational burn plan. Some examples of these operational treatments that would be detailed in the program plan include:

- specific areas that should be excluded from a burn area;
- a season or period when burning should or should not occur; and
- postponement of burn during periods of drought.

Knowledge gaps may have been identified in the evaluation and consultation stages of developing a program plan that provide opportunities for research or monitoring. Priorities for research and monitoring should be framed following careful consideration of conservation values and priorities. Collaborative review of program plans is a useful mechanism to highlight areas requiring improvement and shared knowledge about solutions.

6. OPERATIONAL PLANNING FOR ECOLOGICAL RISKS

6.1 Identifying the risks

During program planning an area has been identified for burning, possibly with approximate boundaries that require further refinement. In most jurisdictions, an operational burn plan is then prepared for the individual burn area detailing a range of components for implementing a burn, for example, an operational risk assessment, the burn objectives, prescriptions, lighting strategy, resource organisation, communications plan, contingency plan and a map (see AFAC 2014 for a comprehensive list of the components of an operational burn plan). An operational burn plan also includes consideration of risks to natural values and how these can be reduced.

6.1.1 Not reflecting strategic and program requirements

There is a risk that a prescribed burn may be undertaken in the wrong time or place, leading to inappropriate fire regimes, if the context provided by strategic and program planning is not considered.

6.1.2 Lack of ecological knowledge among burn practitioners

Even a well-researched and documented burn plan can be implemented poorly if the burn practitioner does not understand the ecological principles and requirements on which the burn plan was developed. An appreciation of ecological theory and its application to local ecosystems is required by burn practitioners to enable them to interpret and implement the expectations of the burn plan.

6.1.3 Poor burn objectives and or prescriptions

Prescribed burning is conducted for explicit reasons. There is a risk that a prescribed burn can be completed yet not achieve any useful outcomes if the burn objectives and their associated success criteria are not clearly stated. Maintenance or enhancement of ecological values will be a primary objective for an ecological prescribed burn, or a secondary consideration for prescribed burns with other objectives such as fuel reduction. Poorly articulated objectives can lead to inappropriate strategies and tactics resulting in poor ecological outcomes, or unacceptable compromises concerning other burn objectives.

6.1.4 Not identifying natural values at risk

There is a risk that some species or vegetation communities may be negatively impacted by prescribed burning if due consideration has not been given to the fire regime requirements of these.

While the general fire regime requirement of the ecosystem should be sufficient to account for the needs of the various species adapted to that ecosystem, some species will need further consideration when planning an individual burn.

6.1.5 Unrealistic and or highly prescriptive risk mitigations

In the preparation of an operational burn plan there may be many issues, species and values to consider, at times pulling prescriptions in apparently contradictory directions, imposing numerous timing and boundary constraints or operational complexities. There is a risk that the operational burn plan will, as a result, have such tight prescriptions and operational requirements that it will be impractical and or costly to execute, and ultimately fail.

6.1.6 Legal and social constraints

There is a risk that legal or social constraints, if not carefully considered and managed, will impose restrictions or lead to prescriptions that prevent the ecological and other objectives being achieved.

6.2 Analysis and evaluation of risks

6.2.1 Strategic and program requirements

Some constraints or considerations required for natural values may have been identified at the strategic and program plan levels (such as the location of exclusion areas, rare and threatened species etc.) and these should be reviewed and addressed in the operational burn plan. This review should include guidelines, strategies, procedures, program plans and approval documents that may be relevant to the individual burn. Additional prescriptions or actions that are required for natural values may emerge during the preparation of the operational burn plan.

6.2.2 Evaluate ecosystem condition and requirements

An operational burn plan for a prescribed burn cannot be prepared entirely as a desktop exercise without appreciation of the local environment, topography, vegetation, fuel characteristics and ecosystem health. A good understanding of the current condition of the proposed burn area is essential and this can only be gained by familiarisation with the country from field assessment. General fire regimes recommendations for ecosystems may need adjustment when applied to the particular condition at the site.

6.2.3 Desktop and field assessment of natural values

Some organisations have some form of environmental impact assessment and approval process that will be required prior to burning; and procedures for conducting these assessments are often part of organisational doctrine. Typical considerations at this stage include threatened species and vegetation communities, including those listed in statutes, and fire sensitive species. The purpose is to identify natural values with fire regime requirements that may not be consistent with the proposed burn, or that may require consideration in the design of burning prescriptions. Some examples include:

Bush Fire Environmental Assessment Code for New South Wales – This document includes standards for conducting prescribed burns to reduce hazard, including protection of biodiversity. Fire interval thresholds are specified for threatened species, endangered ecological communities and vegetation formations more generally. Different standards may apply depending on the zone category.

Prescribed Burn Environmental Assessment Policy and Procedures (SA DEWNR) – This document details the processes required for assessing natural values for prescribed burns conducted by DEWNR.

Where the environmental impact assessment is not formalised, it is still prudent to consider all available information on natural values collated from databases, GIS, program plans and other planning documents.

Field assessments are usually conducted to confirm the location and condition of known values requiring special attention or mitigation action or to search for additional natural values such as threatened species. In some organisations, the methodology and requirements for conducting these field assessments may also be documented formally.

(Source: Department of Parks and Wildlife Western Australia)

6.2.4 Identify environmental risks

Some prescribed burns, for example those close to settlements, depend on good fire breaks and extended mopping up. The containment of these burns can generate environmental impacts such as the falling of habitat trees, weed invasion along fire breaks or spread of soil-borne disease. Other environmental values, such as streams, may be impacted by the burning. The field assessments can identify those issues that require controls for documentation in the operational burn plan. The *Ecological Guidelines for Fuel and Fire Management Operations* from the ACT are a good example of guidelines and principles to manage these risks (ESDD 2012).

6.2.5 Manage legal and social constraints

The timing of a burn and the kind of fire behaviour that can be achieved may be constrained by the social and landscape context. For example, the presence of a major highway adjacent to a burn area may limit the possible wind direction under which a burn can be conducted. The prescriptions in the operational burn plan should account for these constraints while still aiming to achieve the ecological and other objectives.

