Department of
Sustainability and
Environment

Flora monitoring protocols for planned burning: **a rationale report**

Fire and adaptive management

report no. 75

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A Victorian Government initiative

Victoria
The Place To Be

Flora monitoring protocols for planned burning: **a rationale report**

Fire and adaptive management

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Australian Government
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Natural Heritage Trust

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1 Introduction

1. Introduction

1.1 Purpose and scope of this report

Typically, monitoring protocols omit the reasoning behind the methods they propose, which makes it hard for users to understand why a particular approach was taken. This *Rationale report* is part of an alternative approach to developing and managing knowledge because it shows how and why the flora monitoring methods in *Flora monitoring protocols for planned burning: a user's guide* (the *User's guide*) (DSE 2008) were developed. This will demonstrate the variations to the methods that have already been tried and the reasons for selecting the chosen methods.

The *User's guide* (DSE 2008) describes four standard assessment types to monitor flora in planned burn areas:

- vital attributes assessment
- life-stage assessment for burn planning
- indicator-species assessment
- all-species assessment.

It also briefly describes a standard assessment type relating to the assessment of fire severity.

The development of these assessment types involved a review of existing monitoring methods, consultation with stakeholders and extensive field trials. This report describes the process for developing the assessment types and the reasons for choosing particular methods. It includes the reasoning and rationale behind:

- background information used in the *User's guide*
- defining the monitoring objectives
- choosing particular assessment methods
- not including other methods that were trialled
- including causal factors in the assessments
- learning from the data.

This report does not:

- provide a detailed description of the assessment types (the *User's guide* provides these descriptions and should be read together with this report)
- review other monitoring methods used in Victoria (documented in Cawson and Muir 2006)
- discuss the integration of the flora assessment types with other monitoring methods that are being developed separately (e.g. monitoring of fuel hazards, fire behaviour, pest plants and fauna habitat).

1.2 The need for fire monitoring in Victoria

The role of monitoring in fire management planning and fire ecology is specified in the *Code of practice for fire management on public land: revision 1* (DSE 2006) and the *Guidelines and procedures for ecological burning on public land in Victoria* (Fire Ecology Working Group 2004).

The *Fire code* (DSE 2006) clearly states that monitoring be included in fire management plans, and that selected planned burns be monitored using 'soundly-based sampling on an ongoing basis' to measure the effects of burning on fuel levels, flora, fauna and other values. Similar to the adaptive management cycle, the *Fire code* (DSE 2006) uses a 'plan-implement-review' framework (Figure 1).

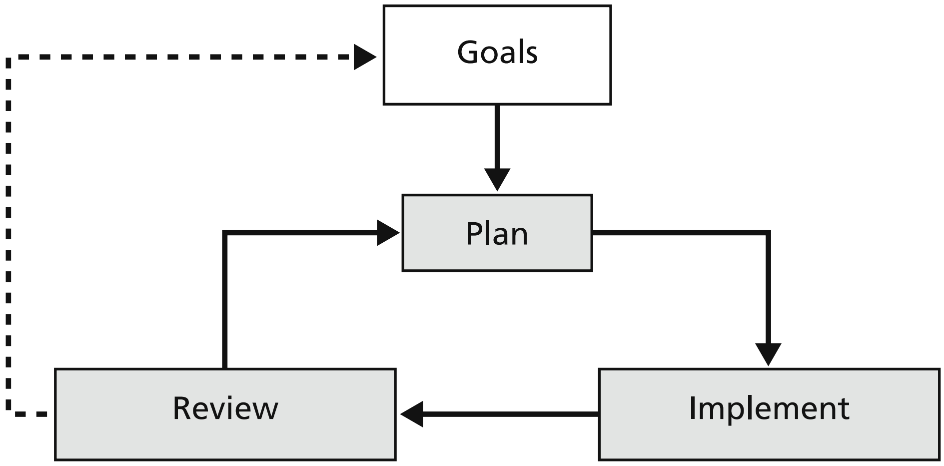


Figure 1: The fire management cycle (plan-implement-review) (DSE 2006).

Monitoring is also a key component of the *Fire ecology assessments* (also known as *Fire ecology strategies*) that are being developed throughout the state. These assessments inform fire management plans and identify areas for potential burning based on fire frequency requirements for Ecological Vegetation Classes (EVCs). Monitoring provides the baseline data on which the *Fire ecology assessments* are based.

In even more recent times the growing recognition that fire managers need to be 'active adaptive', particularly in the face of climate change, has heightened the importance of monitoring as a critical part of fire management. This is reflected in the bushfire strategy scoping paper where 'Risk and adaptive management' is one of six new themes (T*owards a bushfire strategy: scoping paper*, DSE 2008). Active adaptive managers not only monitor the outcomes of management (and adapt subsequent management accordingly), but they deliberately experiment with management actions to 'improve their understanding and predictive capability in regard to the system's response to management' (Walker 1998). Adaptive management, and the role of monitoring within it, is discussed in more detail in Section 3.1.

1.3 Background information and its application to the *User's guide*

This section discusses some of the background information and thinking that underlies the *User's guide*. The desire to monitor burns within DSE and Parks Victoria was evident very early in the development of the *User's guide* during interviews with fire ecology practitioners throughout the state. However, the actual role of monitoring in fire management and fire research was not as clear and thus required much thought.

1.3.1 Adaptive management

Adaptive management is a key concept underlying the *User's guide* and monitoring in general. The adaptive management cycle helps us to better understand the role of monitoring within fire management and also helps us to devise monitoring objectives. Figure 2 shows the adaptive management cycle. There are six steps within this cycle and they occur within a system (such as a forest ecosystem), which may change its state during the cycle. The steps in the cycle are:

1. **Predict** - use a model of the system to predict the outcomes of various management options.
2. **Plan** - plan a management action based on the predictions from the model.
3. **Act** - carry out the planned management action (may lead to a change in the state of a system).
4. **Monitor** - make observations about changes to the state of the system.
5. **Learn** - analyse the monitoring data, interpreting this analysis and then gain knowledge from this interpretation.
6. **Review** - revisit the model's predictions to check their accuracy and then refine the model if this is required.

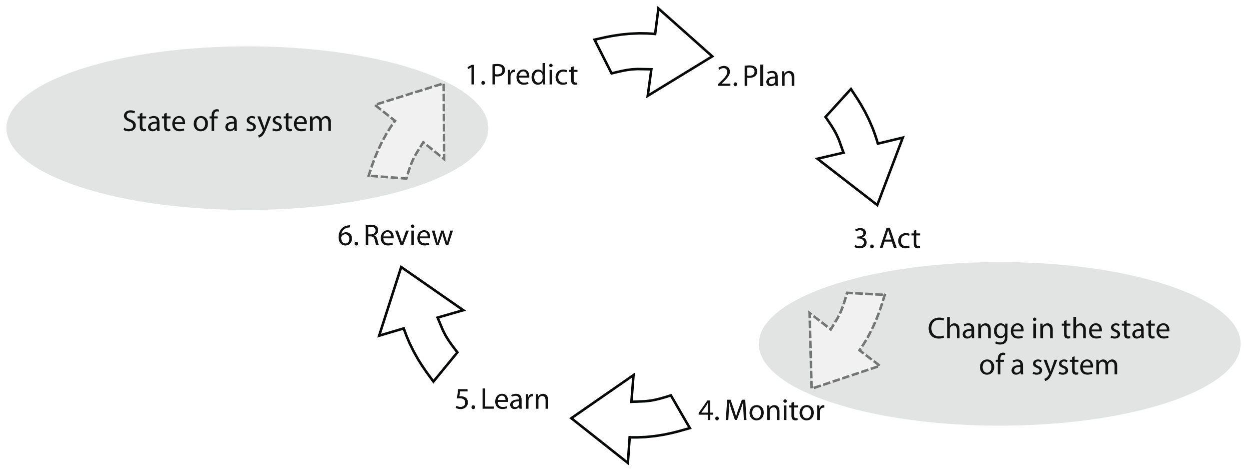


Figure 2: An adaptive management cycle. This cycle shows the actions required to achieve adaptive management.

1.3.2 Land management models

The first step in the adaptive management cycle is to predict the outcomes of management options (see Figure 2). These predictions should be made using a land management model of the system being managed. These models vary in their complexity depending on the amount known about the system.

The land management model that forms the basis of the assessments in the *User's guide* is the 'flora vital attributes model'. It involves using knowledge about flora vital attributes[1] to identify the minimum and maximum 'tolerable fire intervals'[2] for different vegetation types (Noble and Slatyer 1980; Noble and Slatyer 1981; Tolhurst and Friend 2001; Fire Ecology Working Group 2004).

1 Vital attributes are the key life-history features that determine how a species lives and reproduces. These attributes govern how a species responds to fire and/or persists within a particular fire regime (Fire Ecology Working Group, 2004).
2 The tolerable fire interval is defined here as the fire interval that suits the persistence of the vegetation type. It does not refer to other aspects of tolerance, such as human acceptance.

The following is an excerpt from the *User's guide* about the flora vital attributes model:

> Land managers can use the flora vital attributes model to predict the outcomes of a planned burn. For example, the model may predict that a particular species will become locally extinct[3] if fire is too frequent or too infrequent.
>
> Key fire response species (KFRS) are a central feature of the flora vital attributes model. They are 'species within an EVC whose vital attributes indicate that they are vulnerable to either a regime of frequent fires or to long periods of fire exclusion' (Fire Ecology Working Group 2004). The model assumes if the fire frequency fits within the tolerable fire interval determined by the KFRS then all species of vascular flora within the area should survive. This assumption is a largely untested.

Land managers often use the flora vital attributes model to plan ecological burns (Fire Ecology Working Group 2004). An underlying management objective for ecological burning is to ensure that 'environmental values including the ecological health of the state's indigenous flora and fauna are protected and promoted, as far as is practicable, from the deleterious effects of successive bushfires, inappropriate fire regimes, and fire management activities' (DSE 2006). Ecological burn planning strives to meet this management objective by creating a mosaic of age-classes across the landscape with the majority of the vegetation being burnt within the tolerable fire intervals defined by the flora vital attributes. As part of this process Tolhurst and Friend (2001) recommend that field assessments are undertaken to check that the life-stages of the flora, which are predicted by the model, actually occur at the potential burn site.

There are limitations with the flora vital attribute model, even though it is a useful tool for ecological burn planning. Those limitations mostly reflect knowledge gaps in understanding flora responses to fire – gaps that monitoring can largely address:

- Firstly, there are many flora species without information on vital attributes which means that more baseline data about flora vital attributes needs to be collected.
- Secondly, knowledge about the effects of other attributes of the fire regime (fire intensity, extent and season) on flora vital attributes is lacking - the model deals mostly with fire frequency (Noble and Slatyer 1980). The same species may respond differently (have different vital attributes) depending on those other attributes of the fire regime. For example, the regeneration response for a species in a forest may be vegetative after a surface fire or seed-based after a crown fire (Tolhurst and Friend 2001). Vital attributes may also vary depending on the impact of other non-fire influences such as grazing or climate (Noble and Slatyer 1980). Although the current model largely ignores those influences, monitoring could investigate them.
- Finally the model does not predict how fire will affect the relative dominance of a species (Noble and Slatyer 1980) - the model provides only for the prediction of species presence or absence. Predicting relative dominance could be important because it may be related to habitat structure or the ability of a species to persist. Other fire ecology models provide general guidance about the relative dominance of species after fire and how that changes over time (Whelen et al. 2002; Figure 3). The results from monitoring may help to add numbers to these general trend lines and could lead to the eventual incorporation of this kind of information into the flora vital attributes model.

3 If a species is 'locally extinct' it means that the local site has lost the mature population that existed there, either through senescence or a disturbance; and that there is no seed of the species at the site to allow regeneration. The species may still occur in other nearby areas.

