MONITORING FIRE AND BIODIVERSITY – THE FIRE MONITORING PROGRAM OF THE DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT

STEPHEN J. PLATT[1], SHANNON TRELOAR[2] AND GORDON FRIEND[2],

Department of Sustainability and Environment, Victoria, Australia.
[1]123 Brown Street, Heidelberg, 3084
[2]8 Nicholson Street, East Melbourne, 3001
email: stephen.platt@dse.vic.gov.au

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The interaction between fire and the environment is extremely complex. The Department of Sustainability and is taking a risk-based approach to bushfire management to minimise the impact of major bushfires on human life, property and the environment, and to maintain or improve ecosystem resilience. Since 2006, the Department has been undertaking flora and fauna monitoring and has established several programs including pre and post-fire flora monitoring, Landscape Fire and Environmental Monitoring and HawkEye. These fire and biodiversity monitoring programs operate within an ecological management framework based on vital attributes, tolerable fire intervals and growth stages. Biodiversity monitoring is aimed at challenging and strengthening the framework as well as targeting potential risks and providing a scientifically credible platform for decisions about fire management and its effects on ecosystem condition. This paper outlines these developing monitoring programs and their roles in informing the adaptive management cycle in Victoria's risk-based fire management program.

Keywords: biodiversity monitoring, fire monitoring, fire ecology, HawkEye, landscape, mosaic burn, planned burning, adaptive management

The interaction between fire and the environment is extremely complex. This complexity has both spatial and temporal dimensions, including the effects of the 'invisible mosaic' of previous fires (Bradstock et al. 2005, Kelly et al. 2011). It is further complicated by interactions between bushfires and planned burning, both of which may vary in their intensity and season of occurrence. Fires that remove above ground vegetation alter fauna habitat by changing the availability of feeding, shelter, breeding and dispersal opportunities. Ash and sediments mobilized by fire can lead to erosion and may enter waterways and thus affect in-stream and off-site habitats (Lyon & O'Connor 2008). Fires can have far reaching consequences by removing vegetation growth stages. Such growth stages can only be replaced in time, which can take decades to centuries (Cheal 2010). The fire regime – extent, frequency, intensity, season and type – interacting with the broader environment, sets the context for ecological outcomes (Gill and Allan, 2008). In the context of major environmental transformations, such as climate change, fire in its various regimes may lead to novel outcomes (Bridgewater et al. 2011).

Monitoring of the effects of fire on biodiversity is an essential action in any fire management system in order to better understand the interactions between fire and ecosystems, the effects of management actions such as planned burning, and to provide evidence on which to base decisions. Effective and efficient monitoring is, however, a complex issue that demands careful design, implementation and analysis. It also needs to be designed in recognition of the available resources, both short and long-term.

Fire impacts on biodiversity values. Most vegetation types in south-eastern Australia are adapted to fire, but need fire regimes to stay within appropriate ranges of frequency, intensity, scale, season and type in order to persist over time. These regime ranges are likely to be wide. Conversely, some vegetation types, such as cool temperate rainforest, are sensitive to fire and may be seriously damaged by one or more fire events. Thus, monitoring the effects of fire on biodiversity needs to consider the factors that promote resilient ecosystems as well as how ecosystems may deteriorate in the absence of appropriate fire regimes.

In order to deal with this complexity, and determine ecologically appropriate fire regimes, the Department of Sustainability and Environment (DSE) has established an ecological management framework for the Fire Ecology Program (Fig 1.)

