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RCM Project

Designing a Monitoring Program for Significant Native Flora

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Prepared for:

Resource Condition Monitoring Project – Significant Native Species and Ecological Communities

Version 1.0 (January 2010)

Revision History Log

Version #	Revision Date	Author	Changes

Acknowledgments

This guide was written using advice contained in "Monitoring Plant and Animal Populations" (Elzinga *et al*. 2001) and "A Technical Manual for Vegetation Monitoring" (Barker, 2001) The authors would like to acknowledge the contributions of the following reviewers in improving the content of this document: Ken Atkins and Melanie Smith from DEC Species and Communities Branch, Leonie Monks from DEC Science Division for input on monitoring of translocations, Ryan Vogwill from DEC Natural Resources Branch for advice on hydrological monitoring, and Michael Craig from Murdoch University and UWA.

Suggested Citation

This document may be cited as:

Harding, C. and Williams, M. (2010). Designing a Monitoring Project for Significant Native Flora. Version Number 1.0 (January 2010). Prepared for Resource Condition Monitoring project: Significant Native Species and Ecological Communities. Department of Environment and Conservation.

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1 Background

Monitoring is often complex, and requires more preparation, consideration and commitment of long term funding than it is regularly afforded. Flora monitoring can include one of several types of monitoring; population monitoring, demographic monitoring and experimental monitoring (experimental monitoring can apply to both population and demographic monitoring), each of which are described later in this document. The best monitoring however, is that which is linked to clear management action; population monitoring is often undertaken when it is not known how to reverse a population trend, if one is detected, resulting in monitoring of very little value. There are many requirements for developing a successful monitoring program, and these are discussed in this document.

Barker (2001, page 1) states "Monitoring projects typically take many years to complete because they need to observe responses or changes over a number of seasons. Most government conservation agencies have a rapid turnover of project staff and many long-term monitoring projects are never finished because incoming staff have different work priorities and/or are not fully aware of the design and methods of the project. Developing rigorous and standardised monitoring projects will allow incoming staff to complete the monitoring and management commitments made by earlier staff."

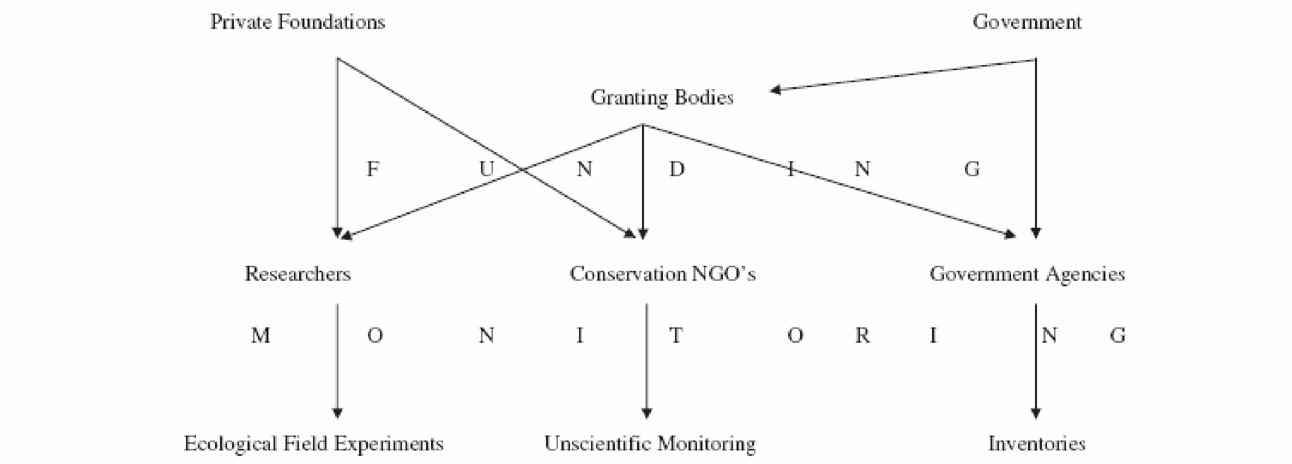
The above quote perfectly states why it is important to develop a monitoring program that is well thought-out, rigorous and with analysis and interpretation issues decided before the monitoring program commences. Given the issues outlined above, there is a need to ensure that monitoring undertaken within the Department of Environment and Conservation (DEC) is well developed, well documented, and that monitoring funding is appropriately utilised. Monitoring needs to be documented in a monitoring plan or protocol, a template for which is provided in Oakley (2003) (http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf).

Elzinga *et al.* (2001, page 2) states that monitoring should only be "initiated if opportunities for change in management exist. If no alternative management options are available, expending resources to measure a trend in a species population is futile." The authors also explore the concept of 'adaptive management' and how the term is commonly used as a 'buzzword', and is often misused. Elzinga *et al.* (2001) provide an outline for successful adaptive management as it relates to monitoring.

Field *et al*. (2007) also discuss problems that regularly occur with monitoring, noting that (page 485) "Millions of dollars are currently being wasted on monitoring programmes that have no realistic chance of detecting changes in the variables of interest. This is partly because detecting change in ecological systems is a genuinely difficult technical and logistical challenge. However, the failure to plan, fund and execute sophisticated analyses of monitoring data and then to use the results to improve monitoring methods, can also be attributed to the failure of professional ecologists, conservation practitioners and bureaucrats to work effectively together." For the reasons detailed above, it is imperative that monitoring programs are carefully planned, and linked to management measures.

The figure below describes some of the shortcomings related to monitoring in Australia, which those developing monitoring should endeavour to avoid.