6.3 Treatment of ecological risks

6.3.1 Increasing ecological knowledge among burn practitioners

Dedicated guidelines and training and development programs focussed on fire ecology is important to embed knowledge meaningfully into the minds of practitioners. For example, Queensland's Planned Burn Guidelines address ecological requirements through use of a photographic guidelines and indicators of ecological health (NPRSR 2013).

6.3.2 Well considered objectives

The operational burn plan needs to state clear objectives for the prescribed burn. Where ecological objectives are given, they should be expressed quantitatively and clearly enough so that it is possible to evaluate after burning whether or not the objective was achieved. These objectives provide a reference point for the design of prescriptions and tactics that are detailed in the operational burn plan.

6.3.3 Weather and tactics to create desired fire behaviour

The link between measurable fire management objectives and fire behaviour should be emphasised. Most fire management objectives will imply the type of fire behaviour parameters (intensity, patchiness and scorch) that would be suitable to achieve the objectives; these fire behaviour parameters will in turn influence the fire prescriptions recorded in burn plans.

For example, an appropriate mosaic may require a low intensity, patchy fire. Alternatively, a fire sensitive vegetation type could be excluded from burning by utilising a moisture differential at vegetation boundaries. To achieve the right kind of fire will require understanding the influence of weather, fuel characteristics, fuel dryness, topography and lighting patterns and then designing the burning prescriptions accordingly.

Natural values will have been considered at various planning stages but the operational burn plan will be the final planning document to capture where and how a prescribed burn will be undertaken. The operational burn plan details the prescriptions for conducting the burn to achieve the objectives, including the ecological requirements. The kinds of burning conditions that may be specified to achieve desired fire behaviour for ecological outcomes include:

- Fire Danger Index;
- Season;
- Rainfall;
- Soil dryness;
- Fuel moisture, internally and externally of the burn area;
- Temperature, humidity, wind speed and direction; and
- Method of ignition, for example, aerial or hand lighting.

6.3.4 Tactics for specific ecological issues beyond fire behaviour prescriptions

Burning under the right conditions, as prescribed by a burn plan in accordance with objectives, will address most ecological issues. However, at times it will be necessary to impose more 'artificial' treatments of risks to ecological values. For example, small bushland remnants and bushland on the urban interface may have natural values that require extra consideration.

Once the natural values information is collated, operational options for managing ecological concerns can be evaluated, or a risk treatment may already have been imposed as a condition for burning or stated in the program plan or other plans. Typical examples include threatened plant species or sedentary animals with very restricted distributions. The operational options for exclusion from burning could include such activities as constructing control lines around the area of a species population, pre-burning and blacking out around the area prior to conducting the main burn, or wetting down with sprinklers, water tankers or aerial water-bombing. Such activities can be costly so the benefits and risks need to be evaluated and balanced.

Some possible ecological risk treatments have been described above and in sections 5.3 and will be detailed in the operational burn plan. Some other controls that could be specified include (see ESDD 2012):

- Weed treatment prior to and after burning;
- Wash down of vehicles and equipment to prevent spread of disease and weeds;
- Habitat trees to be protected from burning or falling near control lines;
- Exclusion zones for machinery constructing control lines;
- Restrictions on the use of bushfire fighting foam near streams and water bodies; and
- Rehabilitation of control lines after completion of the burn.

(Source: Department of Environment, Water and Natural Resources South Australia)

7. CONSIDERATION OF ECOLOGICAL RISKS DURING BURN IMPLEMENTATION

7.1 Identifying the risks

7.1.1 Not understanding objectives and or prescriptions; not understanding risk controls; poor timing of burn

The incident controller and fire crews will need to have sufficient fire ecology knowledge and familiarity with the operational burn plan to ensure that they understand the ecological issues and required actions for implementation. They may also need to undertake field familiarisation for some ecological issues, for example, to identify species, habitat or locations. These risks are higher in situations where the incident controller and or crews were not involved in the preparation of the operational burn plan.

7.2 Analysis and evaluation of risks

7.2.1 Monitoring approaching window of opportunity

Timing is everything if a burn is to encompass the right fire behaviour to achieve good ecological outcomes. The ideal burning 'window of opportunity' for an individual burn may be quite narrow in some situations, for example, perhaps limited to a few days in specific months, or perhaps restricted to a six week period in total for the year. Furthermore, no two years are identical and the window in a given year may be earlier or later than typical. Often the variation will depend on the rainfall pattern leading up to the burning season and the cycles of synoptic weather conditions. Therefore monitoring of approaching conditions prior to the burning season is extremely important. Missed opportunities, for example, if suitable burning conditions arrive early, can have long term outcomes. Monitoring weather forecasts, and monitoring of conditions in the field by an experienced practitioner on or close to the day of burning, particularly of fuel dryness, will minimise false starts, poor results and wasted operational expenditure.

Some burns require a sequence of ignitions to ensure that the fire behaviour conducive to achieving burn outcomes is assured across a number of fuel types within the burn. Burns with a variety of fuel types characterised by different fuel drying schedules require ignitions over a period of time, sometimes months, to ignite fuel components as they become dry enough to carry fire. Once ignition has commenced in multiple fuel type burns it is critical that fuel moisture profiles are closely monitored to take advantage of sequential ignition opportunities as they arise. Uncertainty associated with longer term weather forecasts mean that there is an ever present risk that fuels types may dry more rapidly or be exposed to severe weather conditions that necessitates ignition or suppression operations that may not accord with planned strategies or tactics for the burn. This necessity for burn security may compromise the achievement of ecological outcomes.

7.2.2 Evaluate ignition pattern and strategy, fuel dryness and weather while considering ecological outcomes

The conditions on the day of ignition are assessed to ensure that weather and fuel dryness are suitable to create the desired fire behaviour. Adjustments to lighting strategy may be required to match the conditions on the day. For example, the wind speed or direction may be different to what was anticipated and the commencement and progression of ignition may need to be revised to ensure the appropriate fire intensity can be achieved.

It is important that sufficient flexibility is provided in the prescriptions and ignition strategies in the operational plan to empower experienced operators to make well considered decisions and adjustments on the day of ignition to produce a good result.

Consideration may need to be given to longer term seasonal rainfall patterns. During periods of extended drought that are outside the average pattern of occurrence, post-fire recovery of vegetation may be delayed or significantly altered and some plant species may fail to regenerate. Postponement of burning until the drought has broken may be desirable in these circumstances, particularly if ecological objectives are the main priority.