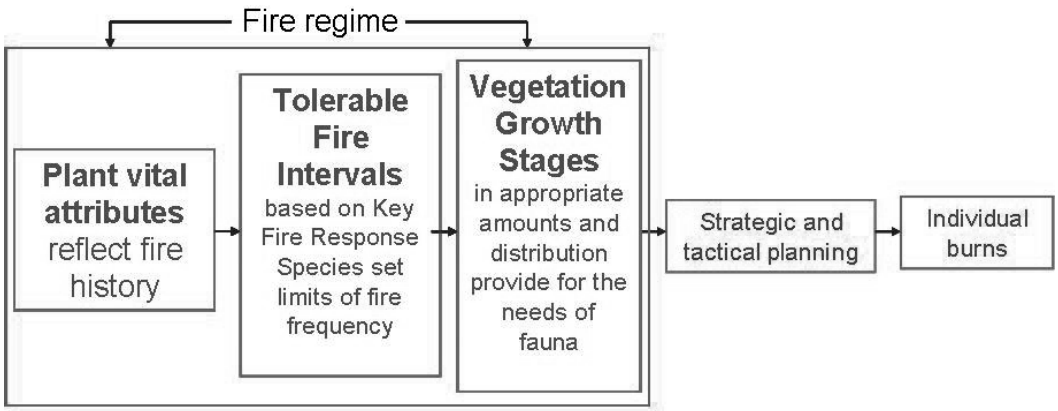


Fig. 1. Outline of the Department of Sustainability and Environment's Fire Ecology Framework.

(Fire Ecology Working Group 2004). The framework contributes to the broader risk management approach to fire management DSE is taking as outlined in the *Code of Practice for Bushfire Management on Public Land* (DSE 2012).

The framework seeks to understand the appropriate fire regimes envelope as it is reflected in the life history of organisms and their environment. It assumes that life history reflects the fire regimes to which organisms have been subject over long periods of time and is thus a useful starting point for understanding what is 'ecologically appropriate'. Such an approach is not reliant upon knowledge of the recent history of application of fire by indigenous custodians, though this would be a useful addition were it available.

The framework has several key elements. Plant 'vital attributes' (relevant life-history traits, Noble & Slatyer 1980; Tolhurst 2000; Burrows et al. 2008) are used to identify the most fire-vulnerable plant species in an area and to set the lower and upper limits of fire frequency. The time period between these limits is termed the 'Tolerable Fire Interval'. It is an expression of the time when fire is considered to have low risk of causing significant change in population abundance to local flora species. Fire outside these limits may have increased risk, though this can be moderated by factors including how the burn is conducted and the patchiness and severity of previous fires and needs to be considered in a landscape as well as local context. Fauna needs are included through the consideration of vegetation growth stages (Cheal 2010; MacHunter et al. 2009; Clarke 2008), the assumption being that a range of growth stages, from juvenile to senescent, will provide for the needs of a wide range of fauna species because they offer a range of habitat features (e.g. hollows in older growth stages) to which fauna species are adapted.

The fire ecology framework is used to inform planning. Spatial tools that consider temporal issues have been developed including Tolerable Fire Interval analyses (Fig. 2) and growth stage analyses (Fig 3). Tools for examining the individual responses of vertebrate fauna (Fig 4) and calculating the optimal distribution of growth stages, using geometric mean of abundance (McCarthy 2011), are also in development.

Such tools are used by fire planners to inform fire ecology assessments, which are an analysis of relevant fire history, species and community data to determine which areas are appropriate for planned burning. These assessments also take into account many other relevant local ecological issues, such as local environmental conditions (e.g. drought) and populations of threatened species that may be at risk of further decline due to fire. They are an input to fire management planning, which includes fire risk and other environmental issues (e.g. carbon, water, timber, smoke), and ultimately influence individual burn plans.

Assessments also provide a capacity to identify areas of risk (e.g. areas burnt below their tolerable fire interval, areas vulnerable to bushfire, growth stages that may be absent in future time periods) and thus direct monitoring activities to locations of highest risk.

The fire ecology framework, whilst an over-simplification of environmental complexity, provides a structure for incorporating knowledge into management processes that might otherwise remain