Figure 1 "Schematic representation of approaches to monitoring by different actors in Australia" (from Field *et al*. 2007)



	Ecological Field Experiments	Unscientific Monitoring	Inventories
Funding	Short- to medium-term, often associated with terms of student projects or grants, discontinued after 3-4 years	Short- to medium-term, discontinued due to lack of interest and focus on activities designed to attract and retain volunteers.	Short- to medium-term, often in response to short-lived political pressures. If long-term, unlikely to be sufficiently spatially and temporally replicated for meaningful analysis.
Objectives and Design	Aim to collect information on specific ecological characteristics of target organisms. Adhere to rigorous scientific design, but abundance and distribution usually measured incidentally and thus unlikely to yield high statistical power.	Aim to gather 'snapshot' inventories of particular locations of interest to volunteers, or which support specific campaign objectives. Usually lack rigorous scientific design and produce datasets that are unusable or with low statistical power.	Aim to gather 'snapshot' inventories of particular locations to meet minimum statutory requirements. Usually lack rigorous scientific design and produce datasets that are unusable or have low statistical power.
Data Quality and Uses	Medium to high quality data, but rarely sufficiently long-term to permit demonstration of trends. Held in personal archives, requiring permission and modification before being effectively used.	Poor to medium quality data, unlikely to be systematically archived except by largest and best-funded organizations. Usually used only in support of specific short-term campaign objectives.	Poor to medium quality data, systematically archived but usually inaccessible to outsiders and rarely used for rigorous analysis to support management decisions.

This document has been developed to guide those developing monitoring in avoiding the commonly encountered problems described above. Several references that have been consulted when developing this document, and that should be referred to for greater detail when developing flora monitoring include;

- 'Monitoring plant and animal populations' (Elzinga *et al*., 2001)

http://books.google.com.au/books?id=H7VjsfGQWHcC&dq=monitoring+plant+and+animal+populations+elzinga&printsec=frontcover&source=bl&ots=5wkTld_YI9&sig=cZXvLfJkyZQ84ziTBbec-pSKUP4&hl=en&ei=atFaStuaPM-9kAXF46TUBQ&sa=X&oi=book_result&ct=result&resnum=1

- 'A technical manual for vegetation monitoring' (Barker, 2001)

http://catalogue.nla.gov.au/Record/1630907

In addition, examples of monitoring undertaken in Western Australia which may be of relevance when developing monitoring are referred to in section 7 of this document.

2 Introduction

For the purposes of this document, monitoring is described as "detecting change and responding to it in a way that favours a desired outcome" (Barker 2001). Monitoring projects should include monitoring the impact of a change in the environment, monitoring the impact of a management treatment, or monitoring changes in plant populations over time (Barker 2001).

This document is designed to guide personnel who are commencing flora monitoring. The document will help develop the question for flora monitoring, outlines steps necessary for developing effective monitoring, details some tools that may be used for flora monitoring, and provides some guidance for interpretation and analysis of monitoring data. Many documents have previously been developed to guide monitoring of flora and vegetation, and will be referred to in this document.

Crucial components of developing effective monitoring involve clearly understanding why monitoring is being undertaken, what the monitoring 'question' is, how appropriate monitoring should be developed to answer that monitoring question, the type and magnitude of change expected to be detected by monitoring, and how monitoring data will be interpreted and analysed in order to answer the monitoring question and influence management. To ensure that monitoring findings feed into management, it is critical to determine who the long term responsibility of monitoring and management rests with. Those developing monitoring need to carefully research and document their monitoring methods in a monitoring plan/protocol, and may need to consult a statistician or biometrician for advice on proposed analyses. The components mentioned above are critical in avoiding 'monitoring the decline' of a species, which occurs if there is no link to management as a result of the monitoring.

Duncan and Coates (2006, page 1) detail how one aspect of monitoring allows us to identify changes in populations, and to determine the magnitude and direction of the change. They note that monitoring can be considered as follows: "At one extreme, a simple presence / absence record of a species may provide all the information deemed necessary for a population. Elsewhere it may be necessary to count all individuals in a population, while at other sites labour-intensive demographic monitoring that collects detailed life history information about individuals (and may incorporate experimental design) may be necessary to answer specific questions about a species or population."

The authors note that the reasons for monitoring can be summarised as "1/ Audit[ing] the status of a population, 2/ Measur[ing] change in a population through time (eg. Is it declining, stable, or increasing?), [and] 3/ Evaluate[ing] and improve the effectiveness of management actions…Monitoring is undertaken to determine whether key attributes of a population fall within predefined limits under the prevailing conditions (environmental, physiological [for example population size, recruitment or seed production], and ecological), or if actions are necessary to restore the population to within these limits. Without effective monitoring, we may not understand how to most effectively manage a species or population for its conservation; we may not detect incipient change (which can act as an early warning); and any benefits derived from improved management actions become *ad hoc* at best." (Duncan and Coates, 2006, page 1). While reasons for monitoring have been outlined above, it is imperative to remember that prior to monitoring, we need to have an understanding of why the changes (decline etc) are likely to be occurring, preferably with data to prove that the changes are for the reasons indicated, and we need an understanding of the management required to reverse the trend.

Currently DEC staff and other conservation officers and community members are able to document and report information on rare flora through use of the Threatened and Priority Flora Report Form (TPRF). Monitoring involves repeated sampling to answer a specific monitoring question. There are many very valuable things that can be undertaken in a conservation context, such as biological survey and documenting the occurrence of rare species. These are often considered monitoring, however, strictly speaking they are reporting. However, the point should be made that both of these activities are just as important from a conservation perspective as monitoring. In most instances when undertaking monitoring of significant flora, a TPRF will be filled out in addition to undertaking specific custom monitoring data collection as required by the monitoring question. In a limited set of circumstances (see Section 4.6.1) the TPRF may be used to record flora monitoring information.