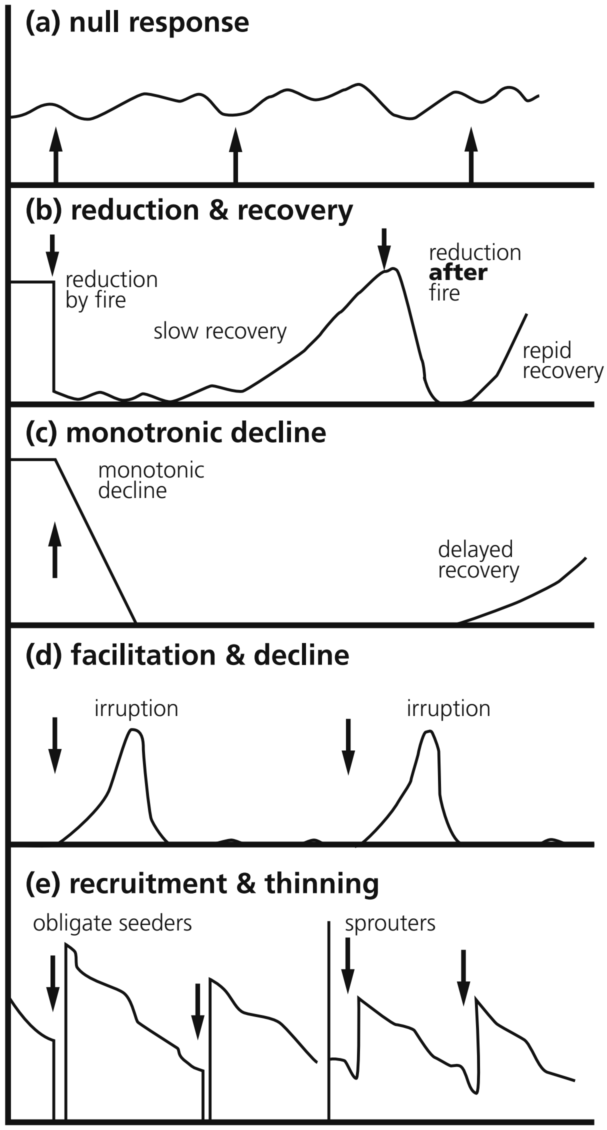


Figure 3: Schematic diagram showing the range of fire response patterns that populations may exhibit over time (Whelen *et al*. 2002). (a) Null response: population remains unchanged in response to a fire; (b) Reduction and recovery: population size declines soon after fire and remains low for some period followed by recovery (fast versus slow recovery); (c) Monotonic decline in population size, leading to local extinction, perhaps with eventual recovery; (d) Facilitation and decline: population size increases after fire and then declines; (e) Recruitment and thinning: population size dramatically decreases immediately after fire, then rapidly increases, followed by gradual decline, for obligate seeders (left) and resprouters (right).

1.3.3 Monitoring versus research

The complexity of a monitoring program can vary significantly from casual observations to detailed sampling designs. This complexity occurs along a continuum from 'no monitoring' to 'research' (Elzinga et al. 2001) (see Figure 4). As monitoring becomes more like research, the amount of replication and the use of controls becomes greater. An early step in the development of the *User's guide* involved deciding where to pitch the methods along this continuum. Trade-offs had to be made because there are advantages and disadvantages for each of the different levels of monitoring.

The main distinctions between monitoring and research are that research involves more replication and the use of controls. Replication is where the same treatment (e.g. a burn) is applied across a number of areas. A control is an area that is exactly the same as the treatment area but that is not treated (e.g. not burnt). Without replication and without control areas it is difficult to identify whether an observed change is caused by the treatment or caused by other factors that are also occurring in the area (e.g. drought, cinnamon fungus or grazing). This difficulty in establishing cause and effect relationships is a major limitation of monitoring data and is reiterated throughout the *User's guide*.

There are trade-offs in choosing a more comprehensive research approach to data collection as well. Data collection for research is much more resource-intensive because both treatment and control plots are used. With limited resources, this means that all the monitoring efforts will be targeted towards just a few areas. This may not be useful to managers who need information that can be applied more broadly.

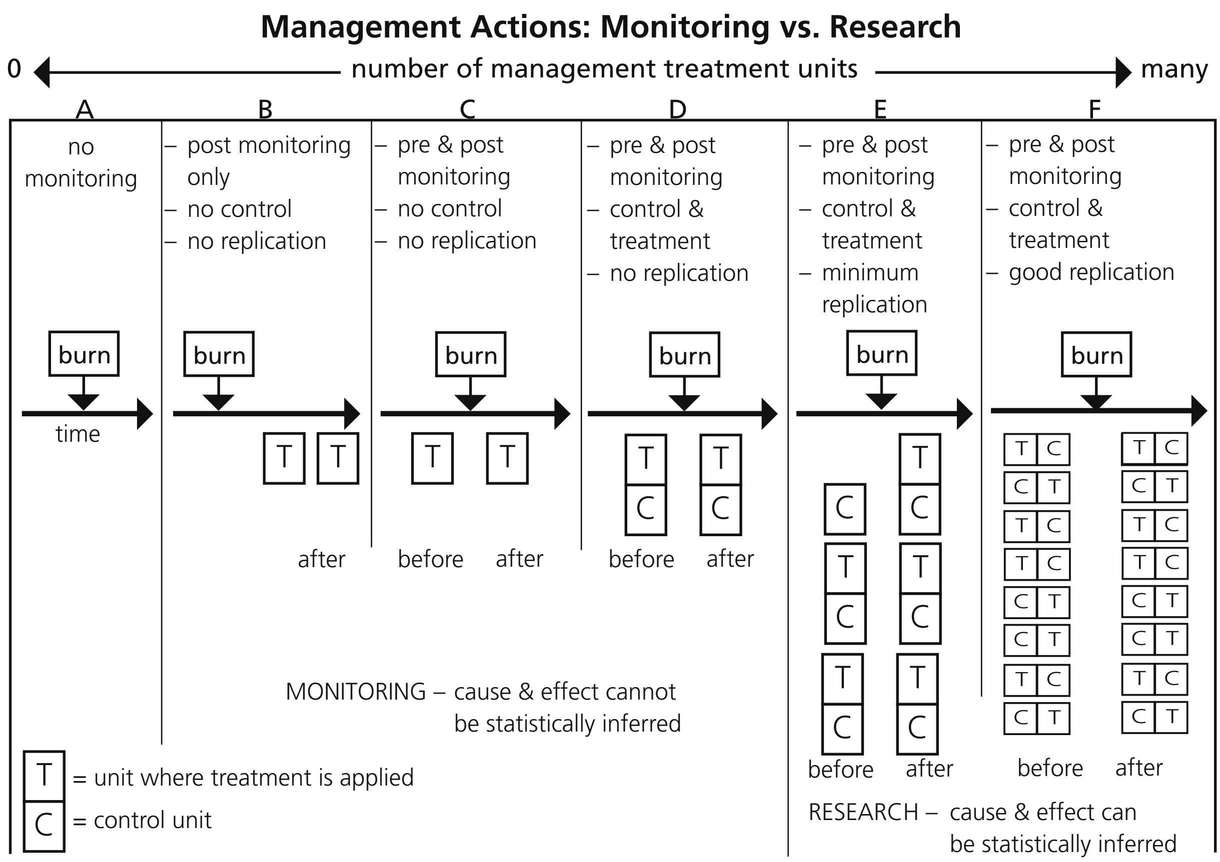


Figure 4: A monitoring to research continuum (Elzinga *et al*. 2001). 'For each of the scenarios shown in columns B-F above, statistical comparisons can be made between different time periods and a decision can be made as to whether or not a statistically significant difference occurred. However, the interpretation of that difference can be confounded by factors that are independent of the burn. There is a continuum of increasing confidence in determining likely causation as you move from left to right in the diagram' (Elzinga *et al.* 2001).

1.3.4 The monitoring triangle

After considering the trade-offs between the different levels of monitoring along the continuum (see Figure 4), we decided to choose a tiered approach to monitoring. The monitoring triangle (Figure 5) shows three levels of monitoring.

Operational monitoring occurs at the base of the triangle. It involves simple techniques, is the least time-consuming method and can be used by many people across many different areas. Operational monitoring can be used to guide decision-making, but it has limited capability for establishing cause and effect relationships because of its basic sampling design (no replication, no controls). The life-stage assessment for burn planning sits within this tier (although technically it is not monitoring because the measurements are not repeated over time). The data collected by this assessment type are used solely to inform burn planning. There is no replication because the sampling design is inadequate for pooling data across multiple areas (it uses a relative measure of life-stage rather than an absolute one). There is no need for controls because the assessment is a snapshot in time rather than a measurement of change.

Scientific monitoring is in the middle of the triangle. This type of monitoring balances operational needs (e.g. resource and skill constraints) with scientific needs (e.g. a statistically valid sampling design). Extensive replication is involved but controls are still not used. The data are suitable for statistical analysis due to a more detailed sampling design (e.g. randomness, non-bias and replication are incorporated into the design). More skills and resources are required to undertake the assessment, and such assessments therefore focus on priority areas. Despite the more rigorous sampling design, this type of monitoring is still limited in its ability to establish cause and effect relationships because there are no control areas.

The indicator-species assessment and the all-species assessment both sit within the scientific monitoring tier of the triangle. Both involve replication within an area and the methods are designed so that data can be pooled across multiple areas, enabling replication across landscapes. Both assessment types are in the same tier of the triangle, but the indicator-species assessment is designed to be more operational than the all-species assessment. This distinction is mostly related to the type of data collected. For the all-species assessment, all the flora species need to be identified, which means that fewer people will have the expertise to undertake this assessment. The flora vital attributes assessment also falls within the scientific monitoring section of the pyramid (although technically it is not monitoring because the measurements are not repeated over time). This assessment requires expertise in plant identification, which makes it more demanding than typical operational monitoring.

The highest tier in the triangle is research. Research is the most comprehensive form of monitoring. It involves extensive replication and the use of controls (an 'experimental design'). Consequently, it is the method most likely to establish cause and effect relationships. The research tier is also the most demanding in terms of skills and resources and therefore fewer areas can be assessed using this approach. Research methods are beyond the scope of the *User's guide*.

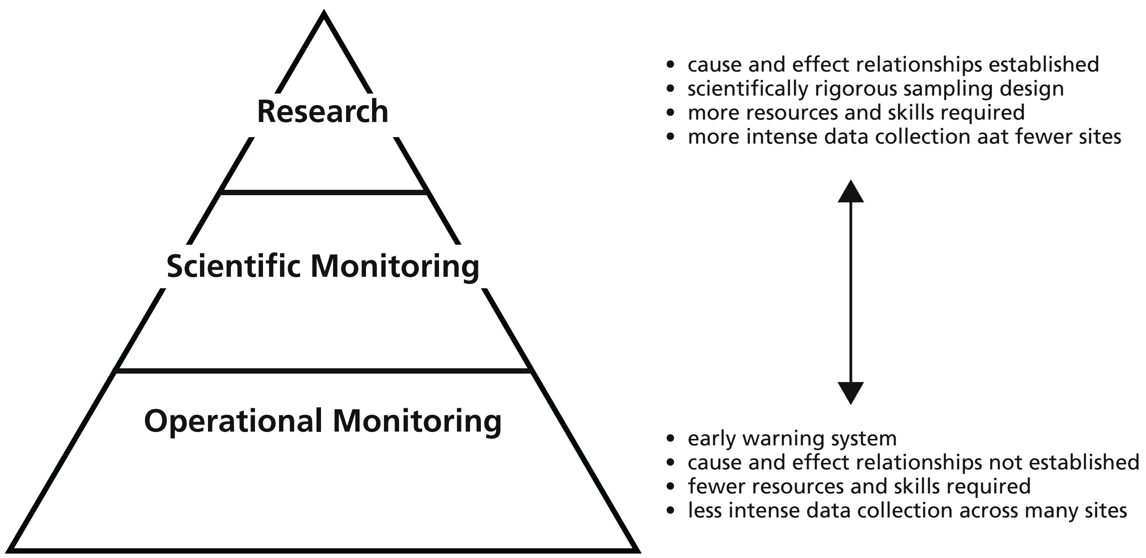


Figure 5: The monitoring triangle showing levels of complexity in monitoring.

1.3.5 Principles of monitoring systems

The design of a successful monitoring program requires careful planning of a number of stages. The principles in Table 1, which have been adapted from Smyth *et al*. (2003), have been used as a checklist in the development of the flora monitoring methods presented in the *User's guide*.

Table 1: Components of a successful monitoring system (adapted from Symth *et al*. 2003).

Principles of monitoring systems	Steps taken to address each principle
Include people with expertise in management and monitoring.…	Fire practitioners and scientists have been consulted throughout the development of the methods. It is recommended that botanists are consulted during the implementation of the methods.
Identify changes to biodiversity values in the environment of concern.	Monitoring objectives and methods are targeted towards establishing changes in the presence, abundance and composition of flora species.
Identify factors driving these changes.	Data will be collected on factors that may cause change - fire frequency, severity and season. However, assessors should be careful not to confuse associations with causations.
Determine what information is needed to allow land managers to react to changes.	Monitoring methods are designed so that the data they generate can be used to test and refine fire ecology models (i.e. flora vital attributes model).
Decide how often information is required.	The *User's guide* has a timeline for each assessment type that specifies how often an area needs to be assessed.
Establish what indicators will be monitored and what techniques should be used.	The *User's guide* has clear guidelines on what to measure and how.
Check if indicators, techniques and reporting will detect changes of concern.	Field trials and advice from a statistician are used to determine the adequacy of methods in detecting particular levels of change. The amount of change that is ecologically significant is often not known. Some monitoring objectives are designed to test basic fire ecology assumptions about the selection and use of indicators.
Establish who will collect, maintain and analyse information.	This will vary throughout the state but is likely to involve a range of employees from the DSE and Parks Victoria, external contractors and volunteer groups.
Review and improve monitoring program.	There is flexibility to review and improve methods as required. This *Rationale report* should aid the review process by providing some background on what has already been tried.

1.3.6 Review of existing monitoring methods and programs

Monitoring programs are often limited by:

- unclear objectives
- inconsistencies in monitoring methods that make it difficult to compare data from different areas, between different assessors and over time
- a lack of understanding about how to draw data together to address monitoring objectives and refine management models.