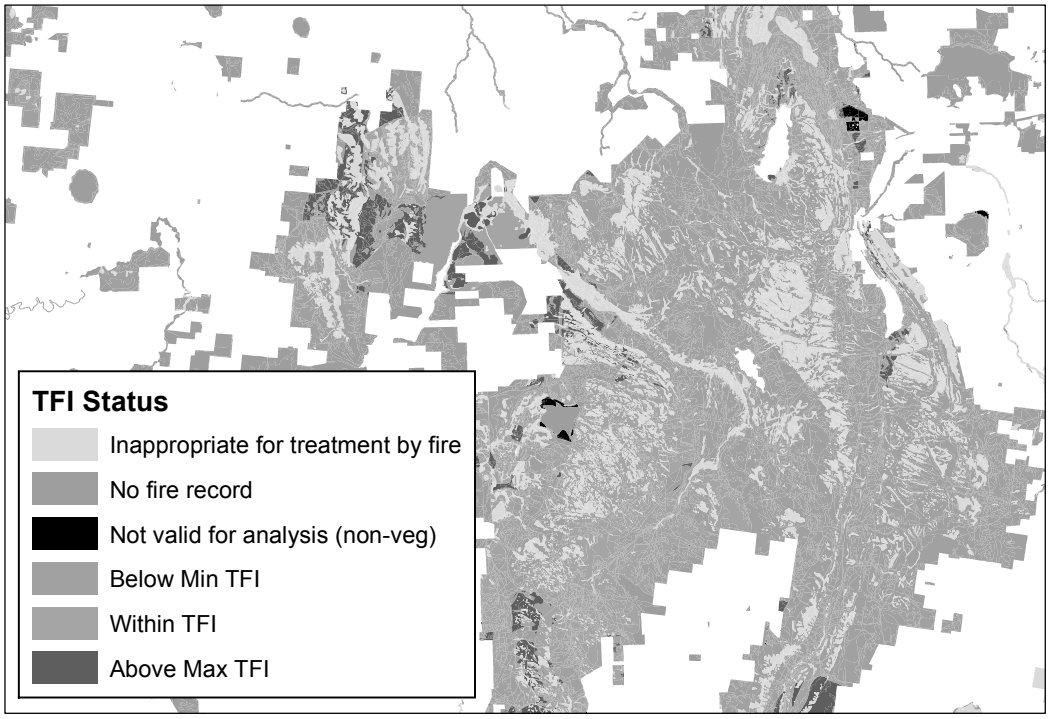


Fig. 2. Tolerable Fire Interval status of part of the Grampians National Park, southwest Victoria, 2010.

disconnected. It has the considerable advantage of providing a conduit to connect scientific evidence to policy and management. The framework is based on current knowledge and can adapt to new information about fire regimes and fire responses.

MONITORING APPROACH

If monitoring is to be effective and inform management, it must form part of an adaptive management approach (DSE 2008; Lindenmayer & Likens 2009; Fig. 5). As part of this process, monitoring should focus on those aspects that are uncertain, where the uncertainty clouds the decisions, and where the monitoring is expected to help reduce the uncertainty sufficiently to improve the relevant management decision (McCarthy 2012). At the strategic level, where we are attempting to better understand and measure ecosystem resilience, a clear focus of monitoring should be on fauna habitat attributes and fire severity and how these habitat attributes vary over time and space and on how key fire response species — species whose vital attributes (life history characteristics) indicate that they are vulnerable to a fire regime of frequent fires, or to long periods of fire exclusion (Noble & Slatyer 1980; McHunter et al. 2009) — relate to these components.

In order to better refine and target its monitoring, the Department recently identified a range of monitoring questions of relevance to planned burning. These include:

- What are the interactions between fire management and other drivers of ecosystem change (e.g. predators, competitors, climate change)?
- What are the desirable ecological output and outcome measures for planned burning?
- Does pyrodiversity beget biodiversity? (i.e. do vegetation mosaics with a range of fire ages, patch sizes and fire severities measurably enhance biodiversity?)
- What constitutes and where are habitat refugia for conservation dependent flora, fauna and ecosystems?
- What is the effect of burning at and beyond thresholds (e.g. tolerable fire interval) on the most sensitive/at risk species and ecosystems?
- How adequate are vegetation growth stages as a surrogate for fauna?