This document will summarise the components of monitoring outlined in various existing flora and vegetation monitoring documents, and refer readers to sources of further information for flora monitoring. This document details the required components of a monitoring project that, regardless of whether the proposed monitoring is very simple, or more detailed and complex, need to be considered before embarking on monitoring. This document may also be applicable to development of monitoring for plant based Threatened Ecological Communities (TECs).

3 Why is monitoring being developed?

Defining why monitoring is being developed enables personnel to develop a specific monitoring question. Monitoring may be proposed to fill a gap in knowledge about a species, to monitor threats to a species, or to monitor a particular management action. Monitoring will in many cases be undertaken because the target species is known to be threatened (Rare) or a Priority species, or of other conservation significance. In all cases though, results of monitoring should be fed into an adaptive management framework, so that if required, management actions can be changed or modified to improve the conservation status of a species or community.

Important components of developing monitoring include identifying who will take long term responsibility for the monitoring project (see Section 4.1), the resources needed, available funding, and identifying the likelihood of success in maintaining or improving the predicament of the plant species or community being measured (Barker 2001). These components emphasise the importance of linking monitoring with management actions, without which monitoring is likely to fail in improving the management and conservation of species and communities.

In addition to identifying the various components of monitoring, an assessment of the likelihood of developing effective monitoring needs to be undertaken, to prevent waste of resources (time and funding) through ineffective monitoring, and to ensure that management regimes are likely to achieve their aims. “Monitoring projects require considerable resources and planning. Therefore, they should be undertaken only when they are likely to improve the management of conservation values” (Barker, 2001, page 1). Clearly understanding the reasons for monitoring, and what it will achieve can ensure that resources are used in the most appropriate manner.

4 Developing a monitoring program

4.1 Identify the long term custodians of the monitoring program

Stakeholders for the projects should be defined, including funding bodies, government officers (DEC), land manager(s) and/or landholder(s), environmental staff for the shire/town/council, scientists, recovery plan authors, relevant community groups or individuals, and other stakeholders as required. Defining the stakeholders will help identify where funding for monitoring is coming from (both at commencement and for the life of the program), who will participate in the monitoring, and who management will be implemented by. The species may occur over several tenures/properties, so all relevant stakeholders need to be considered.

Many monitoring programs fail or are not completed, as they are not funded for the required length of the program, and long term responsibility for the monitoring is dropped, or never established. If a request for monitoring is made, within reasonable bounds, commitment to that monitoring must also be made. The monitoring plan, or monitoring protocol (see section 4.7) that needs to be developed as part of the monitoring program should detail who will establish monitoring, and who will take responsibility (both financially and physically) for subsequent monitoring events. The number of people available for monitoring also needs to be determined, as this will affect both financial considerations, and the resources available for establishing monitoring sites, and undertaking monitoring.

Field *et al*. (2007, page 486) notes with regard to funding “…the commitment needs to be sufficiently long-term to allow a change to be detected over and above the natural temporal fluctuations in the system in question. The time period required will of course vary among study systems, but we would suggest there exist few ecological variables likely to show significant change in less than 5 years, and that 10 years is a sensible minimum target for most ecological monitoring programmes. Note that these time periods can be estimated more rigorously using statistical power calculations based on preliminary data”. This demonstrates the requirement for identifying the long term custodians of monitoring programs.

With reference to the likely monitoring time periods in the paragraph above, data on natural temporal fluctuations may exist, which may mean that a shorter monitoring program could be achieved. However, given the fact that so little is known about many Western Australian species and communities, most monitoring programs will be of the temporal length recommended by Field *et al.* (2007).

4.2 Identify knowledge gaps, and the threat/change or management action to be monitored

As detailed above, there are several reasons monitoring may have been proposed. In order to develop a monitoring program, knowledge gaps need to be identified, and then the threat, environmental change, or management action to be monitored can be identified.

Knowledge gap:

If there is a knowledge gap, then it is highly likely that further research will be required before monitoring can be undertaken. If the reason for a decline is unknown then a monitoring program can not be clearly linked to a management action, as it is unclear what management is required to reverse the decline. Only once the reasons for a decline have been identified can a management action be proposed. The management action can then be implemented if the monitoring shows a continued decline in the species or community of interest. Further survey or trials to assess management actions may also be required prior to developing a monitoring program.

Examples of knowledge gaps may include a lack of knowledge about whether seed for a species are being predated, or how a species is responding to hydrological change. Gaps in knowledge might extend to “important but sometimes cryptic biotic relationships, eg parasitic relationships or dependence on mycorrhizal fungi. These may be crucial to the survival of the target species” (Given, 1989). Gathering of baseline species and site data to address knowledge gaps is discussed further in section 4.5.

Once the factor to be monitored has been identified, the critical step of developing the monitoring question can be undertaken.

Threat/Environmental Change:

Monitoring may be required for assessing effects of threats, for example it may be known that the threat of *Phytophthora* dieback is reducing abundance of species Z, or that the threat of too frequent fire is reducing recruitment of a species that reproduces by seed. Monitoring of these species may be required, so that management can be initiated or altered at a pre-determined trigger point. Other threats for which the effects may be monitored could include the effect of an increasing density of an invasive weed species on a threatened species, effects of recreational disturbance on a species, effects of grazing on a species, or effects of increasing salinisation of ground water on a species. Monitoring an environmental change may include monitoring the impact of a wildfire, a change in the local hydrology, or a development (Barker, 2001).