Before the development of the *User's guide*, we reviewed the fire-related monitoring occurring within Parks Victoria and DSE (Cawson and Muir 2006, internal report). We held a series of interviews with employees from DSE and Parks Victoria about the monitoring they were currently doing and their priorities for monitoring in the future. There was a consensus that monitoring of planned burns should be an essential feature of fire ecology and fire management more generally. In relation to current monitoring the review found that:

> Monitoring of ecological values rarely occurs for fuel reduction burns. For ecological burns, most monitoring is for threatened species and communities, where the objectives are usually to improve the condition of threatened communities or to increase the populations of threatened flora and fauna species. However, many burns with ecological objectives are not monitored. Much of the recent monitoring effort has been focused on the 2003 alpine fires, where long-term monitoring plots are being used to evaluate the recovery of targeted vegetation communities and species.

The absence of standard methods, insufficient resources and a low priority placed on monitoring were identified as key issues that limited the amount of monitoring occurring. The value of data collected diminished when the methods were inconsistent (and data could not be combined for different areas or over time) and when there was no central repository for the data (and it was thus difficult for others to gain access to it).

Some of the monitoring methods for flora being used in Victoria for planned burn areas are:

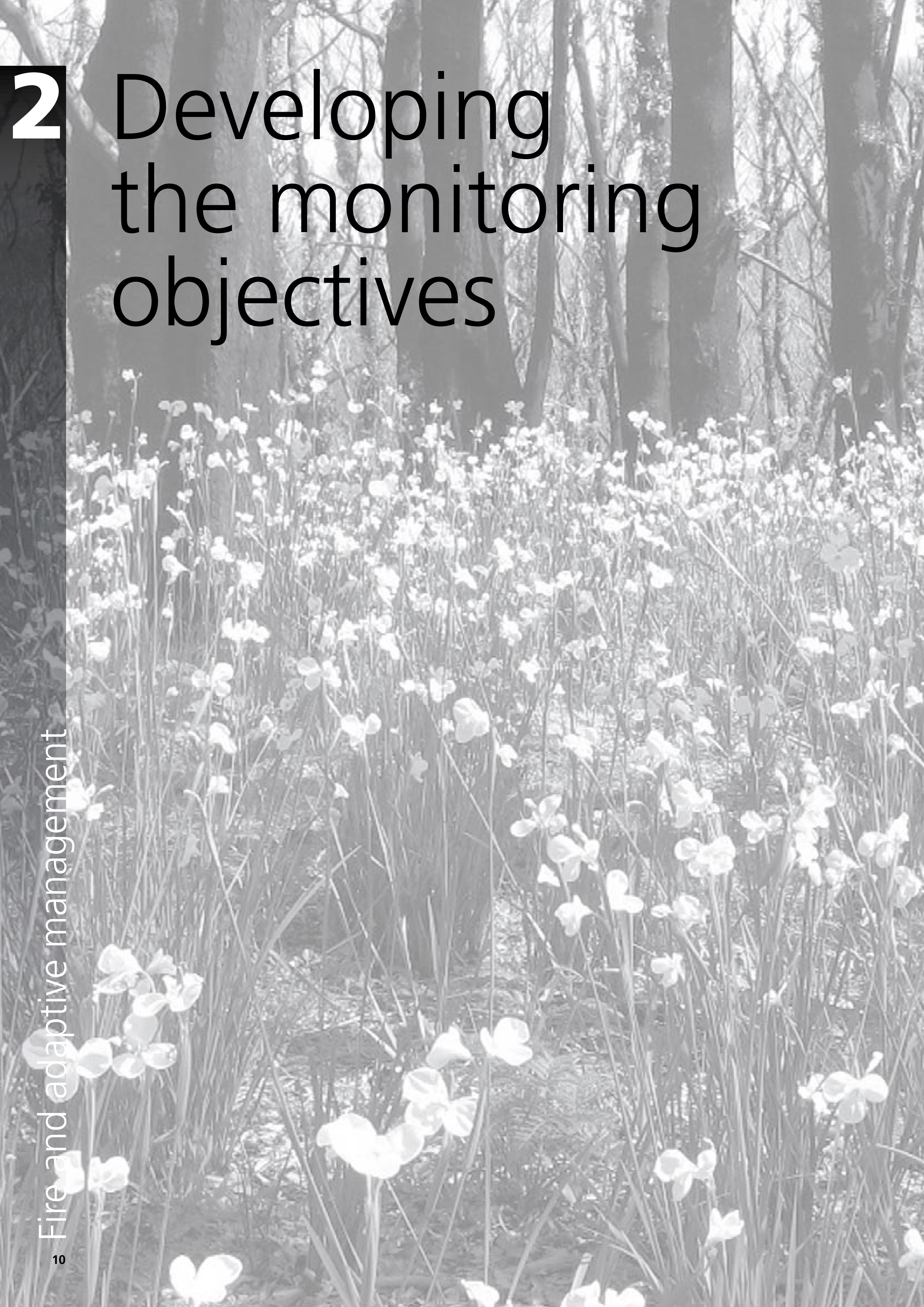
- 'Prescribed burn monitoring record' (Tolhurst, 2005)
- 'Illabrook flora reserve monitoring methodology' (Wright et al. 2003)
- 'Alps vegetation fire response monitoring System' (Forward and Hall 1997)
- 'Wilson's Promontory National Park post-fire integrated monitoring vegetation protocol' (Burrows, 2006).

These methods have been used to guide the development of the *User's guide*. Some interstate and international monitoring methods used during the development of the *User's guide* include:

- 'Fire and biodiversity monitoring manual' (Southeast Queensland Fire and Biodiversity Consortium, 2002)
- 'Fire monitoring handbook' (United States National Park Service, 2003).

Some non-fire related methods from Victoria are:

- 'Pest plant mapping and monitoring protocol' (Parks Victoria, 2005)
- 'Sub-tidal Reef Monitoring Program: standard operational procedures' (Parks Flora and Fauna Division, 2001).



2 Developing the monitoring objectives

2. Developing the monitoring objectives

The first and most important step in developing monitoring methods is the development of suitable monitoring objectives. This section discusses the rationale behind the development of the monitoring objectives for the *User's guide*.

2.1 Steps for developing the monitoring objectives

The steps in the development of the monitoring objectives included:

- consultation with field practitioners, managers and the Fire Ecology Scientific Reference Group to identify the important questions to answer
- a review of existing monitoring objectives used in flora monitoring programs by either DSE and PV or other interstate and overseas organisations
- identification of the land management model used in fire ecology planning (the flora vital attributes model). According to the adaptive management cycle, monitoring should test this model.

Discussions with individual stakeholders showed that different local areas had different questions to answer from monitoring. This made it difficult to derive standard state-wide objectives for monitoring that were also locally relevant. To overcome this difficulty the project team chose broad, flexible objectives that address important questions for the whole state and can be adapted to address a range of locally important questions at the same time.

The monitoring objectives in the *User's guide* are:

- to obtain information on flora vital attributes for those species that lack such data
- to predict whether the vegetation in an area is likely to respond positively to burning at a particular time
- to estimate the size of change in the presence and abundance of indicator species after a fire
- to determine the extent to which key fire response species can be used as indicators for all species after fire
- to estimate the size of change in species composition after fire.

These objectives address the limitations of the flora vital attributes model by:

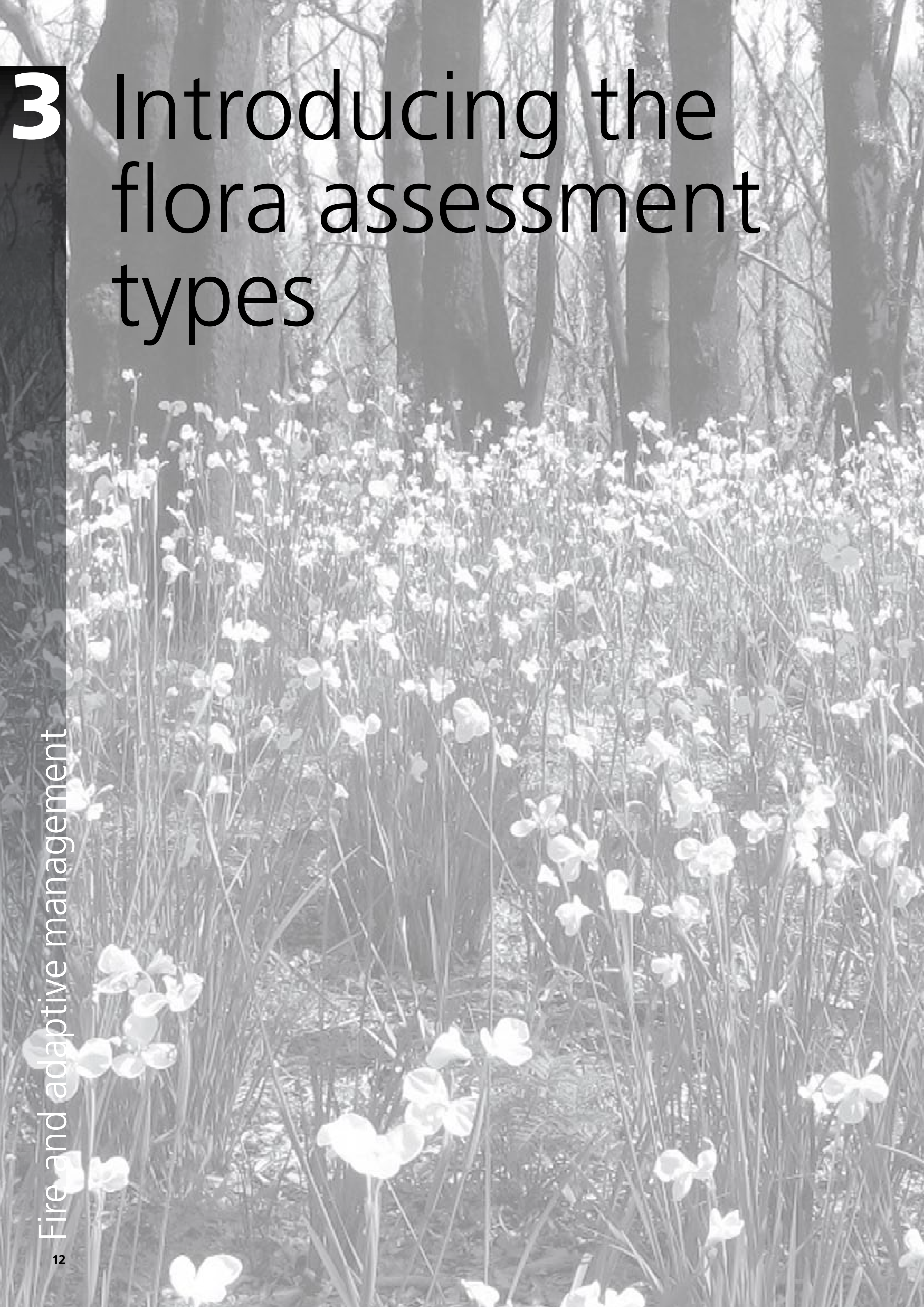
- checking and improving knowledge about flora vital attributes
- assessing the accuracy of the model's predictions for key fire response species
- assessing the effectiveness of using key fire response species as indicators for all species.

Table 2 provides more details about how the objectives may help management activities.

Table 2: Flora monitoring objectives and how they help management activities

Monitoring objective	Role in helping management activities
To obtain information on flora vital attributes for those species which lack such data.	Improve our knowledge of the vital attributes of particular flora species about fire frequency and hence refine the tolerable fire intervals for different vegetation types. Contribute to a better understanding of the effects of other factors on vital attributes, e.g. fire season, fire severity, drought or grazing.
To predict whether the vegetation in an area is likely to respond positively to burning at a particular time.	Assist with the selection of burn areas (by verifying the model's prediction about the timing of life-stages for key fire response species).
To estimate the size of change in the presence and abundance of indicator species after fire.	Assess the effectiveness of management actions in achieving their objectives at the local or landscape scale. Verify the model's predictions for key fire response species after fire. Contribute to a better understanding of the effects of other factors (e.g. fire season, fire severity, drought or grazing) on the timing of life-stages and relative dominance of the indicator species.
To determine the extent to which key fire response species can be used as indicators for all species after fire.	Test the effectiveness of using key fire response species as surrogates for all species.
To estimate the size of change in species composition after fire.	Assess the effectiveness of management actions in achieving their objectives at the landscape scale. Contribute to a better understanding of the effects of other factors (e.g. fire season, fire severity, drought or grazing) on the timing of life-stages and the relative dominance of all species.

3 Introducing the flora assessment types



3. Introducing the flora assessment types

An assessment type is the term used for a monitoring method in the *User's guide*. This section introduces the flora assessment types and describes them in terms of their spatial scale of interest, target population and timeframe, and where they fit within the monitoring triangle.

3.1 The flora assessment types

The four assessment types are:

- **vital attributes assessment** – an opportunistic assessment of the vital attributes of flora species
- **flora life-stage assessment for burn planning** – a routine assessment of the life-stage for key fire response species (KFRS) in all potential burn areas (or as many as practicable)
- **flora indicator-species assessment** – a routine assessment of density, cover and life-stage for indicator species (usually KFRS). By assessing the indicator species it should be possible to learn about the state of all species within the monitoring area
- **flora all-species assessment** – an assessment of the cover and life-stage for all vascular flora species. By assessing all species it is possible to learn directly about species composition, rather than need to infer it from indicator species.