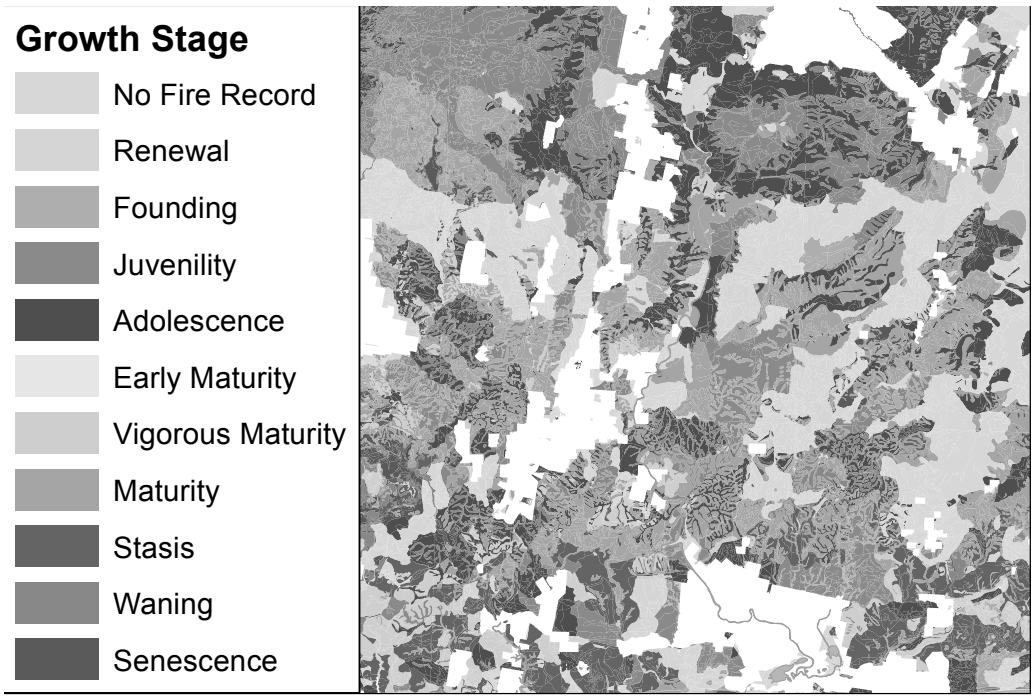


Fig. 3. Vegetation Growth Stage analysis showing a mosaic of patches of different stages of maturity post fire.

• What are the effects of frequency and scale of prescribed fire on vegetation composition, fauna habitat structure, vegetation growth stages (Ecological Vegetation Divisions, Cheal 2010) and fuel hazard levels and patterns?

By addressing key assumptions and knowledge gaps, monitoring can be targeted (Wintle et al. 2010) at improving the management framework and lead to ongoing improvements in delivery of planned burning. In addition, monitoring and research can be undertaken in scientifically valid ways with appropriate controls and replication, thus facilitating interpretation of the data. Some level of surveillance monitoring (continuing watching over a period or periods of time) is also useful to look for unexpected change and this is incorporated through both the breadth of sites being surveyed, the breadth of data collected at a site, including photographic records, and the identification of long-term sites for repeat visitation.

MONITORING PROGRAMS

Since 2006 DSE has invested in developing fire and biodiversity monitoring protocols and collecting monitoring data mainly in response to government initiatives and major fire events. As a consequence the monitoring programs and the number of monitoring sites (Fig 6.) have evolved through mostly short-term funding.

The objective of these monitoring programs is to increase our understanding of the landscape scale effects of fire, both bushfire and planned fire, so that we continue to learn, refine and inform the way we plan for fire and implement planned burning to protect life, property and the environment.

DSE's fire and biodiversity monitoring at present comprises three key programs:

• Flora Monitoring – pre and post fire monitoring of flora (including planned burns and bushfires) with a specific aim of improving plant vital attribute information;

• Landscape Fire and Environmental Monitoring – monitoring the effects of planned burning on flora, fauna, habitat, fuel hazard and fire severity;

• HawkEye – biodiversity monitoring for improved fire management.