Management Action:

Examples of management actions that may be monitored include monitoring the effects of fencing on the density of species Z (which may be susceptible to grazing), or monitoring the effects of weed spraying on the density of species Z. Another example may include monitoring the effect of phosphite injections on the health of a species subject to *Phytophthora* dieback attack.

It is assumed at this point that the species/taxa to be monitored has been selected. If not, and several species require monitoring, prioritisation of species for monitoring may be required. Elzinga *et al.* (2001, page 25) provides advice for setting priorities for monitoring. Given (1989) also notes that when prioritising species to monitor, there is a temptation to monitor those species which are rarest and most endangered, however monitoring other classes of species such as those approaching critical rarity, umbrella and keystone species, known genetic variants and species of cultural significance may be just as important.

4.3 Developing the monitoring question

In order to provide clarity and direction for monitoring, a monitoring question needs to be developed. Understanding the threat or management action to be monitored, and how the resultant threat/change is likely to be expressed, is critical in developing our monitoring question.

Barker (2001, page 7) suggests posing a monitoring question as follows;

> “Think about what you want to know. State the question in terms of the subject (ie plant species/community/impact being measured), the treatment proposed (ie variable being measured), and what you expect will be affected by the treatment.”

The proposed monitoring may involve a hypothesis which can be tested through development of a monitoring question, and experiment. An example may include determining whether an observed reduction in density in a population of species Z is a result of grazing, in which case the monitoring question posed could be;

- is the population of species Z increasing in density in areas that are fenced to prevent grazing?

for which the monitoring may involve the establishment of replicated fenced and unfenced monitoring sites within the populations of the species, to test the effects of fencing on the density of species Z.

The following provides a scenario where a threat to the significant species is monitored; increasing weed levels may be known to threaten a population of significant species Z, and weed control may have been initiated. When attempting to determine whether the weed control is effective, the following monitoring question may be asked;

- does density of species Z increase on transects where weed control activities are being undertaken?

For this scenario, the monitoring may involve the establishment of paired transects within the populations of the species, half of which are subject to weed control (treatment transects), and half of which are not (control transects). If it is determined that the weed control is effective in controlling weeds, the control method could be continued, however if the weed control is found not to be effective, a change of management will be required.

It is important to avoid making assumptions about the cause of impacts on significant species. Elzinga *et al.* (2001, page 5) states “If one were to simply note a decline in a species population after logging, this would support the hypothesis that logging negatively impacts the species, but it does not prove that logging is the cause of the decline. The decline has to be consistently found at several logging sites and not found in uncut areas to confidently determine logging activities as the cause of the decline.”

Barker (2001) notes that having one simple monitoring question to answer will be complicated enough without exploring additional issues, but notes that additional questions may be able to be accommodated if the necessary data to answer additional questions can be collected from the same monitoring sampling unit (for example quadrats).

Developing monitoring without a clear monitoring question, for example establishing monitoring transects without a clearly defined question, without adequate replication, without understanding how data will be analysed or knowing how and at what point management should be changed, is likely to be a waste of time and resources. Examples of information that may need to be gathered, or results of research sought prior to/during definition of the monitoring question and development of monitoring are provided in Appendix A.

4.4 Identify how management may be modified as a result of monitoring

This involves understanding what the current management involves, understanding where your monitoring program will identify changes (for example it will detect a decrease of 10% of species Z along transects), and how the findings from your monitoring will inform management. For example, the monitoring program may involve monitoring the density of a significant species Z along transects, where weed control is being undertaken. The monitoring may be expected to reveal that density of species Z is increasing where weed control is being undertaken, however monitoring may reveal that there is no change, or even a decline in density of species Z, in which case management should be changed. Alternatively, the monitoring program may involve monitoring the recruitment of a particular species in areas that are known to be negatively affected by salinity and which are not currently subject to any management action. It may be the intention for the monitoring program to show that the species is not recruiting in saline areas, however if there is unlikely to be any funds for methods (for example earthmoving works to alter ground water hydrology) available for reducing the salinity of the subject area, the validity of the monitoring program, and associated time and costs are unlikely to be warranted, unless the monitoring outcomes are required to justify a request for funds for management.

In this scenario, a monitoring program should only be initiated if management actions to reduce salinity are likely to be implemented.

Another example includes a potential monitoring program involving the monitoring of effects of grazing on the density of a particular species, within an area not currently managed for grazing pressures. The monitoring program may involve establishing grazing exclusion plots, and recording of the density of a particular species within the exclusion plots, and in non fenced control plots over a period of time. If after the designated monitoring time the densities of the monitored species increase to desired levels in the grazing exclusion plots (and numbers remain low in the non-fenced control areas), it may be deemed that the monitoring has shown that management involving fencing may be warranted. The type of fencing and impacts on other species may then need to be considered.

"Studies that measure change can be implemented in the absence of an identified need for decision making. In contrast, monitoring is characterized primarily by objectives and by being part of an adaptive management cycle in which monitoring data are used to evaluate management and make decisions (Perry et al. 1987, in Elzinga *et al.*, 2001 page 9). Proposed management as a result of monitoring needs to be clearly defined, funding for long term monitoring needs to be ensured, and the monitoring and management need to improve the situation of the species. If these factors do not occur, the monitoring program may not be warranted and funding may be better utilised elsewhere.

4.5 Gathering baseline species and site data

Identifying the monitoring question will help determine the data that need to be collected about the species and/or site. Understanding the species/taxa and the natural processes at the site(s) prior to commencing monitoring is necessary, so that natural variations in a species (or community) are not assumed to be a 'decline' and attributed to an assumed cause. Barker (2001) states "Change is a normal part of all ecosystems because all things ecological are dynamic. You need to understand the nature of the changes that may occur in an ecosystem and the management response needs to be based on a change that is perceived as undesirable for the plant species/community/impact being monitored."