Each assessment type is associated with a monitoring objective (Figure 6).

Objective:		Assessment type:
To obtain information on flora vital attributes for those species which lack such data.	→	Vital attributes assessment
To predict whether the vegetation in an area is likely to respond positively to burning at a particular time.	→	Life-stage assessment for burn planning
To estimate the size of change to the presence and abundance of indicator species following fire.	→	Indicator-species assessment
To determine the extent to which key fire response species can be used as indicators for all species following fire.	→	All-species assessment
To estimate the size of change in species composition in following fire.	→	All-species assessment

Figure 6: Monitoring objectives and their associated assessment types.

3.2 Spatial scale of interest, target population and timeframe

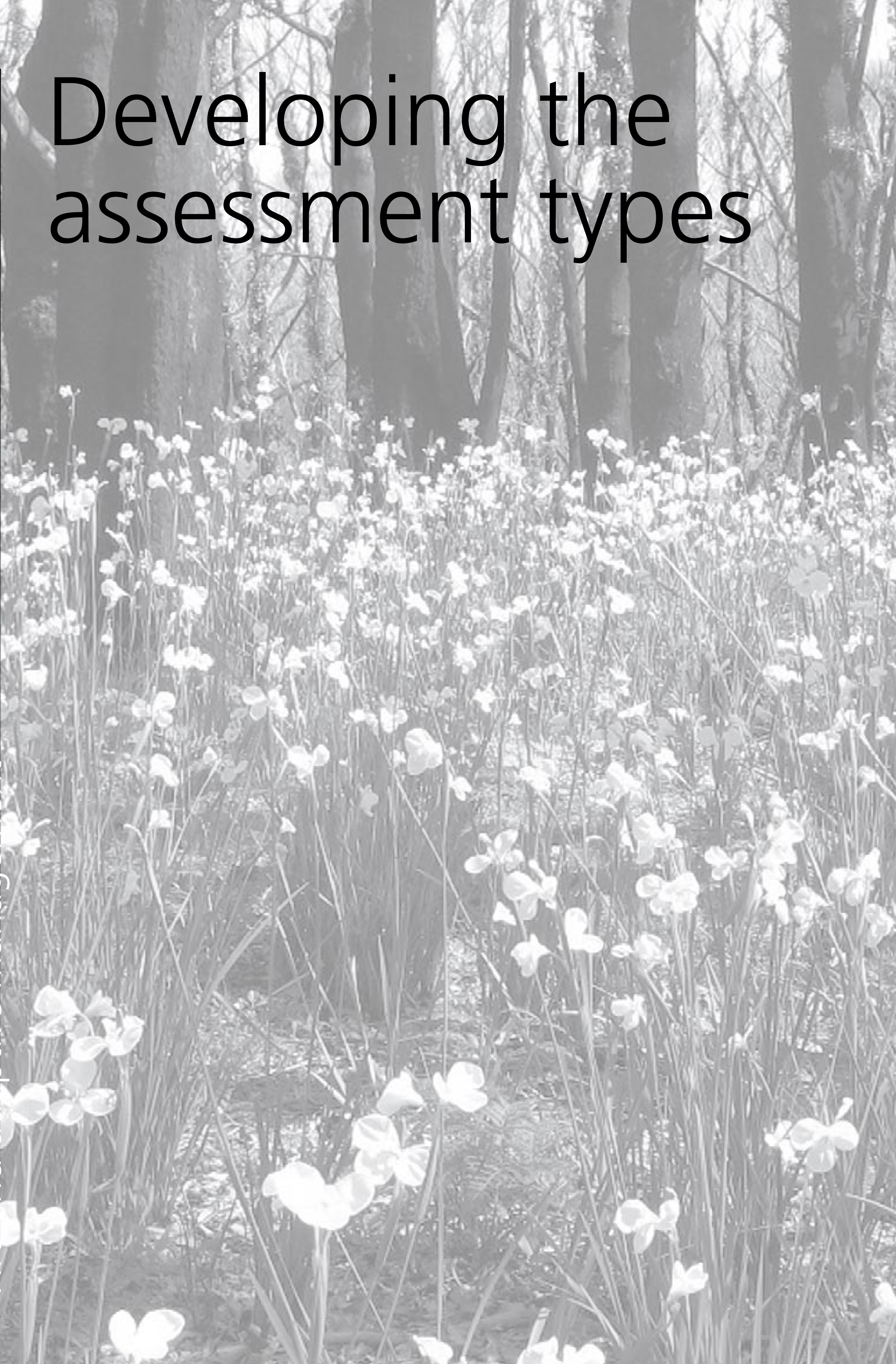
Table 3 shows how each assessment type is different with respect to the:

- **spatial scale of interest** (i.e. the scale at which data can be analysed and inferences made). This depends on the question of interest and the amount of replication in a single area. Where there are only a few plots in an area, the data need to be combined for several areas to analyse
- **target population** (i.e. the group to be examined). For the flora monitoring methods this is either the indicator species (e.g. key fire response species) or all the flora species within an area
- **timeframe** (i.e. the length of time over which monitoring should occur). Some assessment types involve monitoring an area only once, which provides a snapshot in time. Other assessments involve repeated observations over a number of years.

Table 3: Spatial scale of interest, target population and timeframe for each assessment type.

Assessment type	Spatial scale of interest	Target population	Timeframe
Vital attribute assessment	Bioregional or state-wide	All flora species	No repeated monitoring in the same location
Life-stage assessment for burn planning	Individual monitoring area (burn)	Key fire response species (KFRS)	No repeated monitoring in the same location
Indicator-species assessment	Individual monitoring area or across the broader landscape	Indicator species (usually KFRS)	Two years for detecting shorter term impacts or ten years for detecting longer term impacts
All-species assessment	Across the broader landscape	All flora species	Two years for detecting shorter term impacts or ten years for detecting longer term impacts

4 Developing the assessment types



4. Developing the assessment types

Development of the assessment types took about two years. This initially involved a brief review of existing monitoring methods (see Section 3.4), including discussions with field practitioners about the pros and cons of those methods. Field trials (in the Dandenong Ranges, Bendigo, Orbost, Bright and Gembrook areas) were undertaken over many months to develop and refine the methods in different vegetation types and with different assessors. Consultation with fire ecology practitioners and scientists played a major role throughout the development process. Their input was used to revise and improve the methods and the various drafts of the *User's guide*.

Key factors considered during the development of the assessment types were:

- practicality
- aggregation of data
- statistical validity and power
- efficiency.

Practicality is important because a monitoring method is effective only if field staff actually use it, if requirements for specialist expertise are modest, and if the integrity of the method has only limited sensitivity to variation between assessors. Aggregation of data across the landscape and over time is needed so that there is sufficient replication to analyse the data, landscape-scale questions can be addressed and the requirement for high sampling intensity at individual areas and times is reduced. Statistical validity and power means conclusions can be quantified in standard ways. Efficiency ensures that limited resources can achieve as much as possible.

This section describes the underlying rationale behind the development of each assessment type. Key decisions that had to be made for each assessment type relate to the target population, measurement variables, sampling design and data analysis. The following discussion is centred around these themes.

4.1 Flora vital attribute assessment

This is an opportunistic assessment of the vital attributes of particular flora species. The use of flora vital attributes in fire ecology planning and management is well-established in Victoria (Tolhurst and Friend 2001; Fire Ecology Working Group 2004). The methods that the User's guide describes are an adaptation of existing, unpublished methods for vital attribute assessment (Fire Ecology Working Group 2003).

4.1.1 Target population

Chosen approach:

The target population is those plant species that lack flora vital attribute data in the flora vital attributes database. For simplicity, often an assessment will include all species in an area rather than only a few key species.

The target population must occur within a monitoring area when the time since the last fire is known. If other factors (such as fire season or post-fire grazing pressure) that could influence the vital attributes within the area are also well-documented then this is a bonus.

To gain comprehensive information about a species the *User's guide* recommends that a number of assessments are undertaken for the same species to cover a range of age-classes (i.e. time since last fire). It is also recommended that a fire severity assessment is done in conjunction with the vital attribute assessment because the mode of response of some plants to fire depends on fire severity.

Rationale:

This assessment improves baseline data about flora vital attributes. In the first instance, it should target species whose vital attributes are poorly understood in relation to the time since the last burn. The best way to identify these species is by looking for gaps in the flora vital attributes database.

As described in section 3.2, vital attributes are mostly known only in relation to the time since the last burn. However, other factors may also influence the vital attributes (such as fire season, fire severity or grazing pressure). A suggested additional step is to gather information about those other factors in a monitoring area so that the model can be expanded.

4.1.2 Measurement variables

Chosen approach:

The measurement variables used for the flora vital attribute assessment are life-stage and mode of regeneration. These are considered in conjunction with the year since the area was last burnt. For life-stage, assessors estimate the percentage of individuals that are juvenile, mature and senescing. The following definitions are used:

- juvenile – a plant that is not reproductively mature
- mature – a plant that is reproductively mature and shows evidence of flowers, fruit or seed
- senescing – a plant that is senescing or dying. Include plants that are completely dead if they can be identified.

For mode of regeneration, assessors estimate the percentage of individuals that are regenerating from seed and resprouting. The following definitions are used:

- seedling – evidence that plant has grown from seed
- resprouting – evidence that plant has regenerated vegetatively.

Rationale:

These measurement variables have been chosen because they can be used to determine the flora vital attributes of a plant species. The flora vital attributes of a species consist of three parts:

1. method of persistence – the methods or mechanisms by which a plant regenerates after a fire, i.e. by resprouting, by seed or by both)
2. conditions for establishment – the environmental conditions required for a species to regenerate. For example, 'intolerant' species need fire to remove mature plants before juveniles can establish whereas 'tolerant' species easily regenerate while mature plants are present
3. timing of life-stages – the time taken for the species to reach critical life-stages, i.e. the time taken for a species to set viable amounts of seed or become vegetatively viable, or the time taken for a species to become 'locally extinct' from an area in the absence of fire.

Assessors can determine the method of persistence of a species by measuring the mode of regeneration one to two years after a fire. Conditions for establishment can also be determined by assessing the mode of regeneration in older areas rather than recently burnt areas. Species that are regenerating from seed beneath a canopy of older individuals are likely to be 'tolerant' while those that are even-aged and not regenerating beneath a canopy are likely to be 'intolerant'. The timing of the critical life-stages can be determined by assessing the life-stage in a range of different age-classes. By combining data about life-stage for several areas with different times since the last fire, the assessor can identify the likely time intervals for each life-stage.

The assessment does not include a soil-seed bank survey and therefore the persistence of species in the seed bank is not included. This means that the time to local extinction is likely to be underestimated.

Percentage measurements of each life-stage and mode of regeneration are made so that the data can show which categories are dominating an area at a particular point in time. Percentages are easier and quicker to estimate than numbers of individuals or cover of individuals (particularly when the plot is large and the boundary is only roughly defined). A rough percentage estimate adequately shows which life-stage or mode of regeneration is dominant.

4.1.3 Sampling design

Chosen approach:

Assessors select an area that is about one hectare in size, where the year since the last fire is known and consistent and where other potential influencing factors are consistent (such as fire severity or grazing pressure).

Assessors walk through the area observing and recording life-stage and mode of regeneration for each of the species. A minimum of ten individuals for each species should be observed.

Rationale:

The sampling design is very simple and not statistically rigorous. However, concepts of replication and representative sampling are encouraged. Some bias between assessors and for different life-stages could be an issue. For example, the percentage of mature, flowering plants could be over-estimated because these plants may be more visible.

Replication is achieved within an area by observing at least ten individual plants for each species. Across the landscape, replication is achieved by assessing numerous areas with a range of last burnt years.

Assessors will monitor an area that is one hectare in size to help ensure that the results are representative of a broad area. It is likely that a single species will occur numerous times in an area of this size. Future monitoring will better inform the choice of the most appropriate size.

4.2 Flora life-stage assessment for burn planning

This assessment provides a snapshot of the life-stage for key fire response species (KFRS) at a particular point in time before burning. It will enable a prediction about the likely response of the KFRS to burning at that time. This prediction can be used to inform decisions about whether or not to burn the area at that time.

Although predicting the likely response of flora to burning at a particular time since fire can be done using the flora vital attributes model, verifying those predictions in the field is important before committing to a burn schedule (Tolhurst and Friend 2001). The model may wrongly predict the time to maturity or longevity of a species in which case a species may regenerate less well than expected after the burn. Factors such as drought or a particularly severe fire may slow the rate of development from the juvenile to mature life-stage.

Although more reliable than the desktop analysis, this assessment still enables the response of flora to burning only to be predicted. This prediction is based on the underlying principles and assumptions behind the flora vital attributes model. For example, it assumes that if the KFRS are able to regenerate in sufficient numbers then other species within that vegetation type should also be able to regenerate in sufficient numbers.

4.2.1 Target populations

Chosen approach:

The target population is three or more key fire response species (KFRS) per Ecological Vegetation Class (EVC) in an area.