Each program helps inform the fire ecology framework and thus the broader risk-based approach

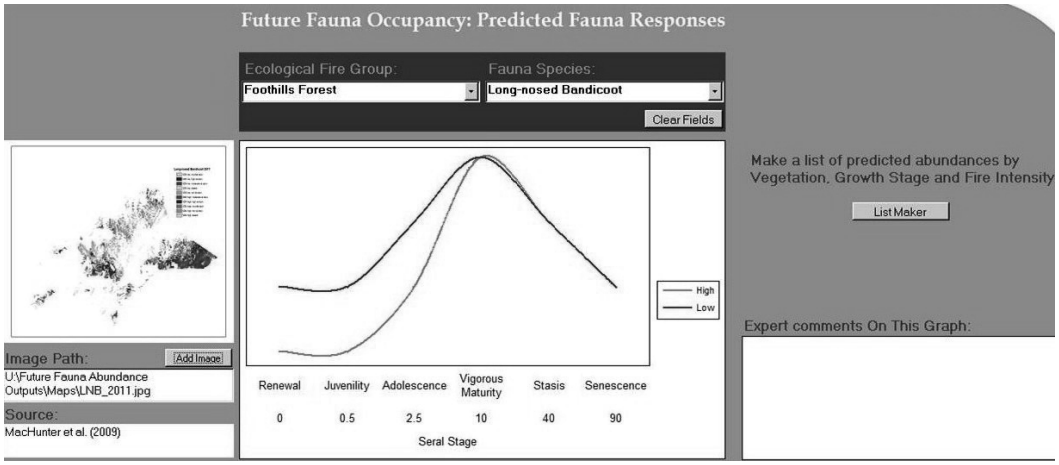


Fig. 4. Future Fauna Occupancy database screen view

to bushfire planning and management.

These programs are delivered independently, yet closely linked through over-arching directions, and each is targeted to:

- Continuously contribute to improving fire management (informed by the fire ecology framework) by addressing assumptions and knowledge gaps
- Respond to potential risks, such as burning below tolerable fire interval, to determine whether these risks are real and the options to reduce or eliminate them
- Individual areas and issues and refined to meet the needs of fire managers, researchers and the broader community in each case.

Recognising the constraints of current funding for monitoring programs it is incumbent of DSE to ensure that monitoring programs are delivered efficiently and effectively – delivering value for money in focussing on key management and policy questions at the activity, output and outcome levels.

To this end DSE will be undertaking a critical review of its current monitoring projects to ensure this objective is achieved and a sustainable monitoring program is designed and implemented.

Flora Monitoring Program

In 2006, with funding support from the National Heritage Trust and the National Disaster Mitigation program DSE embarked on the development of the Flora Monitoring Program, the first formalised approach to systematically document the effect of planned burns on environmental values. The program is based on the 'Flora Monitoring Protocols for Planned Burning; A User's Guide' (Cawson and Muir 2008a). These protocols were developed to test the flora vital attributes model developed by Noble and Slatyer (1980). The aims of the protocols are to guide managers as they plan, implement and draw conclusions from their flora monitoring programs and to improve knowledge about the