Existing data and research need to be gathered prior to developing monitoring, including any baseline survey data and reports for the species and site(s). Barker (2001, page 8) states; "Your monitoring question will determine the data you need to answer it. Do not waste time and money collecting redundant data, ie data not needed to answer the question. Collect only the data you need to answer your monitoring question. When thinking about the data you will need to collect, identify any variables you will need to calculate and make sure you collect the data needed to do the calculations. For example, if you want to know the species richness you will need to know the number of species present, and if you want to know the species density you will need to know how many species are present in each quadrat."

The monitoring project needs to be embedded within an adaptive management framework. This will enable the collection of additional/alternative data as new questions arise. However, well executed monitoring programs should be quite specific in their focus. When developing monitoring, we are not aware of the multitude of future questions that could arise, and therefore want to avoid wasting time collecting data that may not be used, particularly given that time and resources for monitoring are often limited.

Barker (2001) also notes that it can take many years to establish the thresholds of natural variation, or baseline data, and Elzinga *et al.* (2001, page 9) states that for baseline data collection "many variables are measured in the hopes of capturing within the baseline dataset ones that turn out to be important later…The problem with baseline studies…is that the design of the study may be inadequate to detect changes. This inadequacy usually results from including too many variables and using too small of a sample size." While baseline data collection does not constitute monitoring, many of the issues highlighted above will also apply to monitoring programs.

Gathering data prior to developing monitoring design ensures that monitoring relies on facts, rather than assumptions. If some required data is lacking, surveys or research to collect appropriate data (for examples see Appendix A) may be required prior to development of monitoring, and the associated investment of time and funds. Elzinga *et al.* (2001, page 8) states; "Natural history studies investigate basic ecological questions…For plants these questions concern pollination ecology, life history, seed viability, seed-bank longevity, herbivory, and seed predation. These questions often must be answered before effective monitoring can be designed, but such studies are not monitoring".

Department of Environment and Conservation (2009, page 7) details the difference between survey and monitoring; "The terms *monitoring* and *survey* are frequently confused…it is necessary to clearly define the difference between them. A survey is an exercise in which a set of observations are made about some components of an ecosystem. Monitoring is a series of surveys, repeated over time, that is designed to test a specific hypothesis." For example, a survey might involve counting the number of species Z within a given area. This is not monitoring, unless the count is repeated over time in order to test a theory about the species, for example the species response to management that has been implemented.

Trials (for example trials for control methods for *Sparaxis bulbifera* undertaken in Brown and Brooks (2003)) may also need to be undertaken prior to monitoring. Depending on the monitoring question that has been defined, the following data are also likely to be required prior to assist in understanding the processes at the site;

- Maps (topographic, soil, Agricultural Land Systems mapping etc)
- Existing vegetation maps (e.g. Beard, 1974-1981)
- Aerial photographs
- Satellite imagery (e.g. Google Earth)

After baseline data have been collected, a monitoring program can then be designed that will actually detect a real change in the variable of interest, rather than just natural variation.

4.6 Developing monitoring design

The monitoring design will be influenced by several factors; the monitoring question, how the change to be monitored is likely to be expressed (for example as a decrease in abundance of species Z), the magnitude of change desired to be detected (for example a 5% decrease or a 20% decrease of species Z in monitoring quadrats), the nature of the species (for example, whether the species is small or large, its reproductive methods, distribution, and density), the desired scale (for example, whether monitoring will be conducted in one population, or over many populations) and intensity of monitoring (for example monitoring every month to detect the required change, or monitoring once a year for ten years), in what time period the change is expected to be seen/recorded and the resources (funding and personnel) available for monitoring. These factors need to be carefully considered when developing a monitoring design. In reality most monitoring programs will be restricted to some extent by logistical and financial constraints. However, it is critical that a monitoring program is still able to detect the desired change, even within these constraints.

Elzinga *et al.* (2001) notes that as the scale and intensity of monitoring increases, more is understood about the trend and status of species, however the monitoring also becomes more expensive. The author suggests that one or a few species can be monitored at large scale and high intensity, or more species can be monitored at limited scale and at lower intensity.

Several types of monitoring exist: population monitoring, demographic monitoring, and experimental monitoring; though it should be noted that both population monitoring and demographic monitoring can be experimental.

Barker (2001) provides a proforma for developing monitoring that can be used to ensure that all required components of monitoring have been considered (see Appendix B).

At this point, several aspects of the monitoring program will have already been determined, including definition of the monitoring question, and the funding and personnel available for monitoring. When developing a monitoring design, the type of monitoring (sampling design – section 4.6.1) and the monitoring replication/sample size (section 4.6.6) required to adequately monitor the species will need to be addressed, and are influenced by the following;

- How you plan to analyse your data (Data analysis/statistical considerations - section 5.1);
- How variable your data are likely to be (Variability - section 5.1.3);

- How precisely you want to measure the change or trend and the number of years over which you want to detect a trend (Detection of change/trend detection – section 5.1.2); and
- How many times a year you want to/will be able to sample each point (Monitoring frequency and timing – section 4.6.5).

These factors are discussed in sections below and will need to be determined before the number of monitoring samples required for adequate monitoring can be calculated.

4.6.1 Sampling design

Depending on the monitoring question, one of many sampling methods may be appropriate for monitoring. The sampling methods detailed in this section may be utilised regardless of the monitoring type, for example in population monitoring (section 4.6.2), demographic monitoring (section 4.6.3) or experimental monitoring[1] (section 4.6.4). The sampling method used will depend entirely on the species and situation, and detailed consideration should be given to determining the most appropriate method for answering the monitoring question.