Rationale:

KFRS have been chosen as the target population because according to the Flora Vital Attributes Model they can be used as a surrogate for all flora species within that EVC. KFRS are used to determine the likely tolerable fire interval for an EVC based on their flora vital attributes.

In younger age-class areas, the KFRS that are used to determine the likely minimum fire interval are the most important to monitor. If the individuals of those KFRS are mostly 'juvenile' then it is likely that those species and others within the EVC will not be able to regenerate in sufficient numbers after a burn.

In older age-class areas the most important KFRS to monitor are those used to determine the likely maximum fire interval. If the individuals of those KFRS are mostly 'senescing' then it is likely that those species and others in the EVC need fire to prevent them from becoming locally extinct.

The reason that at least three species need to be monitored is to allow for errors in species selection and provide some kind of replication. Decisions about when to burn should be based on several species, not just a single species in the area.

4.2.2 Measurement variables

Chosen approach:

Assessors will estimate the percentage of individuals that are juvenile, mature and senescing within the monitoring area for each of KFRS that has been selected for monitoring. The following definitions are used for each life-stage:

- juvenile – a plant that is not reproductively mature
- mature – a plant that is reproductively mature and shows evidence of flowers, fruit or seed
- senescing – a plant that is senescing or dying. Include plants that are completely dead if they can be identified.

Rationale:

Life-stage information is collected because this information can be used to predict the likely response of flora to burning according to the flora vital attributes model. However, caution needs to be taken when interpreting these data for several reasons:

- The presence of flowers, fruit or seed does not necessarily mean that the species will regenerate adequately after the burn. Full, mature seed production often occurs some years after the first flowering season. Before this stage, there may not be enough seed for adequate regeneration.
- Regeneration is also a function of other influencing factors in the area such as drought, grazing pressure or fire severity.
- The definition of 'adequate regeneration' is a function of the management objective, which may vary over time and space.

This assessment type considers a species to be nearing extinction from an area when the majority of individuals are senescing. This measure of extinction is technically incorrect because it doesn't consider the longevity of the soil-seed bank. Soil-seed bank surveys are too difficult to include in the User's guide. Therefore the proportion of senescing individuals must suffice as an indicator of a species nearing local extinction.

Percentages of each life-stage give an indication of the percentage of individuals within a population that are capable of regenerating after fire or the percentage of individuals that are likely to disappear from an area in the absence of fire. Percentage was chosen as the measurement variable because it is easier and quicker to estimate than numbers of individuals or cover during a walk-through of the monitoring area.

The disadvantage of percentages is that they provide no indication of the overall density of a particular species. This is a problem because the threshold percentage values used to decide whether a species will regenerate adequately may vary depending on the overall density of the species in the area. For example, a species that has a high density across an area may have a high proportion of juvenile individuals, which indicates that the flora is not likely to respond positively to burning. However, due to the sheer numbers of individuals, there may actually be enough mature individuals to allow the species to regenerate adequately. Conversely a species in low numbers may appear to have a high enough percentage of mature individuals to conduct a burn, but there may not be enough mature individuals to allow the species to regenerate adequately.

4.2.3 Sampling design

Chosen approach:

The burn area will be stratified according to Ecological Vegetation Class (EVC) and year of last burn. For each stratification unit, assessors will then walk along one or more pre-determined assessment routes that include most of the likely variation (especially from terrain) in the stratification unit. The assessment routes are randomly selected from several potential assessment routes that are planned by the assessor. Along the assessment route assessors will observe the relative proportions of each life-stage for the targeted key fire response species (KFRS).

Rationale:

The sampling strategy is designed to be easy and fast to implement. This comes at the expense of being less statistically rigorous. It provides a quick snapshot of an area to give managers further information to assist the burn planning process. The sampling strategy evolved from 'ramble' methods used elsewhere and the 'walk-through' method that was originally trialled for the indicator-species assessment.

The major statistical issue with the sampling design is that there is likely to be some bias between assessors and for particular life-stages. The bias between assessors may occur because assessors subjectively estimate a percentage rather than count the number of individuals within each life-stage. If assessors work in pairs, they can discuss why particular values were estimated and thus reduce the amount of bias. The bias for particular life-stages is a function of the relative visibility of each life-stage, such as mature plants that are larger and flowering. This was described for the flora vital attributes assessment.

Some degree of randomness has been included in the selection of assessment routes, which improves the statistical validity of the method (i.e. random selection of assessment route from several potential assessment routes). Assessor bias in choosing where the assessments occur may still, however, cause some bias in the results.

4.3 Flora indicator-species assessment

The process of developing the indicator-species assessment involved numerous field trials and extensive consultation with scientists, field practitioners and a statistician.

The assessment is designed to be relatively quick and simple so that it can be done in many areas and by assessors without a botanical background (although some botanical assistance is required to select and initially identify the indicator species).

The indicator-species assessment involves repeated assessments over time. An assessment is required pre-burn and then two years post-burn and ten years post-burn. A fire severity assessment (discussed in section 5) is also required immediately post-burn.

The indicator-species assessment is a combination of two different methods that were trialled in the field early in the development of the User's guide – a qualitative walk-though method and a quantitative 'nested plots' method. The limitations of both the walk-through and nested plots methods were considered during the development of the indicator-species assessment. The best aspects of both methods have been combined while the problematic components of the methods have been largely omitted.

4.3.1 Target population

Chosen approach:

The target population for the indicator-species assessment is a selection of six indicator species for an EVC. These indicator species will usually be key fire response species (KFRS). However, they can also be other species of interest.

According to the flora vital attributes model, KFRS can be used as a surrogate for all flora species within that EVC. As discussed for the life-stage assessment for burn planning, KFRS are used to determine the likely tolerable fire interval for an EVC based on their flora vital attributes.

The User's guide provides detailed steps for selecting KFRS. These include obtaining a full species list for the area, examining the flora vital attributes for every species to prepare a potential list of KFRS and making the final decision about which KFRS are most appropriate based on an assessment of which KFRS are most common within the monitoring area. The group of KFRS chosen should represent a range of vital attributes. In general, KFRS are those species which are obligate seeders with a single germination pulse, species that require competition first be removed before the seeds can germinate and species with the shortest and longest juvenile periods.

In some circumstances species other than the KFRS will be used as indicator species. This will depend on the interests of the assessor. For example, a weed species may be chosen if the burn is designed to reduce the occurrence of this species. Rare and threatened species can also be chosen if they occur in sufficient numbers within the monitoring area.

Indicator species are selected for the pre-burn assessment in a monitoring area. Subsequent post-burn assessments will use the same indicator species so that a comparison between pre- and post-burn conditions can be made.

Rationale:

This assessment uses indicator species rather than all species as the target population so that:

- the assessment can be undertaken by an assessor with minimal botanical knowledge, as assessors are required to identify only six species for an assessment (note: a botanist is required to initially select and identify the species)
- the time taken to assess each plot is reduced, which means that more plots can be assessed.

In most situations, key fire response species can be used as indicators for all species. This assumption is based on the principle underlying the Flora Vital Attributes Model: that 'viability of the (plant) community can be defined to a large extent by the viability of the individual species (i.e. KFRS) in it' (NRE 2002).

The selection of KFRS is a critical step in the assessment and is probably the most difficult part of it. If inappropriate species are chosen, they may not be suitable surrogates for all species and consequently the assessment will not achieve its objective. Field trials have shown that while the remainder of the assessment can be completed by non-botanists, the selection of KFRS and initial identification of them in the field should be done by someone with botanical skills.

For situations where the indicator species are not KFRS, the rationale behind their selection will depend on the objectives of the burn. For burns that aim to reduce the abundance of weed species, this species may be monitored using the indicator-species assessment to measure changes in presence and abundance.

Some assessors may wish to monitor a rare or threatened species. Generally the indicator-species assessment is not an appropriate method for monitoring these species because it is not intensive enough. However, in some circumstances there may be enough individuals of the species in a particular area for it to be monitored using this assessment type.

Six species is deemed to be an adequate number of species to monitor because:

- this number is large enough to allow a range of KFRS with different vital attributes to be chosen
- this number is small enough that little time is required to monitor each plot and therefore more plots can be assessed. A higher number of plots enables more opportunities for statistical analysis of the data and provides a better indication of species density across the area
- usually at least six KFRS occur within a monitoring area
- this number gives some leeway to allow for changes to the vital attribute database over time, which may lead to some of the chosen indicator species no longer being considered KFRS
- this number of species is not too large for a non-botanist to remember at any one time.

During the field trials several issues emerged with the use of indicator species, and KFRS in particular. These issues and the steps taken to overcome them are outlined in Table 4.

Table 4: Issues raised about the use of indicator species and steps taken to overcome these issues.

Issue of concern	Steps taken to overcome this issue
The assumption that KFRS are effective surrogates for overall species composition has not been tested.	This will be addressed by the inclusion of the fourth monitoring objective: 'to determine the extent to which KFRS can be used as indicators for all species after fire.'
Information on vital attributes may be inadequate for flora species in some areas of the state.	The flora vital attributes assessment is included in the *User's guide* to help overcome this problem. Assessors can also choose to undertake an all-species assessment if the vital attributes are inadequate to choose KFRS.
There is a risk that unsuitable KFRS will be selected for monitoring and that species that are sensitive to long or short intervals between fires will be overlooked.	The *User's guide* recommends that a botanist assist with species selection. This should help ensure suitable species are chosen. Also, the all species assessment is included in the User's guide to help overcome this problem.
The detectability of some species can be much more difficult during autumn and winter. This means that if the pre-burn and post-burn assessments are undertaken at different times of year then the differences in species abundance are likely to be at least partially due to the time of year.	The *User's guide* recommends that pre-burn and post-burn plots are undertaken at the same time of year, and preferably all monitoring is undertaken in spring or summer when the plants are easiest to identify.
An inter-assessor reliability test showed that variability between assessors can be high. This appeared to be caused largely by the failure of some of the assessors to identify particular indicator species at that time.	The *User's guide* recommends that a field botanist assist with the initial identification of species, training in species identification is thorough and assessors carry plant samples as a reference.
During field trials EVC maps often showed EVC boundaries incorrectly. This became a problem for the indicator-species assessments because non-botanist field assessors found it difficult to distinguish between two similar EVCs.	The *User's guide* recommends that each plot is located at least 200 metres from a mapped EVC boundary.
There is a lack of information on longevity of soil seed banks, which has implications for the definition of recommended inter-fire periods. For example, a species may disappear from an area and then theoretically the area is ready for a burn, but in fact the species may survive for several decades as soil-stored seed.	Further research is needed in this area.
There is some risk that it may be difficult to make comparisons between areas or pool data across a bioregion for an EVC. This is because different indicator species are often chosen for the same EVC due to variability in species composition across the landscape.	This problem has not been properly explored or overcome.

4.3.2 Measurement variables

Chosen approach:

There are four measurement variables for the indicator-species assessment: frequency of occurrence, density, cover and life-stage.

Frequency of occurrence is collected by default as it is based on presence-absence of the species in each plot.

Density is collected by counting all individuals when there are less than 20 individuals in the plot. When there are more than 20 individuals density is estimated by counting the number of individuals in a small, representative part of the plot and then scaling this number up to work out the density for the whole plot. Rules for density estimation are provided in Table 5.

Table 5: Rules for density estimation

Density range	Estimation procedure
0 to 20	Count Individuals
21 to 50	Estimate to the nearest 5
50 to 100	Estimate to the nearest 10
100 to 300	Estimate to the nearest 20
300 to 1000	Estimate to the nearest 50
Over 1000	Estimate to the nearest 100

Cover is estimated using the following cover classes:

- 0 = cover 0%, species absent
- + = cover < 5%, few individuals
- 1 = cover < 5%, more than a few individuals
- 2 = cover 5-20%, any number of individuals
- 3 = cover 20-50%, any number of individuals
- 4 = cover 50-75%, any number of individuals
- 5 = 75-100%, any number of individuals.

The dominant life-stage is recorded for each indicator species. Dominant is defined as the life-stage of the greatest number of individuals. If two life-stages are equally dominant then they should both be recorded. The following life-stage categories are used:

- juvenile – a plant that is not reproductively mature
- mature – a plant that is reproductively mature and shows evidence of flowers, fruit or seed
- senescing – a plant that is senescing or dying. Include plants that are completely dead if they can be identified
- unknown – unable to determine life-stage because there is no evidence of flowers, fruit or seed or for some other reason.

Rationale:
A number of factors had to be considered when choosing these measurement variables. Some advantages and disadvantages for frequency of occurrence, density and cover measures are described in Table 6.

Table 6: Advantages and disadvantages for potential measures for the indicator-species assessment (adapted from Elizinga *et al*. 2001)

Measure	Description	Advantages	Disadvantages
Frequency	Percentage of possible plots within a target area that contain a target species.	Appropriate for any growth form. Longer window for sampling. Reduced assessor error or bias. Quick measure at each plot.	Dependent on plot size and shape – for comparisons over time all plots must be the same size. Affected by both spatial distribution and density of species and therefore changes can be difficult to interpret.
Density	Number of individuals per unit area.	Most effective when the change expected is recruitment or loss of individuals. Less dependent on plot size or shape.	Not suitable for plants that fluctuate dramatically in population size from year to year. Estimation or counting is error prone when plots contain numerous plants.
Cover	Percentage of the sample area covered by the vertical projection of foliage.	Most sensitive to changes that are related to plant vigour. Does not require the identification of individuals and therefore well suited to rhizomous species such as grasses.	Short window for sampling because cover often fluctuates with the growing season.