The occurrence of conditions suitable for burning may occur at different times of the year and/or different times of the day than would be suggested by historical precedent due to climate change. Conditions unsuitable for burning may also occur at times of the year than historically presented acceptable burning opportunities.

7.2.3 Review and understand objectives and risk controls

The incident controller and field supervisors tasked with implementing a burn should carefully review the burn objectives and operational risk controls in the operational burn plan, particularly if they were not involved in preparation of the operational burn plan. If understanding of the objectives is not clear then briefing from the person(s) who prepared the plan may be required. This is an important step in the translation of ecological outcomes identified at the program plan and operational burn plan stages to appropriate fire behaviour and operational activities.

7.2.4 Determine if pre-burn activities are complete

Pre-burn activities specified in the operational burn plan should be checked to ensure that they have been completed, for example, weed treatments, establishment of control lines, tactics for exclusion zones and establishment of monitoring plots.

7.3 Treatment of ecological risks

7.3.1 Skill and experience

The successful control of ecological risks and creating the desired fire behaviour during burn implementation will depend on the actions undertaken by burn practitioners; therefore, adequate skill and experience of the practitioners is very important. Prescribed burning is an art and there are many nuances to producing the right kind of fire. Ensuring adequate competence of burn supervisors and crews will lead to better outcomes for the burn. Formal training, competence certification and strategies such as pairing inexperienced burn practitioners with more experienced operators will facilitate skills development and maintenance, ensure appropriate fire behaviour is created, and facilitate operational safety. Experienced burn practitioners will have sufficient understanding to confidently make the adjustments and decisions on a given day to achieve the right kind of fire.

7. CONSIDERATION OF ECOLOGICAL RISKS DURING BURN IMPLEMENTATION

7.3.2 Identify ecological objectives and issues at briefings

Briefing is an important stage in translating a good operational plan into good outcomes. Supervisors and crews should be properly briefed to ensure that the actions that are required for ecological outcomes are adequately explained and tasks are understood. In particular, how the ignition is carried out may be critical to achieving the desired fire behaviour and crews will need a good understanding of these subtleties to ensure under-lighting or over-lighting does not occur. Operational risk controls will need to be identified at the briefing, with responsibilities and tasks assigned.

7.3.3 Implement hygiene and operational risk controls

All crews should follow hygiene procedures identified in the operational burn plan such as wash down of vehicles, tools and boots. Operational risk controls should be implemented and the responsibility for these resides with incident controllers and field supervisors.

7.3.4 Ensure fire behaviour meets objectives

Test fires may assist in assessing whether or not conditions on a given day are appropriate to achieve the desired fire behaviour. Test fires, however, may take considerable time to develop to a size that will reveal the maximum potential rate of spread and therefore maximum fire intensity and this must be taken into account. Test fires can be used to ensure that non-target vegetation is too damp to burn.

Ultimately, a good burn result is about the fire behaviour that the conditions on the day permit. Fires may lack adequate intensity if fuels are too damp and or there is insufficient wind. Conversely, if fuels are too dry and or it is too windy the fire behaviour may be too intense to achieve objectives. If conditions on the day are not suitable to achieve the specified fire behaviour and objectives, burning should be postponed. This can be just as important for ecological objectives as it is for other objectives such as fuel reduction or the safe containment of a fire.

7.3.5 Post-burn assessment, mapping and continuous improvement

Each and every prescribed burn provides an opportunity to extend ecological knowledge. Recording of burn outcomes in relation to objectives is a key concern. Recording of fire behaviour during a prescribed burn is beneficial for post-burn evaluation and learning for future operations. Ecological strategy and program evaluation depend partly on good data collected at individual burns, including mapping of the burnt/unburnt mosaic to the highest level of accuracy and resolution possible with the available technology and budget.

In some organisations the mapping is undertaken mostly or wholly by remote sensing, so this mapping can be considered to take place at the strategic level rather than at the burn implementation level. In other organisations, post-burn mapping is often derived from a combination of methodologies – ground inspection, aerial intelligence, aerial photography and remote sensing.

Collecting and collating information on fuel conditions, weather conditions, fire behaviour and the observed effects of fire on species and communities of interest are invaluable sources of learning and improvement. Recording and collating ecological information from burns across the burn program is a powerful mechanism for improvement if the lessons that are identified are shared with other practitioners.

8. MONITORING AND EVALUATION FOR ECOLOGICAL RISKS

The activities that are involved in managing ecological risks cascade down from the strategic level to the burn implementation level. Research, monitoring and evaluation all have roles to play at different levels.

8.1 Burn implementation

The fundamental question that should be answered for a prescribed burn is: did the burn achieve the objectives stated in the operational burn plan? To answer this question, some form of during-burn and post-burn evaluation is required, usually undertaken utilising observations on the ground, from the air or by remote sensing. The methodology for evaluation should be consistent across an organisation and designed at the strategic or program plan level. The evaluation criteria that will be used should be considered when formulating the objectives stated in the operational burn plan. Consideration of resources and budget will influence the complexity of evaluation methods. The evaluation should be quantitative where possible but the methods need not be complex and expensive to provide useful information. Examples of simple evaluation methods are given in Planned Burn Guidelines for Queensland Bioregions (e.g. DNPRSR 2013).

Examples of measured and recorded parameters used for burn evaluation include:

- flame height;
- fire intensity;
- scorch height;
- various measures of burn patchiness;
- fire scar boundary;
- retention of grass stubble;
- retention of habitat features;
- retention of some portion of the fuel profile;
- post-burn residual fuel hazard; and
- short-term post-fire responses of plants.

These parameters will be used to evaluate ecological objectives, evaluation of other objectives such as fuel reduction, and ongoing operational learning for future burns. The during-burn and post-burn evaluations will inform both short-term and long-term planning for ecological values and bushfire risk. Maps of fire scar boundaries are collected, stored and analysed using increasingly sophisticated GIS tools and are one of the most fundamental ecological evaluation and planning tools.

8.2 Operational planning

The evaluation at the operational planning level focuses on the questions:

- Was the operational burn plan comprehensive enough, practical, suitable but flexible?
- What improvements can we make in delivering burn operations?

Failure to undertake evaluation at this level can lead to repeated sub-optimal burn outcomes, some of which may have ecological implications.