Barker (2001) describes the methods commonly used in monitoring projects in Sections 4–12 of his document, and Elzinga *et al.* (2001, Chapter 5) details various monitoring tools/methods. Note that Barker states that "Sections 4–5 describe two monitoring techniques that can be used by people who are not trained ecologists. Sections 6–14 outline a range of specialised monitoring techniques used by ecologists." These references should be referred to for greater detail when developing sampling design. Sampling may be required at a single site, multiple sites, or in replicates at several sites, as discussed by Barker (2001, page 43).

Some available sampling methods (as discussed by Elzinga *et al.*, 2001, page 107) include:

- Individual plants: "Plants are the sampling units for attributes such as plant height, number of flowers per plant, or cover if the cover measurements are made on individual plants (e.g., tree stem diameters, bunchgrass basal areas measurements)."
- Plant parts: "Fruits might be sampling units if the attribute is the number of seeds per fruit or the percentage of fruits containing some seed herbivore. Or, you may be interested in estimating the number of flowers per inflorescence, in which case the inflorescence is the sampling unit."
- Quadrats (plots): Clarke (2009, page 1) "The standard method chosen for the assessment of plant diversity by DEC staff in WA involves the use of square vegetation quadrats ('plots'). Quadrats can be used to measure most vegetation attributes in most vegetation types. They are two-dimensional sample units, typically square but can be of any size or shape." Elzinga *et al.* (2001) notes that estimates of plant density, frequency, or biomass will require the use of quadrats as the sampling unit, and notes that quadrats can also be used for sampling where visual estimates of cover are undertaken within quadrats.
- Lines (transects): Elzinga *et al.* (2001) "When cover is measured using the line-intercept method, the line is the sampling unit. Lines can also serve as sampling units when points (for cover) or quadrats (for cover, density or frequency) are positioned along lines and the points or quadrats are not far enough apart to be themselves considered the sampling units (because they are not independent of one another)." Line transects, including using the line intercept method, the point intercept method, and transects with quadrats are detailed in SOP 6.2 at http://www.dec.wa.gov.au/content/view/5389/2239/ .

Elzinga *et al.* (2001) also describes the use of methods including points, point frames and distance (plotless) methods, about which more can be read on page 107 of the document. The methods in point form above are among those used more frequently in flora monitoring in Western Australia. Barker (2001, page 46) also provides a useful reference for deciding on an appropriate quadrat size and arrangement, if this is the chosen sampling unit for monitoring. It may also be appropriate to use quadrat sizes as recommended for survey in particular regions of the state, as detailed in the Guidelines for Terrestrial Vascular Flora and Vegetation Surveys for Environmental Impact

[1] It should be noted that both population monitoring and demographic monitoring can be experimental.

Assessment, which are currently being drafted by DEC. Alternatively, nesting of smaller monitoring quadrats inside larger regional survey quadrats may be appropriate, if the aim is to link monitoring findings to an area subject to regional survey. As always though, the size of monitoring quadrats will be dependant on the monitoring question, and gathering appropriate monitoring data should be the primary objective when selecting quadrat size.

Barker (2001, page 54) further discusses the use of line transects; "Transects are useful when gradients are evident in the vegetation…transects would be appropriate…between heaths and forests, through a riparian zone, or across a break in slope or fire boundary…you might use a transect to show the changes in plant species across the edge of remnant vegetation following clearing or to investigate the effects of species composition of a pollutant leaking from a septic tank." Barker (2001, page 56) also describes the advantages and disadvantages of using transects, including the fact that dense line transects can be very time consuming over long distances, and that data from quadrats along contiguous belt transects may not be independent and may not be suitable for statistical analysis.

DEC standard operating procedures for establishing vegetation transects and for establishing vegetation quadrats http://www.dec.wa.gov.au/content/view/5389/2239/ have been developed, and can also be referred to when developing monitoring design using these sampling methods.

For discussion of the appropriateness of monitoring using macroplots, or different sampling unit sizes and shapes, readers can refer to Elzinga *et al.* (2001, page 104 and 108 respectively). Elzinga *et al.* (2001, page 117, Table 8.1) also provides a useful summary of random sampling types, and their advantages and disadvantages.

Photographic Monitoring

Photographic monitoring does not provide quantitative data, but is a simple method for providing information over a long time period, if adequate standardisation is implemented. Barker (2001) states that photographic monitoring could range from simple photo points, to satellite imagery, and could be used for monitoring involving measuring fuel loads, or grazing intensity and provides an excellent description of how to carry out photopoint monitoring.

Remote sensing may also be a valuable tool for effective monitoring (see reference in Appendix A), especially where change is expected to be distinct over large areas. The use of remote sensing is becoming more common in monitoring of vegetation (for example for monitoring plant growth, plant stress, plant water content, plant nutrient content, soil moisture), with the imagery of such good quality that it can be used for assessing individual plants, making quantitative monitoring possible.

Rapid Diversity Assessment

Barker (2001, page 17) details when use of this method may be appropriate; "Rapid diversity assessment is a reasonably reliable technique that can be used to monitor the composition of vegetation relatively quickly and easily. It is used when a quick assessment needs to be made but strict scientific rigour is not needed. The technique can be useful [for example] if you want to measure the response of a patch of vegetation to a new stock management regime such as cell grazing or if you want to monitor the species composition and richness of two sites with different fire frequencies. Rapid diversity assessments are designed to be undertaken by non-ecologists. However, if you are not a trained ecologist you may need help to identify which species you should use as the species indicators." Barker (2001) also details the methods for undertaking a rapid diversity assessment, and should be referred to for monitoring using this method.