After considering the points in Table 6, the project team decided to use all three variables. Frequency was chosen by default because if any of the other variables are collected then frequency is automatically collected too. Despite being a default measure, it may become the most useful measure because it is less subject to bias between different assessors.

Density was chosen because it provides more information than frequency and relates more directly to recruitment or loss of individuals rather than to cover.

However, there are also disadvantages with density. A major disadvantage is that it is not suitable for particular life forms such as multi-stemmed and clumped plants. This is one reason why cover has also been selected as a measurement variable. Another issue with using density is the time required to count the individuals. Counting was trialled in some early field trials and it was found to take significantly longer than estimation. This was overcome by recommending that the assessors estimate rather than count the number of individuals when there are more than 20 individuals.

For estimating the number of individuals we tested descriptive classes, numeric classes and actual numbers during the field trials. Table 7 summarises the various estimation methods that were trialled. The descriptive classes were too ambiguous and caused bias between assessors, even after the definitions were refined. The numeric classes were effective because they were relatively quick and simple to use, did not suggest a higher level of accuracy than actually existed and reflected the lesser importance of exact numbers at higher densities. However, these classes were deemed much more difficult to analyse than actual numbers and resulted in substantial underestimation during the field trials. As a result of these disadvantages, it was decided that estimates of actual numbers would be made using the estimation rules described in Table 5.

Table 7: A record of the density classes that were trialled.

Descriptive classes (modified from Tolhurst and Oswin 1992)	**Numeric classes 1**	**Numeric classes 2**
Always: individuals of the species are always seen. Usually: individuals of the species are usually seen. Occasionally: individuals of the species are occasionally seen. Rarely: individuals of the species are rarely seen. Never: individuals of the species are never seen.	0, 1-3, 4-10, 11-30, 31-60, 61-100, 101-200, 201-500, >500	0, 1-5, 6-25, 26-125, 126-625, >625

A further issue that emerged with density is the lack of consistency between assessors in their estimations. This was found during an inter-assessor reliability test using numeric density classes across different assessors. To minimise this inconsistency the *User's guide* recommends that assessors 'count the number of individuals in a small, representative part of the plot and then scale this number up to work out the density for the whole plot'. Thorough training and working in pairs is also recommended to reduce variability between assessors.

As outlined above, cover is included as a measurement variable so that species which are multi-stemmed or clumped can also be included in the indicator-species assessment. It is also included so that results from the indicator-species assessments can be more easily compared with the results from all-species assessments.

The biggest concern with including cover in the indicator-species assessment was the extra time that it would involve at each plot. However, it was found that this extra time is minimal and worthwhile.

A modified version of the standard Braun-Blanquet cover estimation classes were chosen because they:
- are often used to measure flora, which means assessors are more likely to be familiar with them
- place a greater emphasis on precision when cover is low, which is important because changes in cover are most significant when the species is uncommon
- are compatible with existing data in the Flora Information System (FIS).

The other measurement variable used for the indicator-species assessment is the dominant life-stage. This information is collected to check predictions made by the flora vital attributes model about the timing of critical life-stages. It is hoped that this data can also be used to better understand the effects of factors such as drought, fire severity, fire season and grazing on the timing of critical life-stages.

Two issues have arisen about assessing life-stage during the trials. Firstly, assessors who do not have a botanical background often find it difficult to determine life-stage. Secondly, all assessors (botanists and non-botanists) find it difficult to assess the life-stage of some species in autumn and winter. As a consequence of these issues we recommend that assessments be undertaken in spring and summer when species are flowering and therefore when life-stage is easier to determine. Also, an additional life-stage category - 'unknown' - was added so that assessors are not forced to record a life-stage when they are not sure.

4.3.3 Sampling design

Selected approach:

The sampling design consists of:
- monitoring areas that are stratified by Ecological Vegetation Class (EVC), the year since the area was last burnt and any other factor of interest. An assessment should be undertaken in each stratification unit
- a pre-determined route along which assessors regularly space the plots. Assessment routes are selected randomly from several potential assessment routes that are identified by the assessor. The assessment route should cover obvious sources of variation such as different aspects
- circular plots with a 2.5 metre radius. The perimeter of the plot should not be permanently marked but a stick (or rope) that is 2.5 metres long should be used to identify the boundary during the assessment. The coordinates for the centre of the plot are recorded using a GPS
- an approximate distance between plots of 50 metres. Plots may need to be further apart if the area is large or may need to be closer together if the area is small. Distance between plots must be consistent along an assessment route
- a minimum of 20 plots per stratification unit. However, more plots may be required if the vegetation is sparse, the area is large, species are frequently absent from the plots, the distribution of species is highly variable or statistical analysis is desired for the individual area
- assessing the same plots after the burn.

Rationale:
In any sampling design a trade-off must be made between the precision of the measurements and the randomness of the sample. To meet the basic statistical assumption of 'randomness', plots must be located randomly. However, if the sampling is to be representative of the variation within an area, then pure random sampling can be very resource intensive.

It became evident early in the field trials that the resource requirements to implement a state-wide monitoring program that produces data that are representative of the variation across the landscape and at the same time uses pure random sampling would be prohibitive. As a result, some randomness in the sampling design was sacrificed to increase the representativeness of the samples.

Firstly, the User's guide specifies that monitoring areas should be stratified into sub-areas with uniform EVCs, years since last fire and other factors of interest. Individual assessments should occur in each sub-area. This stratification is done to reduce the amount of variation in assessment, making it easier to identify smaller changes. Also the selection of indicator species is EVC dependent.

Then, within a sub-area plots are located along a pre-determined assessment route. These assessment routes are designed to cover the likely variation (especially any variation caused by terrain) within a sub-area. This approach means that sampling can be representative of the variation within a sub-area with fewer plots than would be required to achieve the same degree of representativeness if sampling was purely random or purely systematic.

These measures enable representative sampling to be achieved with fewer plots. The assumption of randomness is still largely met by the assessment routes being randomly selected from several potential assessment routes, the first plots along an assessment route being randomly located and subsequent plots being evenly spaced.

The use of an assessment route was first trialled in the walk-through method. The walk-through method involved walking through the monitoring area along a predetermined route and estimating the abundance, life-stage and mode of regeneration of key fire response species (KFRS) using descriptive categories. Although the 'walk-through' method was quick to carry out, it had some major drawbacks. These included inconsistency between assessors in their estimation of abundance, bias for different flora species (a tendency to overestimate prominent species and overlook smaller species) and different fields of view for different stages and types of vegetation (assessors were able to see much further in less dense vegetation and were thus assessing a larger area).

To overcome some of these drawbacks the indicator-species assessment uses plots along a walk-through path. Assessors can focus on estimating the abundance of a species within a defined area and this makes the data from different assessors more comparable.

The coordinates of each plot are recorded so the plots can be found post-burn and the assessments at a given site can be paired to increase the statistical power during analysis. Physical marking of plots is not required because this is expensive and time-consuming. The time spent in setting up star pickets (and finding them again later) would be better spent in monitoring more plots. Although plots will not occur in exactly the same location pre-burn and post-burn, the locations should be quite close using a GPS, and from a statistical point of view can be regarded as paired. Any variation in the data caused by differences in plot locations for paired plots should be compensated for by having a larger number of plots.

A single plot size was chosen regardless of the species or EVC to make the method simpler and allow data to be pooled across the landscape. Determination of the appropriate plot size involved trialling a series of nested plots in several different EVCs (see Figure 6) and then considering the advantages and disadvantages of the different sizes. The nested plots method involved counting or estimating the numbers of individuals for each KFRS in nested plots along transects. The plot sizes for nested plots were 2.5 metres x 2.5 metres, 5 metres x 5 metres and 10 metres x 10 metres. Figure 7 shows how the nested plots were arranged at each plot point.

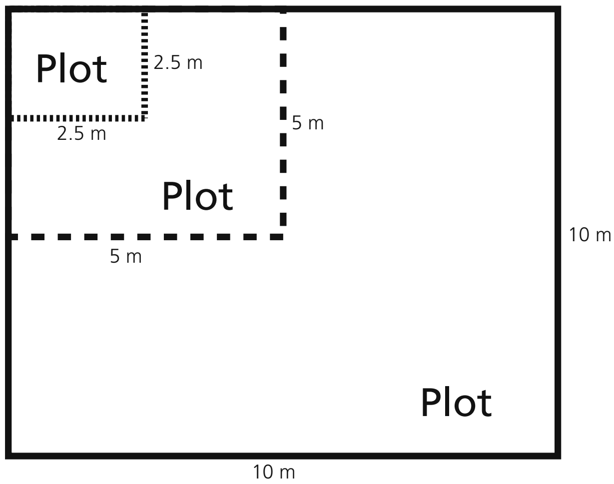


Figure 7: Nested plot layout for early flora monitoring field trials.

Larger plots (10 metres x 10 metres) usually yield more information than smaller plots (2.5 metres x 2.5 metres). However, the time needed to assess a larger plot is greater (eg five minutes for a small plot versus 20 minutes for a large plot in the Dandenong Ranges). Larger plots can also lead to poorer quality information because within them assessors often have more difficulty finding a species, reliably counting it or estimating its density. We chose an intermediate plot size to offer a balance between the detectability of several different species across different EVCs and the time required at each plot. The plot size chosen for the indicator-species method is 2.5 metre radius (19.625 metres2) making it similar in size to the intermediate square plot used during the early trials (5 metres x 5 metres).

Despite using square plots during the nested plots trials, circular plots were eventually chosen because they are easier to assess when the plot size is small. A further advantage is that they have a smaller perimeter for a given area, which leads to fewer decisions about whether or not a plant should be included.

The most difficult sampling design decision was about the number of plots. Initially statistical advice was for a very large number of plots (more than 200 plots and in some cases up to 1000 plots per monitoring area!). However, the use of temporally paired plots (pre-burn and post-burn) and the pooling of data across the landscape mean that fewer plots are sufficient for statistical purposes. The recommendation of 20 plots per EVC per monitoring area assumes the burn is relatively small (50 – 100 hectares). The *User's guide* highlights a number of scenarios when more plots will be required, such as when a species is frequently absent from plots or the species is patchy in distribution across the monitoring area. Exactly how many more plots is difficult to determine. An additional 20 is recommended simply because it seems operationally achievable and gives a definite answer. The actual number would vary according to particular circumstances.

4.4 Flora all-species assessment

The all-species assessment developed as a result of numerous field trials and extensive consultation with scientists, field practitioners and a statistician.

This assessment is designed to target high profile areas, Ecological Vegetation Classes (EVCs) of management concern or EVCs with poor fire response information. The method is more time consuming on a plot-by-plot basis than the indicator-species assessment and requires assessors who can identify plants.

The all-species assessment involves repeated assessments over time. An assessment is required pre-burn, two years post-burn and ten years post-burn. A fire severity assessment (see section 5.1) is also required immediately post-burn.

The nested plots method discussed for the indicator-species assessment also formed the basis of developing the all-species assessment. However, in the event the resulting methodology is quite different because the objectives for the all-species assessment are different.

4.4.1 Target populations

Chosen approach:
The target population is all the vascular flora species within an EVC.

Rationale:
After some field trials and consultation with various people, we decided to include an assessment that recorded information about all flora species rather than just the indicator species. There are three reasons for this:

1. There needs to be some testing of the assumption that KFRS can be used as indicators for all species. This is a major assumption underlying the flora vital attributes model and it is largely untested. This assumption can be tested by monitoring all species and comparing the changes that occur for the KFRS with the changes that occur for all the species.
2. Species composition data allows unexpected changes to be identified that may not be apparent when only indicator species are assessed.
3. Species composition data are better for investigating other factors of interest (such as fire severity, fire season or grazing) because the KFRS derived from the flora vital attributes model may not be good indicators of the effects caused by these other factors. Over time as more data are collected it may be possible to incorporate these other factors into the flora vital attributes model.

The main disadvantage of assessing all species is that there are relatively few people within DSE and Parks Victoria who have the skills to identify all species. As a consequence, this type of assessment will probably involve the engagement of external botanists to work with DSE and Parks Victoria staff.

4.4.2 Measurement variables

Chosen approach:
The primary measurement variable for the all-species assessment is cover. Foliage cover for each species is estimated using the same classes as those used for the indicator-species assessment:

- 0 = cover 0%, species absent
- + = cover < 5%, few individuals
- 1 = cover < 5%, more than a few individuals
- 2 = cover 5-20%, any number of individuals
- 3 = cover 20-50%, any number of individuals
- 4 = cover 50-75%, any number of individuals
- 5 = 75-100%, any number of individuals.