Evaluation at this level involves groups or teams of practitioners and can occur at various times during and after burning operations including:

- daily debriefs at the end of operational shifts;
- after action reviews at the conclusion of single or multiple burn operations;
- seasonal reviews; and
- workshops including field visits to recent burns.

The aim is to get feedback from burn practitioners and learnings to improve future operations and operational burn plans. Some learnings may feedback to actions or changes to program planning and strategic planning. Systematic storage of knowledge gained from operational evaluation is desirable.

8.3 Program planning

Burn programs should have clearly stated objectives, strategies and success criteria that reflect the mission of the organisation. From an ecological perspective, monitoring at the program planning level aims to answer the question: did the program achieve longer-term ecological outcomes such as maintaining or improving ecosystems, diversity or species populations? Activities at this level will provide guidance for developing the next cycle of program planning and contribute to longer-term adaptive management.

The success of achieving the goals of maintaining ecosystem health and biodiversity cannot be determined without some form of monitoring. What are considered appropriate fire regimes for any vegetation type or ecosystem is a model based to varying extents on knowledge of the ecosystem and species responses. Where the knowledge base is weaker, the risk of inadvertently applying an inappropriate fire regime is greater.

There is a substantial literature on ecological monitoring and some jurisdictions also have guiding standards and methods specifically relating to prescribed fire (e.g. SEQFBC 2002; Cawson 2008; DELWP 2015). At an organisation level and even across multiple organisations, consistency in design of monitoring methods, data storage and data sharing facilitates pooling of data for wider evaluation and application. Some key features of an effective monitoring program are provided in DELWP 2015 (after Lindenmayer and Likens 2010):

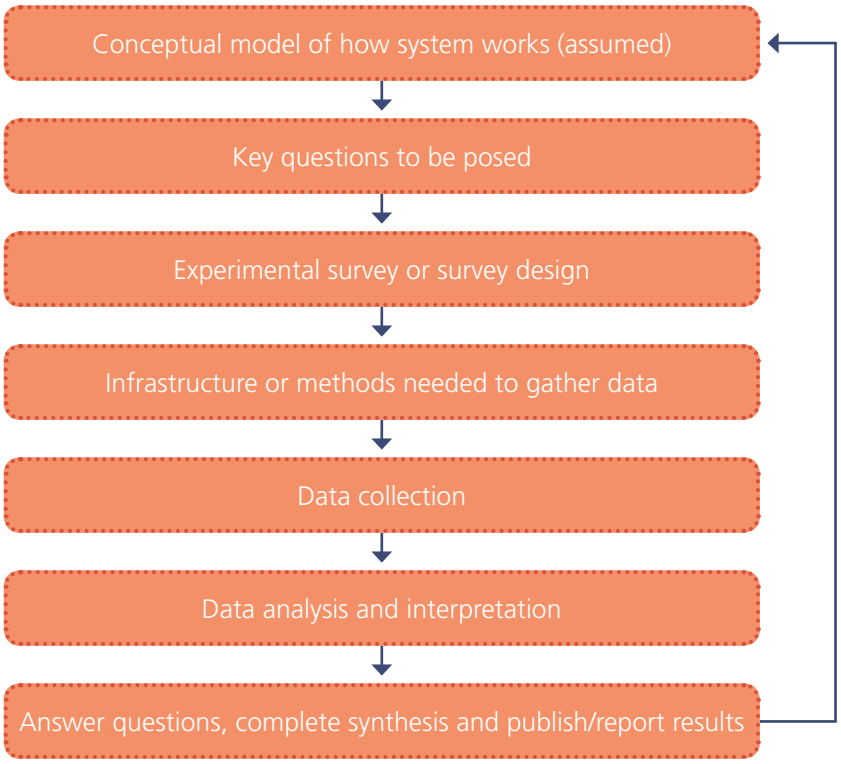
- questions that set measurable objectives against which progress can be measured;
- the use of conceptual models to guide the selection of appropriate metrics;
- robust study design;
- well-developed partnerships between practitioners, scientists and policy makers;
- frequent use of data; and
- maintenance of data quality and consistency of field methods.

The steps involved in monitoring are indicated in Figure 11.

Even simple monitoring will benefit from keeping the features and steps above in mind. The questions may be about individual species or ecosystem health and structure and need not involve complex sampling methods to be useful. For example, at the simplest level a question may be whether or not the abundance of a species has increased, decreased or stayed the same and the method may be repeated photographs.

In many instances the performance of the burn program will be determined by assessing indices rather than direct measures. For example, remote sensing the patchiness of a burn or patchiness at a landscape scale and measuring length of edge or the frequency distribution of fuel age are surrogates for ecotone and functional habitat diversity.

Figure 11 *Flow diagram of the sequence of key steps in a monitoring program (from Lindenmayer and Likens 2010)*



The implied assumption that there is a consistent relationship between the index and the desired outcome should be explicitly stated with any qualifications to enable consistent interpretation of the results.

Methods that are commonly used for monitoring burn programs include:

- ***Species responses*** – Data is collected on plant responses to fire based on life history characteristics and vital attributes. Not all species can be monitored so strategic selection of species is required; examples include key fire response species, keystone species, threatened species and weed species.
- ***Monitoring plots*** – Permanent sampling plots, quadrats or transects are established in vegetation and resampled at periodic intervals. Sampling may range from simple photographs to detailed and comprehensive inventories of plant and animal species and abundance.
- ***Fire history*** – The fire history can be used to evaluate the burning program against ecological fire regime ideals, as well as providing a basis for longer-term research and strategic planning.

Well-established, long-term monitoring is guiding prescribed burning programs in several jurisdictions (e.g. Abbott and Burrows 2004; Russell-Smith *et al.* 2009). It is commonly recognised, however, that not enough monitoring and evaluation of the ecological outcomes from prescribed burning is undertaken, whether the burning objectives are fuel management, ecological or some other objective. Some jurisdictions have well-funded and developed monitoring and evaluation programs associated with substantial prescribed burning programs. Smaller organisations will not be able to match the scale of such programs but must still meet the challenge of having at least some level of monitoring and evaluation of burning programs. The minimum should include tracking the fire history of planned and unplanned fire against fire regime ideals and monitoring the response to prescribed fire of critically endangered species and biological communities.