Vegetation Mapping

Barker (2001, page 31) notes that "Vegetation mapping is a useful monitoring tool when a change in the extent of a particular type of vegetation is anticipated." Barker suggests that mapped units can be compared over time to reveal changes in:

- the extent and rate of spread of *Phytophthora*;
- the expansion or contraction of a weed infestation; and
- the extent of an endangered community.

Vegetation mapping may also be used when monitoring the extent of vegetation that has been subject to fire.

Barker (2001) provides a description of the method for undertaking vegetation mapping and notes that "Mapping methods vary widely and depend on the scale of the subject being mapped and the level of accuracy needed. For example, satellite images are useful for mapping the extent of vegetation when monitoring vegetation clearance at the regional, national or global scale. However, any mapping done at a national scale would not usually be accurate enough to be useful in a small-scale project." This could include, for example, mapping small separate patches of a vegetation community using GPS/DGPS or detailed aerial photography with ground truthing.

Vegetation Cover

Vegetation cover may be used if monitoring involves, for example, assessing the cover provided by new recruitments (seedlings). Duncan and Coates (2006) state: "Looking from above, determine the percentage cover of the threatened species in each quadrat. A commonly used cover abundance class system is the Braun-Blanquet cover value (Mueller-Dombois and Ellenberg, 1974):

5 – 76-100% cover
4 – 51-75% cover
3 – 26-50% cover
2 – 6-25% cover
1 – 0-5% cover"

However, from an analysis point of view it is often better to measure cover to the most accurate level possible, for example by measuring a plant at it's widest, and then at the perpendicular to the widest point. Cover measurements can later be converted to a Braun-Blanquet scale, but Braun-Blanquet values cannot be converted to % cover estimates.

Vegetation cover will, typically, need to be measured at the same time each year. However, if the monitoring using vegetation cover is related to effects of, for example presence of fire, vegetation cover measurements could be undertaken at differing times of the year, for example if one fire was in September, and the following fire was in April. In this scenario you might monitor cover in response to these fire events one, two and six months post fire. There might be benefits though, in ensuring that at least one of the monitoring events after each fire was conducted at the same time each year.

General monitoring plan for plant translocations

Translocation can be defined as the deliberate transfer of plant material from an ex situ collection or natural population to a location in the wild (Vallee *et al*. 2004). Plants can be translocated into an area where the plant formerly (reintroduction) or currently (augmentation) occurs, or to a new safe location (introduction). Due to the prevalence of soil borne pathogens, such as *Phytophthora cinnamomi*, plant translocations in Western Australia are almost exclusively undertaken using seedlings or vegetatively propagated plants (greenstock) or seed. Additionally whole plant transplantation is generally less successful than seed or greenstock based translocations.

The aim of a plant translocation is to achieve a viable self-sustaining population. The time frames required to achieve this aim will vary between taxa and need to take into account the number of plants available for planting at any one time, seasonal influences on maturation times and survival. Monitoring to ascertain whether the aim of a viable population has been achieved will need to be long term and will depend on the life history of the taxa.

Frequency of monitoring will depend on the life history of the taxa. Monitoring of the translocated population should commence at planting out of the seedlings and then at set intervals for the first year and then at least annually thereafter. Monitoring should include counting the number of surviving seedlings, height of the surviving seedlings, width of the crown of the surviving seedlings in two directions, reproductive state, number of flowers, number of pods, general health of the plants and whether any second or subsequent generations have naturally recruited.

Monitoring of the original population should also occur in conjunction with monitoring of the translocated population. This will provide essential baseline data for assessing the performance and therefore the success of the translocated population. Monitoring should include counting the number of individuals, height and crown width of the individuals, reproductive state, number of flowers, number of pods, general health of the plants and whether any natural recruitment has occurred.

Additional reading regarding translocations:
Vallee L., Hogbin T., Monks L., Makinson B., Matthes M. and Rossetto M. 2004. *Guidelines for the translocation of Threatened Plants in Australia. Second Edition.* Australian Network for Plant Conservation, Canberra, Australia.

Anon. 1995. Policy Statement No. 29. Translocation of Threatened Flora and Fauna. Unpublished document. Department of Environment and Conservation. Perth Western Australia.

<u>Threatened and Priority Flora Report Form</u>

A Threatened and Priority Flora Report Form (TPRF) (See Appendix C) may also be filled out when undertaking flora monitoring. In a limited set of circumstances the TPRF could be used for capturing monitoring data. For example if the monitoring program involved very basic data collection with repeat sampling from the same location, and where data required for monitoring could be captured within fields on the TPRF, or if monitoring only required repeat counts of individuals within one population with small numbers of Rare Flora, the TPRF may be used to capture this data. However, for most programs involving monitoring of Rare Flora, much more detailed and specific data collection is likely to be required, and a TPRF can be filled out in addition to the collection of more specific data on custom designed monitoring field sheets.

4.6.2 Estimating population size/Population monitoring

The monitoring question may dictate that a monitoring design using population size estimates will be appropriate for answering the stated question. Counting every individual in the population may not be appropriate, or necessary to answer the monitoring question, or the population may be too large to do so. In these instances, sampling to estimate population size or site specific changes in plant numbers may be appropriate. Elzinga *et al.* (2001, pg 77) describes a sample as “simply part of the population, a subset of the total possible number of sampling units” and notes that efficient sampling designs try to achieve high accuracy and precision, where “Accuracy is the closeness of a measured or computed value to its true value. Precision is the closeness of repeated measurements of the same quantity.”