The dominant life-stage is also recorded using the same categories as those used in the indicator-species assessment:

- juvenile – a plant that is not reproductively mature
- mature – plant that is reproductively mature and shows evidence of flowers, fruit or seed
- senescing – a plant that is senescing or dying. Include plants that are completely dead if they can be identified
- unknown – unable to determine life-stage because there is no evidence of flowers, fruit or seed or for some other reason.

Rationale:
Cover is the only measure used for this assessment because it is difficult and time-consuming to accurately count or estimate numbers of individuals in large plots. Also, species that are clumping or multi-stemmed cannot be counted.

A potential issue with measuring only cover is that cover is more sensitive to changes in plant vigour than other measures such as density. If the cover of a species decreases following a fire then it may appear that the species has decreased in abundance when in fact the dominant life stage has simply changed from large, mature plants to smaller juvenile plants. When comparing assessments of cover before and after a burn, you should wait until the vegetation age or the dominant life stages of the species should be the same. Until that stage is reached after the burn, cover may seem to have decreased, but the reason may simply be that a younger plant covers less area.

A major disadvantage of using classes rather than percentage values is that the data analysis will be more difficult. However, the decision was made to use classes because cover is often measured in this way and percentage values can be highly variable between assessors. The rationale for selecting the modified Braun-Blanquet cover classes is the same as that described for the indicator-species assessment (i.e. commonly used for flora surveys, finer resolution at lower end of scale).

As described for the indicator-species assessment, the information about life-stages for each species is collected to check predictions made by the flora vital attributes model about the timing of critical life-stages and provide information to better understand the effects of factors such as drought, fire severity, fire season and grazing on the timing of these life-stages.

4.4.3 Sampling design

Chosen approach:

The sampling design consists of:

- monitoring areas, stratified by EVC, the year since the area was last burnt and any other factor of interest. An assessment should be undertaken in each stratification unit
- square plots that are 20 metres x 20 metres
- a minimum of three plots per stratification unit
- a number of criteria for selecting potential plot locations including: easy access; far enough from roads to avoid edge-effects; representative of EVC; 200 metres from EVC boundary; substantial distance apart within the burn; and likely to be burnt during planned burn
- random selection of plot locations from a short-list of 10-20 potential plot locations
- plots are permanently marked using a star picket in the north-west corner
- visiting the same plots after the burn.

Rationale:

As discussed for the indicator-species assessment, in any sampling design a trade-off must be made between the precision of the measurements and the randomness of the sample. The sampling design for this assessment sacrifices some randomness to increase the representativeness of the samples and therefore reduce the number of plots that need to be assessed.

Representativeness is achieved by stratification of the monitoring area into sub-areas with uniform EVCs, years since last fire and other factors of interest. Individual assessments should occur in each sub-area. This stratification is done to reduce the amount of variation in an assessment, making it more likely that a change will be detected. Then, within a sub-area potential plot locations are identified using a list of criteria.

To maintain some randomness, the plot locations are randomly selected from the shortlist of potential plot locations.

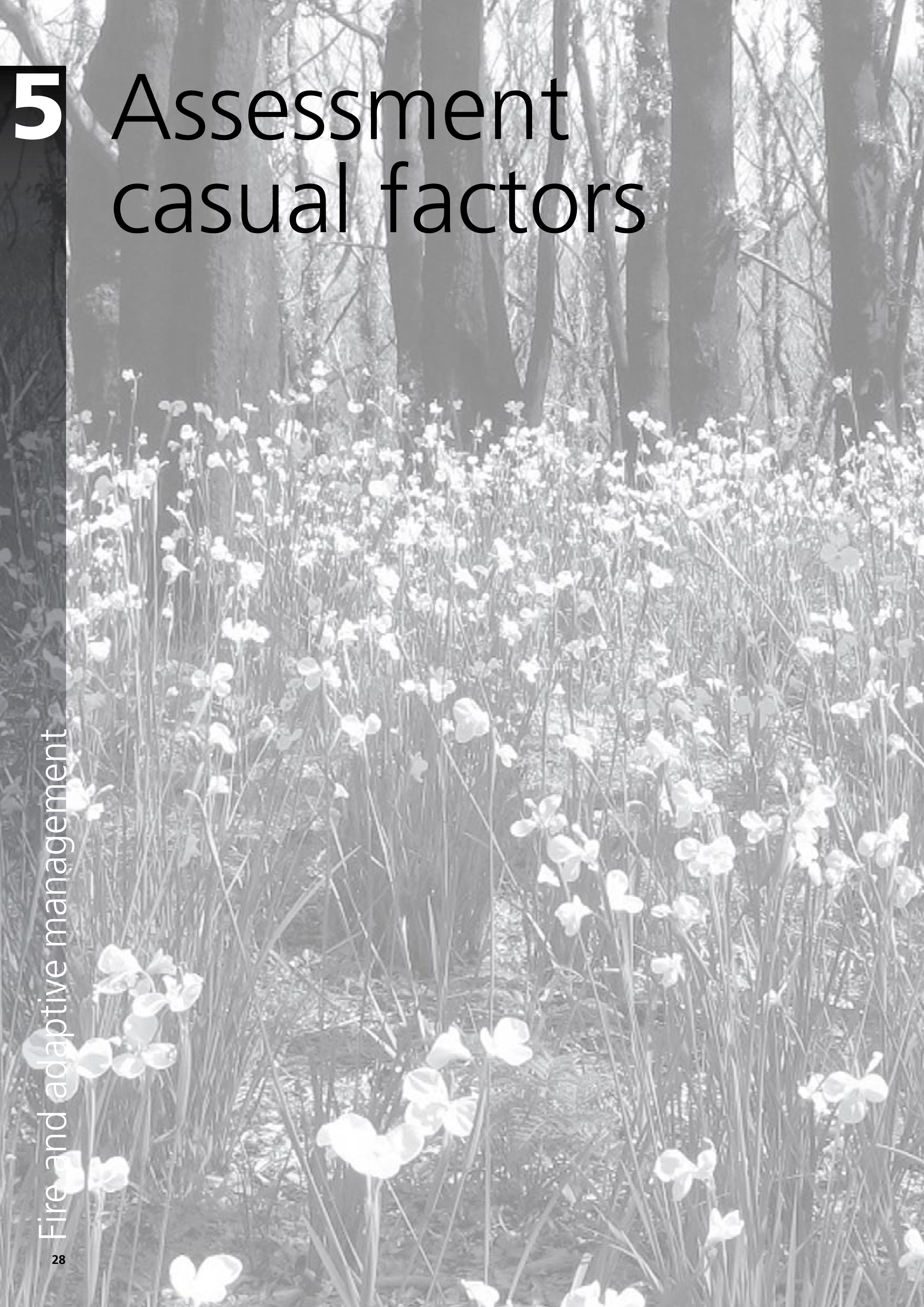
A 20 m x 20 m plot is used because this size appears to be large enough to detect the majority of species within the general vicinity. Smaller plots were trialled but they often missed the larger species which are spaced further apart (e.g. Eucalyptus species) and since there will be only a few plots across the monitoring area it is important that these species are included. Plots larger than 20 metres x 20 metres would probably detect more species but the time taken to assess each plot would increase and the accuracy of the assessment would diminish.

The plots are square because botanists are accustomed to square plots and determining the boundary of large circular plots is difficult.

A much smaller number of plots is recommended per stratification unit for the all-species assessment compared with the indicator-species assessment. This is because the all-species assessment data are pooled across the landscape for analysis. The time needed to assess many plots in a single area would reduce the number of plots that can be assessed in other areas and this would diminish the landscape-scale perspective. Unless there is a specific need for better data in a particular stratification unit then any further available effort should be applied to carrying out assessments in other areas where data is needed.

Plot boundaries are marked with star pickets because there are fewer plots within an area and the cost of marking plots is lower relative to the time needed to assess a plot.

5 Assessment casual factors



5. Assessing causal factors

Land managers are interested not only in how much change occurred to the flora but also in the cause of that change. As mentioned in section 3.2 the flora vital attributes model currently looks at change only in relation to the number of years since the last fire. However, there are many other factors that may cause change. These factors include fire severity, fire season, grazing and drought.

For much of the time that the flora monitoring methods were being developed and trialled these other potential causal factors were omitted from the design of the methods. This occurred for two reasons:

1. The list of potential causal factors is large, the actual factor of interest is very site-specific and a different method is often required to assess each causal factor. This would make the development of a generic, state-wide monitoring protocol impossible.
2. It is difficult to establish a cause and effect relationship from monitoring data when there are no control plots. Association is not the same as causation.

However, in the first major implementation phase it became apparent that to make the monitoring relevant to local areas, make sense of the data and extend the flora vital attributes model, some data on causal factors other than year of last fire needed to be collected.

Consequently, some late changes were made to the *User's guide* to include causal factors. These changes included more detail about stratifying a monitoring area in relation to potential causal factors in addition to vegetation type and the year since the area was last burnt. Additional comments sections were also added on the datasheets for the assessors to record details about any potential causal factors.

Those additional comments sections may be adequate for a number of potential causal factors. However, others may need to be assessed in more detail and even at separate times. With the exception of fire severity, the User's guide does not provide guidance about undertaking these separate assessments. A fire severity assessment has been included in the guide because it is considered essential for the indicator-species and all-species assessments. Without assessing severity after the burn there is no way of reliably knowing whether the burn actually even burnt a plot and to what extent. The rationale behind the development of the fire severity assessment is briefly described below.

5.1 Fire severity assessment

This section provides a very brief description of the rationale behind the development of the fire severity assessment. More details are to be provided in a future document developed specifically for fire severity.

Fire severity has numerous definitions; here it is interpreted as the amount of change caused to the vegetation immediately after the burn (i.e. the extent of burnt, scorched and unburnt areas).

This assessment was developed in conjunction with remote sensing specialists to help ensure that the data collected are compatible with the maps of fire severity and that the data can be used to help validate those maps.

Fire severity should be assessed in all areas where an indicator-species assessment or an all-species assessment has been undertaken. This assessment is important even when there are remotely sensed severity maps because those maps may be too low in resolution, too inaccurate or contain insufficient detail about fire severity beneath a forest canopy.

5.1.1 Target population

Chosen approach:
The target population for this assessment is the fine fuel component of all the vegetation within a monitoring area. The three layers of vegetation that are assessed are the:

- tree canopy layer
- heath or shrub layer
- leaf litter or grass layer.

The tree canopy is assessed as a separate vegetation category only when the canopy height is greater than four metres. If the canopy is less than four metres in height it will be assessed as a part of the shrub layer.

The 'fine fuel component' of the vegetation is everything less than six millimetres in thickness for dead fuels and two millimetres in thickness for live fuels (Tolhurst and Cheney 1999), e.g. grasses, leaves, pine needles and fine twigs that ignite readily and which fire consumes readily when they are dry.

Rationale:
Given that fire severity is a measure of vegetation consumption, it makes sense that the target population for this assessment is all the vegetation in a monitoring area.

The vegetation has been divided in three strata for the assessment (rather than simply assessing total biomass change) because the extent of the fire in each of these layers is thought to be important from an ecological and fuel hazard perspective and more can probably be concluded about the fire behaviour and intensity if this information is known. From an ecological perspective, the regeneration of vegetation after the fire will be different depending on which components of the vegetation were impacted. For example, 'intolerant' species (i.e. those that cannot regenerate beneath a canopy) may not regenerate after a fire if the tree canopy was not impacted by the fire.

The four metre threshold for the canopy layer is used because where canopies are lower than this the canopy and understorey layer will typically (though not necessarily) all burn together.

The assessment is restricted to fine fuels because these are the fuels that are burnt in the flaming front of the fire and therefore an assessment of these fuels provides some indication of fire intensity. Also, it is much more difficult to assess the amount of coarse fuels that have been burnt.

5.1.2 Measurement variables

Chosen approach:
The following information is collected at each plot during an assessment:

- for the litter and grass layer, an estimate of the percentage of the total area that is unburnt
- for the heath and shrub layer, an estimate of the percentage of the total area that is covered (i.e. this is the degree to which the heath and shrub layer shades or covers the ground)
- for the tree canopy layer, an estimate of the percentage of the total area that is covered (i.e. this is the degree to which the tree canopy layer shades or covers the ground)
- for the heath and shrub layer, a percentage estimate of the amount of the vegetation that is burnt, scorched and unburnt
- for the tree canopy layer, a percentage estimate of the amount of the vegetation that is burnt, scorched and unburnt.

Rationale:
The percentage of cover measurements for the heath/shrub layer and tree canopy have been included in the assessment to assist with the interpretation of the data for remote sensing. The density of these layers will influence the degree to which the understorey can be seen in a remotely sensed image. Where the canopy cover is high, the understorey will not be visible in a remotely sensed image. Where the cover for the heath/shrub layer is high, the litter/grass layer will not be visible unless the heath/shrub layer is completely burnt.

Severity is assessed using percentage estimates of scorched, burnt and unburnt vegetation because this is more flexible than grouping the various severities into classes. The most appropriate severity classes for different purposes (such as understanding the impacts on ecology, fuel hazards or soils) are not currently known and may be different depending on the purpose. In the future these percentage estimates can be grouped into the desired severity classes.