8.4 Strategic planning

At the strategic planning level, the following monitoring and evaluation questions are posed:

- Is the organisation's stated appetite for ecological risk appropriate?
- Are existing strategies for controlling adverse ecological outcomes sufficient?
- Are current fire regimes on track, off track or well outside of ideal regimes?

Examining these questions will enable the organisation to regularly adapt its expectations concerning acceptable ecological risk; recast its policy settings and strategic guidance that influences what the agency does and how it does it; and re-appraise the resources provided to implement prescribed burning programs and maintain the knowledge, skills and tools required to manage such programs.

The evaluation focuses on the longer-term trends of ecosystem health and resilience leading to revision, where required, of what are considered to be ecologically appropriate fire regimes; as well as the strategies to identify and maintain these fire regime ideals. Given the gaps in ecological knowledge and level of uncertainty under which prescribed burning must be carried out, this ongoing review is essential. Fire management strategies and prescribed burning adapt to learning from new knowledge, research and experience.

Research is one strategy to improve knowledge on fire regimes and fire science, along with analysis of long-term monitoring data and recorded fire histories. Collaboration between land managers and researchers should be encouraged and key research questions identified that will improve knowledge of fire regimes.

Figure 12 *Key elements of the Monitoring, Evaluation and Reporting Framework (MER) for Bushfire Management on Public Land, Victoria (DELWP 2015).*

The MER Framework is underpinned by a set of principles and built around a group of key elements which establishes the framework for the Victorian Bushfire Monitoring Program (VBMP). These elements are Program Logic, Models and Assumptions, Key Evaluation Questions, Monitoring, Evaluation, Reporting and Continuous Improvement and Adaptive Management and are described below.

Principles of MER

The principles of MER support the improvement of bushfire management and ensure the quality of the VBMP. The first five are adapted from the Code's principles for bushfire management on public land, ISO31000:2009's principles of risk management and the principles from DELWP's Monitoring, Evaluation and Reporting Framework for Land, Water and Biodiversity. The last two are principles developed specifically for the VBMP.

The Program Logic

The Program Logic describes the relationship between activities and outcomes at different timeframes. It allows for assumptions to be documented, which can help to target effective monitoring and research, and provides a basis for change to be evaluated against.

Models and Assumptions

The Program Logic is the visual representation of the models and assumptions underpinning a program while the Key Evaluation Questions (KEQs) are the questions used to evaluate the assumptions and improve those models.

8. MONITORING AND EVALUATION FOR ECOLOGICAL RISKS

Key Evaluation Questions

Key Evaluation Questions (KEQs) are carefully focused questions used to guide evaluation activities. They provide the basis for data collection to assess a program's effectiveness for achieving objectives and validate assumptions that underpin the Program Logic.

Monitoring

Monitoring is focused on measuring outputs and outcomes within the Program Logic and testing underlying assumptions. Focused monitoring questions are derived from the KEQs to implement monitoring.

Evaluation

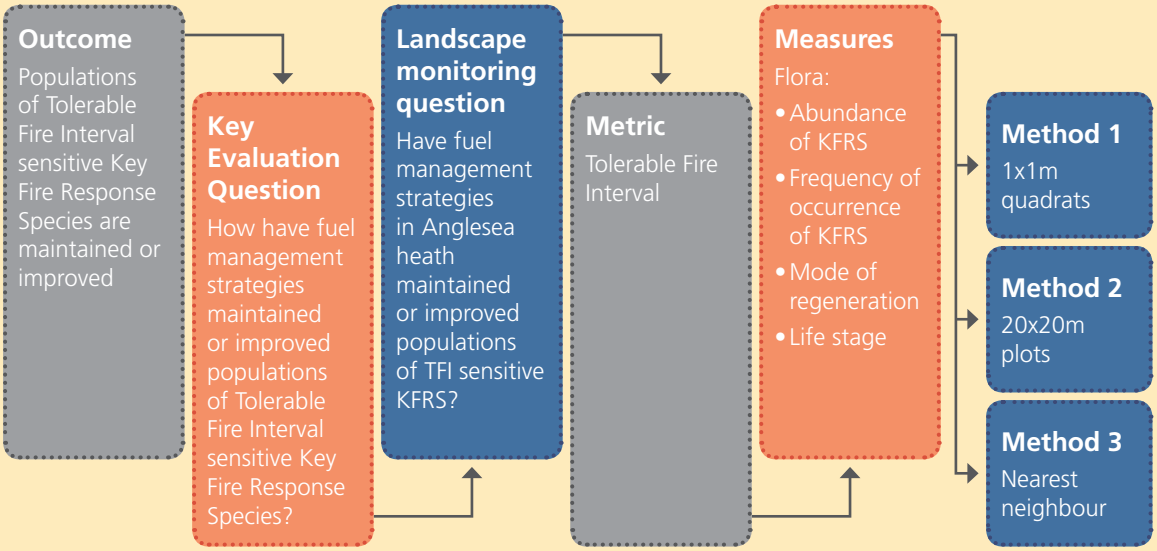
Evaluation is the process of collating, synthesising and analysing information. Evaluation considers what was or wasn't achieved against each of the KEQs, tests assumptions and considers alternative strategies that might improve the future performance of the activity or program.

Reporting

Reporting is the process of formally communicating information. Monitoring and evaluation inform reports to provide information on activities, outputs and outcomes. The VBMP and this MER Framework supports DELWP to move from activity and output focused reporting to meaningful reporting on bushfire management outcomes.

Continuous improvement and adaptive management

Monitoring, evaluation and reporting is viewed as a continuous cycle of participation rather than as a single event. MER promotes learning that enables improvement in program design and achievement of desired outcomes.



The relationship between outcomes, key evaluation questions, monitoring questions, metrics and the measures that feed into them. Several different methods can be used to quantify a measure.

8. MONITORING AND EVALUATION FOR ECOLOGICAL RISKS

(Source: Department of Environment, Water and Natural Resources South Australia)

The Victorian Department of Environment, Land, Water and Planning has a framework for their bushfire management program to provide guidance on how to monitor, evaluate and report on the effectiveness of the planned burn program (DELWP 2015, see Figure 12, page 62). The framework poses Key Evaluation Questions which guide monitoring activities. DELWP has developed three metrics of ecosystem resilience as components of this framework which will provide a basis for reporting on biodiversity outcomes. The development of two new metrics for this framework reflects the understanding that Tolerable Fire Interval, the long established metric used in Victoria, is not a robust measure of ecosystem resilience on its own and provides only limited insight into the composition and functioning of an ecosystem. While few organisations engaged in prescribed burning will be able to match this scale of monitoring and evaluation, the DELWP investment will provide benefits for other organisations and jurisdictions.