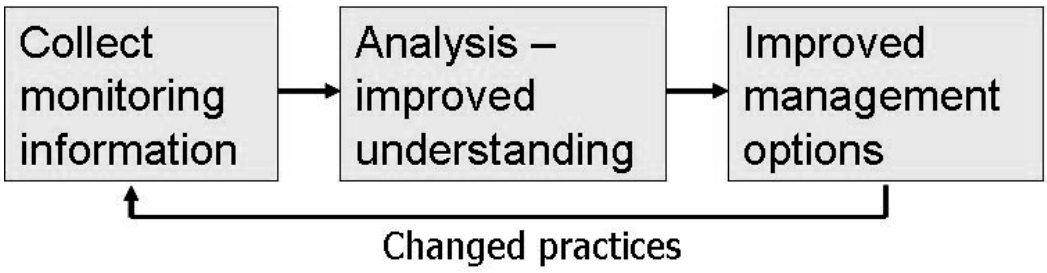
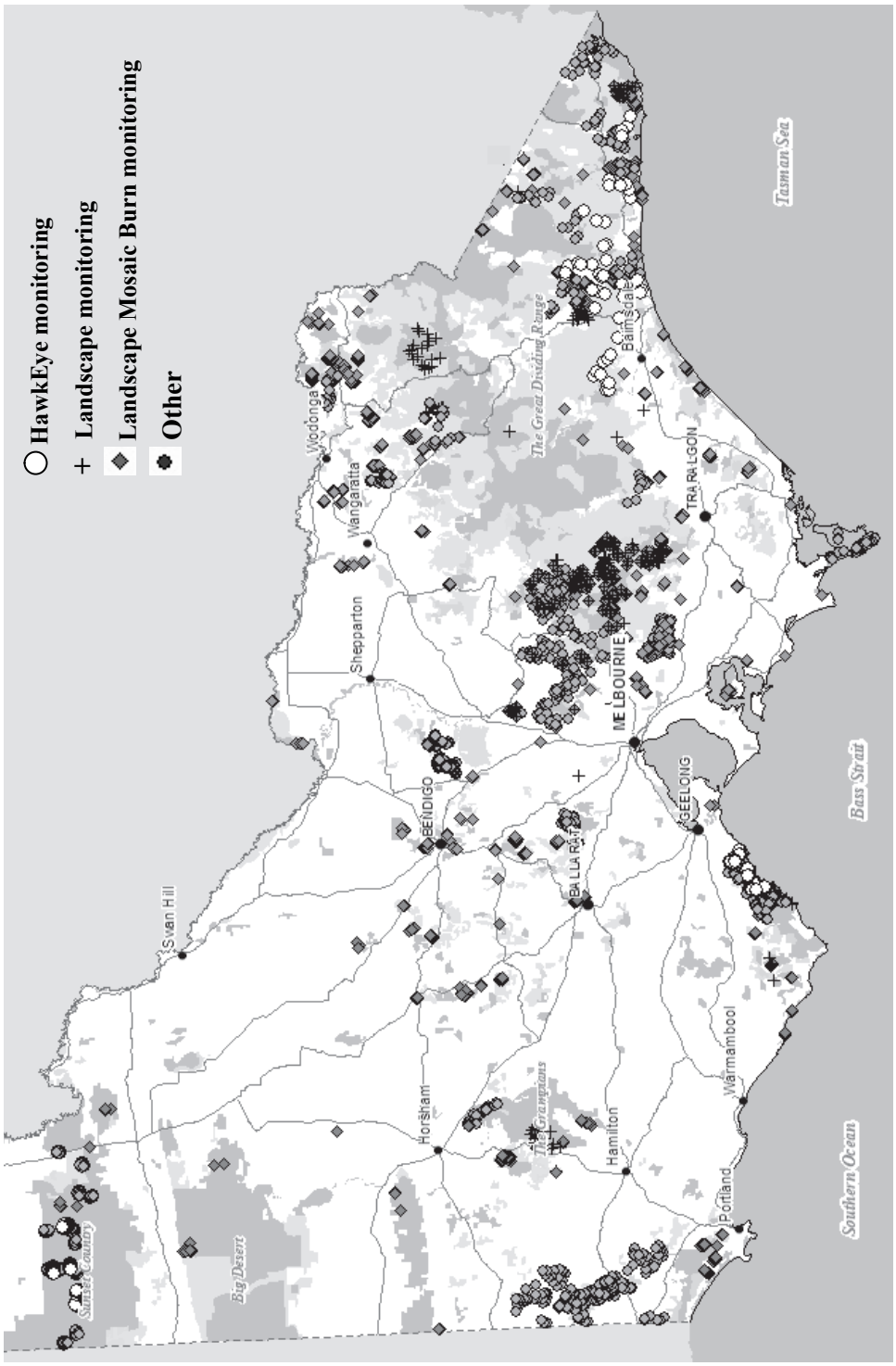


Fig. 5. Monitoring links to adaptive management.