5.1.3 Sampling design

Chosen approach:

This assessment involves revisiting existing indicator-species and all-species plots. For the indicator-species plots the fire severity should be assessed in a ten metre radius from the plot point. For the all-species assessment the severity should be assessed within the same 20 metre by 20 metre plot.

Rationale:

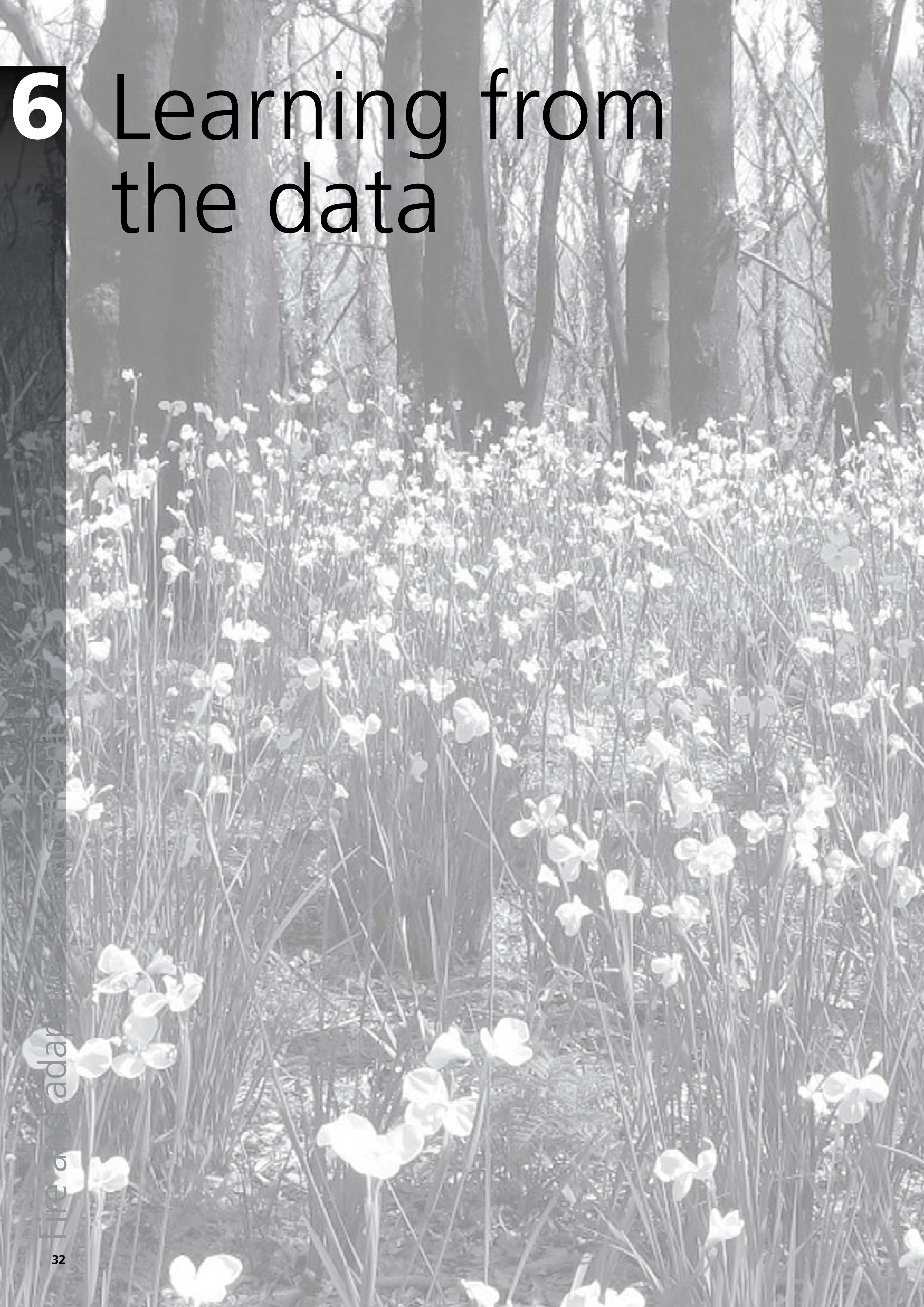
The ten metre radius plot was chosen for the indicator-species assessment because:

It is the same size as the plots presently used for validating the remotely sensed severity maps and therefore the data have the dual purpose of validating the remote sensing imagery as well as providing information for the flora monitoring.

A larger plot (more than 2.5 metre radius) is important to allow for variations in GPS accuracy. The flora indicator-species plot is very likely to fall within this area, even if the GPS accuracy is less than ideal.

Since the all-species plots are permanently marked with a star picket, their boundaries are easier to relocate. Therefore, we decided that the severity assessment should occur within the same plot boundary.

6 Learning from the data



6. Learning from the data

Often a downfall of monitoring programs is that the data are never used. This is a problem because the entire exercise of monitoring becomes a waste of time and the learn and review steps in the adaptive management cycle are never achieved. Furthermore, without a clear end use for the data, getting people to undertake and continue monitoring is much more difficult.

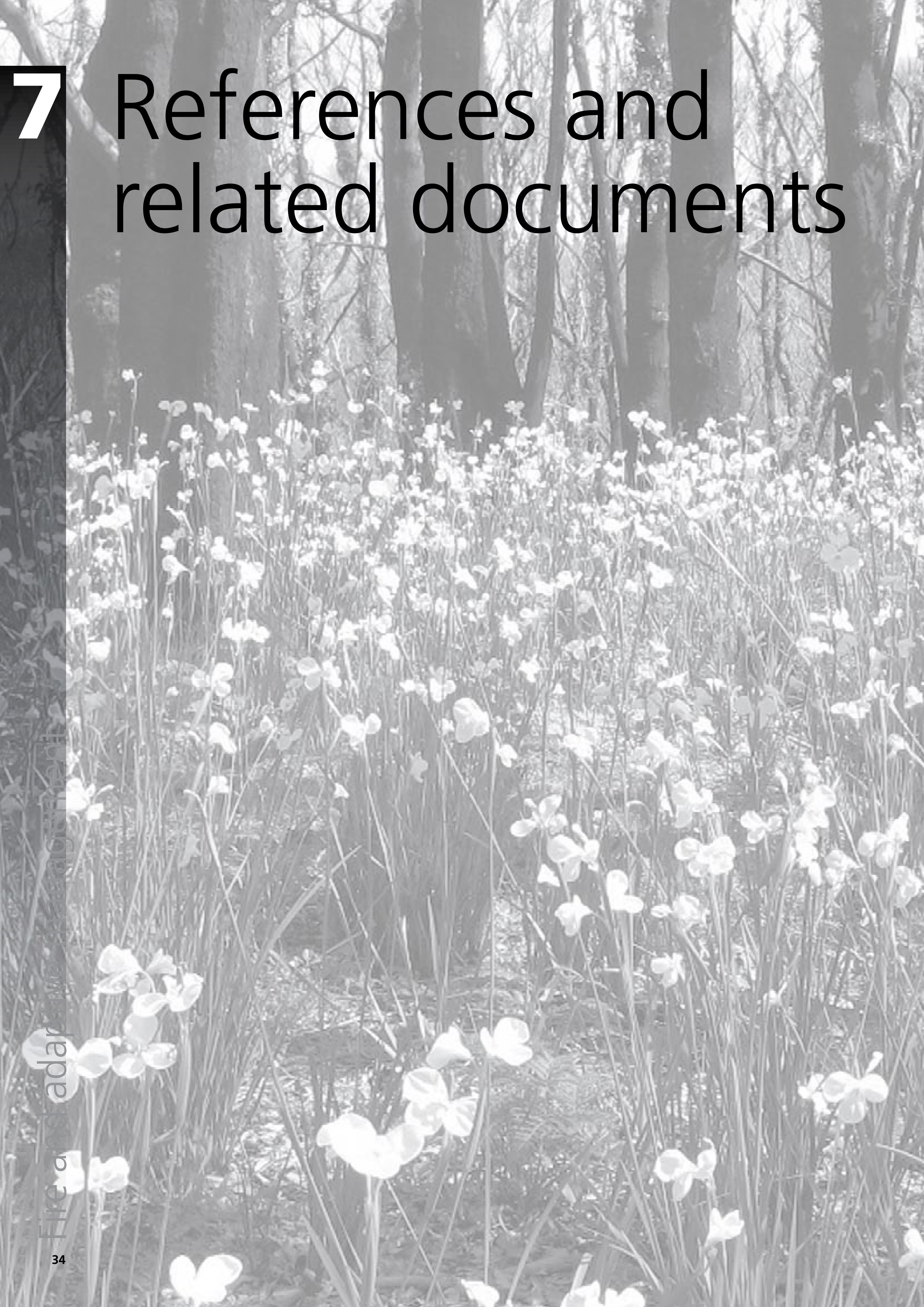
The reasons that the data are not used are probably many, including:
- the data collected do not meet the needs of management
- lack of skills
- lack of time.

We spent a lot of time considering whether or not a particular measurement is entirely relevant to the objective of that particular assessment type. Only data that have a clear and relevant use is collected. Extraneous information is not used and it would be collected at the expense of more plots.

In relation to skills and time, the *User's guide* provides some simple guidance about how to use the data, which should help people to get started. However, more detailed analysis will also be required and this will need to be done by a statistician.

The data analysis methods explained in the *User's guide* are designed to be:
- relatively simple
- best-suited to smaller datasets (i.e. data from one or a few monitoring areas)
- possible to do in Microsoft Excel (rather than statistical software).

Key philosophies the *User's guide* emphasises on data analysis:
- **ecological significance** – for statistically significant changes, the assessor needs to consider whether or not the change is ecologically significant (i.e. does this amount of change matter from an ecological perspective?)
- **association is not the same as causation** – the data may show that two variables are strongly associated but this does not necessarily mean that one of these variables is causing the other to behave in that way. This is because 'confounding variables' not obvious in the data may be influencing the situation.



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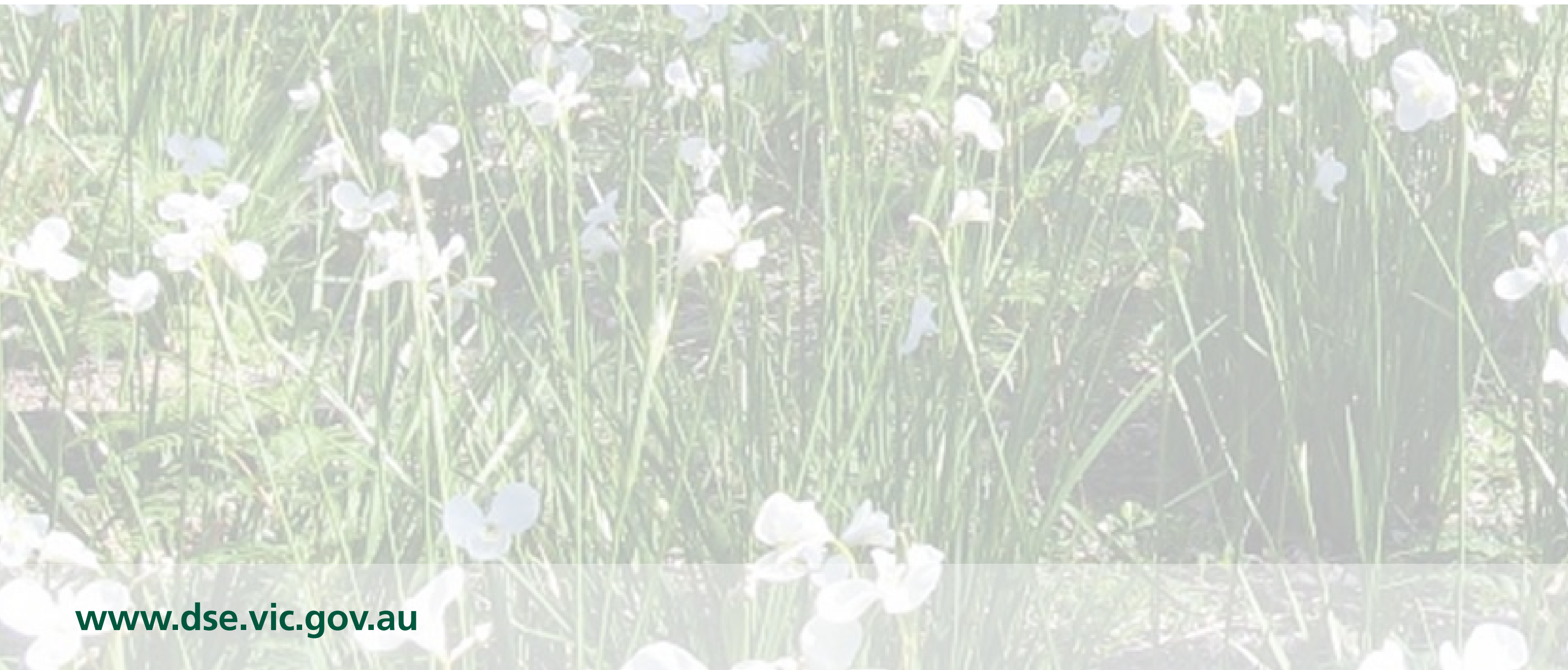
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