9. A NATIONAL FRAMEWORK FOR MANAGING ECOLOGICAL RISKS ASSOCIATED WITH PRESCRIBED BURNING

The national framework is a synthesis of concerns, approaches and activities that organisations across Australia engage in to manage ecological risks associated with prescribed burning. Many of the management activities to control these risks are approached in similar or parallel ways. Despite the large variation in fire regimes and the significant differences in extent and frequency of planned and unplanned fires in landscapes, particularly between northern and southern Australia, there are some key common principles that emerge:

- Large, intense bushfires are a concern and will dominate fire regimes, causing significant ecological harm, in the absence of prescribed fire.
- Minimising inappropriate fire regimes and maintaining natural diversity is the goal and prescribed fire is integral to achieving this.
- Applying fire regimes on the ground should include the ability to observe the condition of country in order to apply appropriate fire in the appropriate locations.
- Traditional Owner burning played an important role in shaping the patterns of biota that are present in Australia today and still does in some areas. Prescribed fire is an inherent part of culture for Traditional Owners. Where possible, prescribed burning programs should be informed by knowledge of Traditional Owner burning practices.
- Fire sensitive species exist across Australia; this sensitivity ranges from a need for appropriate spatial diversity and fire intervals to total fire exclusion. Prescribed fire has an important role to play in managing the fire regime for these fire sensitive species.
- Fire management is required to a) protect and conserve the biota; and b) to reduce the occurrence of large, damaging bushfires. The biological impact of a single fire event and the rate of recovery are directly proportional to the intensity and size of the fire.
- Knowledge of appropriate fire regimes is far from complete but prescribed burning must be undertaken, while management adapts and changes when new knowledge becomes available.
- The social and economic context for prescribed burning poses various challenges that limit ecologically beneficial prescribed burning.

Figure 13 on the next page summarises the national framework for managing ecological risks associated with prescribed burning. The hierarchy of levels or phases of management associated with prescribed burning in the framework may not be recognised in all organisations, or the labels may be different, but these management activities should still be considered in applying prescribed fire.

9. A NATIONAL FRAMEWORK FOR MANAGING ECOLOGICAL RISKS ASSOCIATED WITH PRESCRIBED BURNING

Figure 13 *A national framework for managing ecological risks associated with prescribed burning*

Communicate and consult

Strategic Planning	Program Planning
Identify the Organisational Policy for Ecological Risk • Document organisational level objectives • Document the level of ecological risk acceptable • Document organisation's procedures, training/competency expectations, knowledge management and other systems **Identify Potential Sources of Risk** Examine political, environmental, social, technical, legal and economic (PESTLE) sources of risk including: • Loss of ecosystem function or biodiversity due to inappropriate fire regimes • Management factors such as incomplete knowledge & uncertainty • Social factors leading to inappropriate fire regimes • Natural factors such as climate change, drought and cyclones • Lack of integration of land management objectives • Competing objectives **Assessment & Evaluation of Risk** Evaluate the potential sources of ecological risk against the organisation's policy for risk: • Ecosystem / region specific synthesis of all available knowledge to identify appropriate fire regimes from research, local knowledge including practitioner, Traditional Owners, expert opinion, monitoring, surveys, modelling & extrapolation • Compare current fire management trends against desirable fire regimes and the organisations' position for ecological risk • Evaluate areas & causes of unacceptable risk, e.g. inappropriate fire regimes • Evaluate competing objectives (e.g. fuel management, grazing) **Risk Treatments** • Document expectations for the management of ecological risk • Develop & improve databases, mapping & modelling for fire history, vegetation & threatened species • Targeted research • Strategically designed natural value monitoring program • Guidelines for practitioners • Practitioner training & support • Integrate planning across tenure • Design strategic plan/zoning format & objectives • Strategic plans to guide fire management that synergise risks, risk treatments, zoning and objectives • Streamlined approval processes	**Document the Objectives of the Prescribed Fire Program** • Document the organisation's expectations for the prescribed fire program to manage ecological risk (e.g. targets, key performance indicators, risk landscape profiles, acceptable level of risk) **Identify Potential Sources of Risk** Examine political, environmental, social, technical, legal and economic (PESTLE) sources of risk including: • Inappropriate fire regime • Prioritisation risk (ecological burning not high enough priority/traded off, sometimes need to prioritise specific ecological issues over others) • Scheduling risks (season, conditions, species needs, addressing particular issues with correct timing) • Resourcing risks (sufficient resources?) • Community engagement and support **Assessment & Evaluation of Risk** Evaluate the potential sources of ecological risk against the objectives of the program: • Review strategic requirements including fire regime requirements and objectives • Review previous fire history (including bushfire) and its influence on the burn program (are burns/objectives still valid?) • Review current fire regime status against identified ideals or targets • Review competing priorities for burning and find synergistic solutions • Review any timing requirements for burns (e.g. for threatened species), consult experts as required • Identify timing constraints (e.g. social impacts) • Be aware of progressive burning requirements (burning off the back of other burns) **Risk Treatments** • Identify suitable scheduling of burning that balances competing objectives and priorities • Identify suitable scheduling of burning that respects timing requirements of ecosystems, species • Identify suitable scheduling of burning that respects timing constraints (e.g. social and natural) • Identify a burning program that achieves good ecological value for money/resources • Engage with and garner community support for the program
Are strategies controlling adverse ecological outcomes? Are current fire regimes on track, off track or well outside of ideal regime? (Strategy review, review of monitoring outcomes and research)	Did the program achieve longer term ecological outcomes such as maintaining ecosystems, diversity and species populations? (Monitoring)

Monitoring and evaluation

9. A NATIONAL FRAMEWORK FOR MANAGING ECOLOGICAL RISKS ASSOCIATED WITH PRESCRIBED BURNING

Communicate and consult

Operational Planning

Document the objectives of each prescribed burn

- Document measurable objectives
- Document the expectations for the management of ecological risk in a burn plan, document consultation requirements.