HawkEye monitoring
Landscape monitoring
Landscape Mosaic Burn monitoring
Other
Woodonga
Wangaratta
Shepparton
The Great Dividing Range
Bairnsdale
TRARALGON
MELBOURNE
GEELONG
BENDIGO
BALLARAT
Swan Hill
Horsham
Hamilton
Warrnambool
Portland
Sunset Country
Big Desert
Tasman Sea
Bass Strait
Southern Ocean

vital attributes of species with little or no data to improve predictions about their response to fire. A rationale report (Cawson and Muir 2008b) was also written which provides supporting materials for field assessors, documents the process for developing the User's Guide and provides rationale for why certain methods were chosen (or not chosen). The protocols have five different techniques for assessing flora, each with a specific objective, and together the techniques collect information about species presence, cover, density, frequency of occurrence, life stage and mode of regeneration. The flora monitoring component has been underway since 2007. A preliminary analysis of this data has recently been completed (Moxham and Kennedy, in press).

Landscape Fire and Environmental Monitoring Program

Following on from the Flora Monitoring Program DSE began focusing its efforts on what is now referred to as the Landscape Fire and Environmental Monitoring Program. The aim of this program was to develop a science-based approach to monitoring the effect of fire on the environment by working with ecological experts and land managers to develop a suite of standard methods for monitoring that can be applied across the state, and to support a number of research programs that inform the monitoring.

The standard monitoring methods aim to measure the 'state' of key environmental variables and biodiversity assets/species potentially influenced by fire and to quantify the effect that fires, and ultimately the fire regime, have on that variable or asset. The methods chosen needed to be relatively simple, structured and consistent, and able to be applied by DSE and Parks Victoria (PV) staff across Victoria.

With the flora protocols in place, a clear focus in this broader program has been on developing similar approaches for fauna so that such information can be incorporated into fire planning. Previously, there had been little or no inclusion of the needs of fauna into fire planning, with the assumption that if the needs of flora were catered for so would the needs of the fauna (Clarke 2008). This was a cause of major concern but with the development of a fauna vital attributes model (MacHunter et al. 2009) a framework was created against which the assumptions about the needs of fauna could be tested. The faunal vital attributes model has two main components that require modeling and testing through monitoring:

i. The development of habitat over time and in relation to disturbance (stand replacing and non-stand replacing fire)

ii. The relationship between habitat and faunal species distributions and abundances.

A guide to test the first component of the model was developed from 2008 (Treloar 2012) focusing on monitoring the structural components of habitat that provide critical feeding, breeding and shelter sites for fauna. The guide was developed in consultation with scientists from the Arthur Rylah Institute for Environmental Research, Melbourne University, La Trobe University and Deakin University and tested by DSE and PV staff across Victoria.

In 2009, the monitoring effort was augmented through funding from Living with Fire: Victoria's Bushfire Strategy (DSE 2008). This allowed the implementation of a holistic monitoring program that brought together the separate methods (flora, fauna, habitat, fuel hazard and fire severity) to test the assumption of mosaic burning as a strategy to mitigate the risk of large fires to life and property whilst maintaining ecosystem resilience. The assumption is that an increased heterogeneity of age classes across the landscape will increase species richness and diversity and reduce the size and severity of large-scale bushfires i.e. pyrodiversity begets biodiversity (Parr and Andersen 2006).

The program also allowed DSE to begin testing the second component of the fauna vital attributes model with the implementation of vertebrate fauna monitoring via remote camera monitoring and bird surveys. The cameras provide a technique of assessing fauna that can be implemented by a wide range of people following some basic training and allow the cameras to be set up in remote locations for several weeks at a time to not only capture species presence but behavioural attributes as well.

At this time the landscape-focused program has been implemented on-ground for two years, with five monitoring areas being set up in 2009, six in 2010 and three being set up in 2011. Each monitoring area comprises 15 to 25 two-hectare sites, placed in the landscape using a 1km spaced grid with a randomly placed starting point, then removing or relocating sites based on accessibility criteria . Methods have been developed for flora, fauna, habitat, fuel hazard

Fig. 6. (facing page) Location of recent fire and biodiversity monitoring sites in Victoria.

and fire severity, with method development beginning recently on fire behaviour. Other methods focusing on other aspects such as invertebrates, carbon, fungi, and soils will be considered in the future.

As method development evolved, four general philosophies were developed to maintain consistency across the program.