Identify Potential Sources of Risk

Examine political, environmental, social, technical, legal and economic (PESTLE) sources of risk including:

- Not reflecting strategic/program requirements
- Poor burn objectives or prescriptions
- Properly identifying values at risk
- Unrealistic or overly prescriptive risk mitigations
- Legal/social constraints

Assessment & Evaluation of Risk

- Evaluate the potential sources of ecological risk against the objectives of the burn
- Review strategic/program requirements
- Observe/understand your ecosystem's condition and requirements (consult experts as required)
- Desktop and field assessments of specific values at risk (species, sensitive vegetation etc.)
- Identify environmental risks (to waterways, weed spread-etc.)
- Manage legal and social constraints in a timely and strategically considered fashion

Risk Treatments

- Well thought out objectives that understand the ecosystem and any specific biodiversity needs and balance competing needs
- Identify prescriptions and ignition tactics to achieve the desired fire behaviour to meet objectives
- Identify specific ecological issues, species and fire sensitive vegetation that require specific measures above and beyond the ecological prescription above (do not include issues that are already catered for within the ecological prescription above unless required for legal or social reasons)
- Identify specific risk management strategies for issues, species and fire sensitive ecological values identified above
- Identify environmental controls (e.g. to reduce weed spread, waterway impacts etc.)

Burn Implementation

Identify Potential Sources of Risk

- Not understanding objectives or prescriptions
- Not understanding risk controls
- Poor timing of burns

Assessment & Evaluation of Risk

- Monitor approaching windows of opportunity for best timing
- Review and understand objectives and risk controls
- Determine if pre-burn activities are complete (e.g. species management, weed control, establishment of monitoring plots, control lines)
- Evaluate ignition pattern & strategy, plus weather, fuel dryness to achieve desired fire behaviour
- Allowing flexibility of ignition, but understanding how different fire behaviour scenarios will effect ecological outcomes

Risk Treatments

- Adequate documentation and briefing of the operational burn plan
- Adequate skill & experience of practitioners to create ideal fire behaviour & patterns
- Identify ecological objectives & issues at briefings
- Implement hygiene & operational risk controls
- Ensure fire behaviour meets objectives, record fire behaviour
- Post-burn evaluation
- Good mapping of burn contributing to useful fire history

Was the burn plan practical, suitable and comprehensive but flexible? (Debriefs)

Did the prescribed burn meet objectives? (Post-burn evaluation and mapping).

Monitoring and evaluation

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(Source: Adrian Pyrke, Eco Logical)

11. REFERENCES

Abbott I, Burrows N (2004) Monitoring biodiversity in jarrah forest in south-west Western Australia: the FORESTCHECK initiative. In 'Conservation of Australia's Forest Fauna' 2nd ed. (ed. D Lunney) (Royal Zoological Society of New South Wales: Sydney) pp. 947 – 958

AFAC (2014) Review of Best Practice for Prescribed Burning. Report for National Burning Project – Sub-project 4. Australasian Fire and Emergency Service Authorities Council Limited (Melbourne: Victoria)

AFAC (2015a) Risk Management and Review Framework for Prescribed Burning Risks Associated With Fuel Hazards. Report for National Burning Project – Subproject 3. Australasian Fire and Emergency Service Authorities Council Limited (Melbourne: Victoria)

AFAC (2015b) Risk Management Framework – smoke hazard and greenhouse gas emissions – Subproject 3. Australasian Fire and Emergency Service Authorities Council Limited (Melbourne: Victoria)

AFAC (2015c) National Guidelines for Prescribed Burning Operations – Subproject 4. Australasian Fire and Emergency Service Authorities Council Limited (Melbourne: Victoria)

AFAC (2016) A Risk Framework for Operational Risks Associated with Prescribed Burning. Report for National Burning Project – Subproject 3. Australasian Fire and Emergency Service Authorities Council Limited (Melbourne: Victoria)

Bradstock RA, Gill AM and Williams RJ (2012a) 'Flammable Australia: Fire Regimes, Biodiversity and Ecosystems in a Changing World' (CSIRO: Collingwood)

Bradstock RA, Williams RJ, and Gill AM (2012b) Future fire regimes of Australian ecosystems: new perspectives on enduring questions of management. In 'Flammable Australia: Fire Regimes, Biodiversity and Ecosystems in a Changing World' pages 307 – 324 (Eds. RA Bradstock, AM Gill and RJ Williams) (CSIRO: Collingwood)

Burrows N (2003) Using and sharing indigenous knowledge. In 'Australia Burning: Fire Ecology, Policy and Management Issues' pages 205 – 210. (Eds. G Cary, D Lindenmayer, S Dovers) (CSIRO: Collingwood)

Burrows N and Abbott I (2003) Fire in south-west Western Australia: synthesis of current knowledge, management implications and new research directions. In 'Fire in ecosystems of south-west Western Australia: impacts and management' pages 437 – 452 (Eds. Ian Abbott and Neil Burrows) (Backhuys Publishers: The Netherlands)

Cawson J (2008) Flora monitoring protocols for planned burning: a user's guide. Fire and adaptive management report no. 74. Department of Sustainability and Environment (Melbourne: Victoria)

Cheal D (2010) Growth stages and tolerable fire intervals for Victoria's native vegetation data sets. Fire and Adaptive Management Report No. 84. Department of Sustainability and Environment (Melbourne: Victoria)

DELWP (2015) Monitoring, Evaluation and Reporting Framework for Bushfire Management on Public Land. Department of Environment, Land, Water & Planning (Melbourne: Victoria)

DEWNR (2013) Ecological fire management guidelines for native vegetation in South Australia. Department of Environment, Water and Natural Resources (South Australia)

DNPRSR (2013) Planned Burn Guidelines Southeast Queensland Bioregion of Queensland. Department of National Parks, Recreation, Sport and Racing (Brisbane)

DSE (2012) Code of Practice for Bushfire Management on Public Land. (Melbourne: Victoria)

ESDD (2012) 2012-13 Ecological Guidelines for Fuel and Fire Management Operations. Conservation Planning and Research Section, Environment and Sustainable Development Directorate (ACT)

11. REFERENCES

FFMG (2014) National Bushfire Management Policy Statement for Forests and Rangelands. Prepared by the Forest Fire Management Group for the Council of Australian Governments. (O'Connor: ACT)

Lindenmayer DB and Likens GE (2010). The science and application of ecological monitoring. *Biological Conservation* **143**, 1317 – 1328

Noble I and Slatyer R (1980) The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetation* **43**, 2 – 21.