1) The methods are developed based on conceptual models encompassing the best available science and research at the time (Gill 2009; MacHunter et al. 2009; Cheal 2010). This provides a framework against which the assumptions of the model can be tested through monitoring.

2) The methods are developed as part of an adaptive management approach to fire management (Williams 2011; Moore et al. 2011). This approach applies at both the broad, strategic level of fire management, and at the tool development level with each method tested and adjusted based on the outcomes of field testing.

3) A range of people with varying backgrounds, skills and experience are involved in the development. This helps ensure the methods are accepted and agreed upon by the full range of users, increasing their ownership of the program and the likelihood they will consistently and repeatedly undertake monitoring.

4) A multi-level approach is applied to the methods so that skill and experience is not a limiting factor. This increases the number of people that can participate in the program, increasing the amount of data that are collected.

HawkEye Program

In 2010, DSE established a long-term biodiversity monitoring project, HawkEye, to inform the way it conducts planned burning and guide how it balances the dual objectives of reducing the impact of major bushfires on communities and of enhancing the health and resilience of natural ecosystems so they can maintain biodiversity and other services. HawkEye includes monitoring, research, modelling and evaluation of the effects of planned burning on biodiversity. Monitoring of biodiversity will assist in understanding the short and long term impacts of planned burns and how to apply ecologically appropriate fire regimes – including the appropriate frequency, intensity, extent and season of fire. HawkEye responds to the Victorian Bushfire Royal Commission recommendation (Teague et al. 2010) for a significant expansion to the State's long-term program of planned burning. In association with this, the Commission made recommendations for increased biodiversity monitoring and reporting.

HawkEye takes a targeted monitoring approach, investigating key monitoring questions of relevance to the effects of planned burning on biodiversity. These questions are being investigated in specific landscapes, with a focus on vegetation types likely to be subject to planned burning. Seven key themes for commissioned investment have been identified with sub-projects being undertaken in partnership with institutions having fire ecology monitoring and research expertise.

1. Otways HawkEye — involves monitoring biodiversity in the forest and heathlands of the Otways, an area where high value biodiversity assets intersect with human occupation. The project is working in collaboration with a DSE/University of Melbourne research project 'Fire, landscape pattern and biodiversity' and will help to inform DSE's 'Future Fire Management' project (Ackland et al. 2010) being piloted in the Otways.

2. Gippsland HawkEye — is investigating the effects of planned burning on the foothill forests of Gippsland. It builds on DSE's retrospective (or 'space for time') mosaic burning research project, undertaken by staff of the Arthur Rylah Institute, that is examining the outcomes of various fire regimes across the landscape. HawkEye funding has added additional sites and enabled analysis of the effects of disturbance from fire on weed invasion.

3. Mallee HawkEye — is a collaborative project between DSE, LaTrobe and Deakin Universities. It builds on the six-year Mallee Fire and Biodiversity Project (Clarke and Bennett 2008).

4. Interaction between fire and threats to biodiversity — includes projects investigating the relationships between planned burning and predation, and weed invasion.

5. Opportunistic monitoring — provides support for monitoring projects where they contribute to answering key management questions. Projects funded include a PhD study of the effect of invertebrates on decomposition of leaf litter at Murrindindi, and a large study of fire in Box-Ironbark ecosystems.

6. Community involvement — is supported where it can contribute to the science program and to increase transparency and confidence, through independent observers witnessing the data collection and having confidence in its validity, in the HawkEye project.

7. Information systems and monitoring protocols — Improving monitoring infrastructure will enable greater use of existing data and help to coordinate monitoring activity. HawkEye is investigating the feasibility of creating a monitoring and research sites database and spatial layer with monitoring sites displayed along with their metadata (who, what, when) in a searchable format. In addition, HawkEye will seek to improve biodiversity data collection systems, data standards and protocols.

DSE is making a significant investment in biodiversity and fire monitoring. In the years ahead, the program has the capacity to improve understanding of many aspects of fire ecology that are critical to how we manage fire in the landscape.

Further information is available at www.dse.vic.gov.au/fireecology

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