Russell-Smith J, Edwards AC, Woinarski JCZ, McCartney J, Kerin S, Winderlich S, Murphy BP, Watt F (2009) An assessment of the first ten years of the three parks (Kakadu, Litchfield, Nitmiluk) fire regime and biodiversity monitoring program. In 'Culture, ecology and economy of savanna fire management in northern Australia: rekindling the Wurrk Tradition' Pages 257 – 285 (Eds. J Russell-Smith, PJ Whitehead, PM Cooke) (CSIRO Publications: Melbourne)

SEQFBC 2002. Fire and Biodiversity Monitoring Manual. Southeast Queensland Fire & Biodiversity Consortium (Gold Coast)

Standards Australia (2009) Risk management: Principles and Guidelines (AS/NZS ISO 31000:2009). http://standards.org.au/ [Verified 1 October 2014]

Standards Australia (2009) Risk management (AS/NZS 4360:2004). http://standards.org.au/ [Verified 1 October 2014]

Williams RJ, Griffiths AD and Allan GE (2001) Fire regimes and biodiversity in the savannas of northern Australia. In 'Flammable Australia: the fire regimes and biodiversity of a continent' (Eds R Bradstock, J Williams and Gill, A) pp. 281 – 304 (Cambridge University Press: Cambridge)

APPENDIX A: LIST OF PARTICIPATING ORGANISATIONS

ACT Parks

Bushfires – Northern Territory

Charles Darwin University

Department Natural Resources and Mines – Queensland

Department of Agriculture and Fisheries – Queensland

Department of Defence

Department of Environment, Land, Water and Planning – Victoria

Department of Environment, Water and Natural Resources – South Australia

Department of Fire and Emergency Services – Western Australia

Department of Land and Resource Management – Northern Territory

Department of Parks and Wildlife – Western Australia

Fire and Landscape Strategies

Firescape Science

Githabul Working on Country Rangers

NSW National Parks and Wildlife Service

NSW Rural Fire Service

Nature Conservation Council of NSW

Office of Bushfire Risk Mitigation Western Australia

Office of Environment Heritage – NSW

Parks Victoria

Parks and Wildlife – Northern Territory

Powerlink Queensland

Public Safety Business Agency – Queensland

Quandamooka Yoolooburabee Aboriginal Corporation

Queensland Fire and Emergency services

Queensland Parks and Wildlife Service

Savanna Solutions

Southeast Queensland Fire and Biodiversity Consortium

Sunshine Coast Regional Council

Tasmanian Fire Service

Ten Rivers

The City of the Gold Coast

University of Melbourne

University of Tasmania

Wildlife Conservancy

APPENDIX B: PROJECT SURVEY QUESTIONS

AGENCY AND ORGANISATION SURVEY ON ECOLOGICAL RISKS OF PRESCRIBED BURNING

AFAC NATIONAL BURNING PROJECT

Agency/Organisation name:

Completed by (name and email address):

1. Organisation concerns

1.1. What are your organisation's foremost concerns about ecological values in connection with prescribed burning?

2. Strategic planning: the region/reserve, organisation or jurisdiction-wide, system level

2.1. In relation to prescribed burning, how does your organisation attend to landscape health issues?

2.2. How are ecological values considered when developing prescribed burning objectives?

2.3. How are ecologically appropriate fire regimes and natural values determined?

2.4. How is knowledge acquired, stored, shared and retrieved (including indigenous knowledge, scientific knowledge and data systems) to inform and guide prescribed burning?

2.5. In relation to prescribed burning, what innovations could reduce ecological risks?

3. Tactical planning: the burn program level

3.1. How does your organisation design burning programs and how are ecological values considered at this level?

3.2. How are the potential adverse ecological impacts of burning considered in burn programs?

3.3. What innovations could reduce ecological risks at the burn program level?

4. Operational Planning: individual burn level

4.1. How are ecological values considered for individual burns?

4.2. How are adverse ecological impacts controlled for individual burns?

4.3. How does the knowledge of burning conditions (e.g. suitable fuel moisture and weather) contribute to protecting or enhancing ecological values?

4.4. What innovations could reduce ecological risks at the burn operation level?

5. Monitoring and evaluation

5.1. How does your organisation implement monitoring and evaluation of prescribed burning?

5.2. How is pre-burn and post-burn monitoring undertaken of ecological responses and burn objectives?

5.3. Is the amount of monitoring and evaluation of prescribed burning specified in written doctrine?

5.4. How does knowledge from monitoring and research feedback to future burning?

5.5. What innovations in monitoring and evaluation could reduce ecological risks?

6. Doctrine

6.1. Does your organisation have written policies, procedures, guidelines or other doctrine to guide the management of ecological values and risks in prescribed burning? If so, please could you summarise here and include copies with this completed survey.

These reports are available at the AFAC shop www.afac.com.au.

Information about the National Burning Project is available at www.afac.com.au/initiative/burning

A Risk Framework for Ecological Risks Associated with Prescribed Burning

National Burning Project: Sub-Project 3

Author

Adrian Pyrke (Eco Logical Australia)

Editor

Wayne Kington, *AFAC*

The challenge for land managers is to understand and apply the right kind of fire with the right techniques at the right times and places to deliver the various outcomes that prescribed burning can achieve. This risk management framework for ecological risks associated with prescribed burning provides a way to consider the steps and processes that all land managers can take when seeking the best ecological outcomes. It offers a synthesis of concerns, approaches and activities that organisations across Australia engage in to manage ecological risks associated with prescribed burning. Despite the large variation in fire regimes and the significant differences in extent and frequency of planned and unplanned fires in landscapes, particularly between northern and southern Australia, there are some key common principles that emerge. In an environment where the competing objectives for fire and land management are increasingly complex, underpinning our prescribed burning with the best possible ecological outcomes is an important part of fire management.

– Mike Wouters, A/Manager, Fire Management Department of Environment, Water and Natural Resources, South Australia

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