One of several sampling designs may be used to estimate population size, as discussed by Barker (2001, page 58); “Short of counting every individual no survey will be absolutely precise…The number of plants in a population can be easily estimated by counting the number of plants in a series of randomly distributed quadrats of known size and extrapolating the mean density to a measured area of occupied habitat. The number of samples (quadrats) required will vary with the size of the habitat, the variation in plant density, and the precision required of the estimate”. Barker (2001) should be referred to further for methodologies for calculating population size. Variability in distribution of the plants also needs to be considered (see Section 5.1.3 below).

Plant count methods for estimating population size have been defined in Appendix 3 of the TPRF Manual which is due for finalisation early in 2010. Readers can also refer to Barker (2001, page 58), for discussion of the use of quadrats, transects, or non-permanent quadrats in undertaking population size estimates.

When undertaking plant counts, Duncan and Coates (2006, page 14) note that it is possible to “Temporarily mark each individual encountered within each quadrat using either a random or parallel line search technique (depending upon quadrat size). This will avoid double-counting if a random search technique is used or more than one person is conducting the count. A wooden skewer with a piece of flagging tape tied to it is often an effective marker.” This is, however, only practical where plant numbers/density are relatively low.

It may be preferable in some situations to measure frequency rather than density. Duncan and Coates (2006, page 15) note that “This is achieved by measuring a simple presence / absence value of the threatened species in each quadrat of a grid established across the site. The frequency of the threatened species is then calculated as the percentage of quadrats in which it was recorded. The advantages of this method are that it is quick and simple, while the disadvantages are that it is not an absolute measure, because the frequency value for a species is dependent upon quadrat size." This method might be more appropriate if the species is patchily distributed over a large area.

4.6.3 Demographic monitoring

Elzinga *et al.*(2001, page 36) describes demographic monitoring as involving "marking and monitoring the fate on individuals through time. It is extremely labor-intensive and represents that most intense level of monitoring that can be used" and cites several references as good introductions to demographic monitoring – see further reading below:

Barker (2001, page 58) states with reference to demographic monitoring that "…individual plants can be marked and any number of attributes can be measured and monitored, including recruitment, mortality, number of flowers and rate of growth. The collation of these data constitutes a demographic census. A demographic census is recommended for monitoring populations of single species because it allows you to estimate population size, describe the health of the population and predict future changes."

Duncan and Coates (2006, page 16) also describe demographic monitoring as "a census study of individuals in a population (eg. measuring births, deaths, age class distribution), which is then used to determine growth, reproduction and survival rates of the population as a whole, calculate the rate of population change, and identify critical stages in the life cycle. Individuals are monitored through time to gain a better understanding of the ecology of the population and species. Demographic monitoring is fundamental to threatened flora recovery programs, and is commonly used when little is known about a species, a site, or a population (eg. population size, age structure, reproduction or growth rate etc). This information can be critical in understanding why a species is threatened, why the threat has become a problem, and how to best manage / remove the threat. Demographic monitoring provides greater knowledge and more detailed information than any other type of monitoring. However, a decision to establish demographic monitoring requires significant funding and staff time, and a commitment over an extended period of time. As a result, demographic monitoring should be thoroughly planned to ensure that it addresses all questions, and is scientifically robust, efficient and cost-effective".

Examples of demographic monitoring are provided in Section 7 of this document.

Further reading:

Elzinga, C., Salzer, D., Willoughby, J. 1998. *Measuring and monitoring plant populations.* Technical Reference 1730-1. Denver, CO. Bureau of Land Management, National Business Centre.

Menges, E.S. 1986. *Predicting the future of rare plant populations: demographic monitoring and modelling.* Natural Areas Journal 6:13-25.

Menges, E.S. 1990. *Population viability analysis for an endangered plant.* Conservation Biology 4:52-62.

Pavlik, B.M. 1993. *Demographic monitoring and recovery of endangered plants.* In: M.Bowles, C. Whelan (eds.), Recovery and restoration of endangered species. Cambridge, England: Cambridge University Press.

4.6.4 Experimental monitoring

Experimental monitoring may be required in some circumstances to test or compare management actions. Duncan and Coates (2006, page 19) note that; "In some cases it may be possible to set up (replicated) paired quadrats, one with and one without the management action applied to it. This is the simplest way to do field-based experimental monitoring, but generally hard to achieve with threatened flora due to their low population size and non-continuous distribution across a site."

Experimental monitoring is also described in Department of Environment and Conservation (2009, page 15) "Showing causation, or lack of it, is a common requirement of monitoring programs. It means showing a relationship exists between two variables such that a change in one (the cause) causes a change in the other (the effect). To be sure of the relationship between cause and effect, it is also necessary to show that the effect will not occur if the cause does not. Demonstrating this requires the use of a control. A control is a subject that is identical to the experimental subject in every way, except that the experimental subject receives a treatment[2] and the control does not. If a change is observed in the experimental subject after the treatment, but not observed in the control, that change could only have occurred due to the treatment. It is also necessary to replicate the treatments and controls to ensure that the observed effect is not a chance occurrence."

Variability in data can influence effectiveness of experimental monitoring and needs to be taken into consideration. Barker (2001, page 8) states "Several…design considerations will affect the accuracy and precision of your estimates and hence the power[3] of your analysis. To maximise your chances of correctly identifying a significant treatment effect or change you will need to maximise the size of the treatment effect by minimising data error, reducing variability, and choosing variables that are strong indicators of change". Given the inherent spatial variability over small scales in Australian landscapes, it is also critical that plots from different treatments are interspersed, to sample this variability. Barker (2001, page 8) continues; "Vegetation cover is a good example of a variable that can introduce variation and error into your data depending on how and when it is estimated and who estimates it. Vegetation cover will vary or appear to vary during the year so it needs to be estimated at the same time each year — not only in the same season each year but also at the same time in relation to other factors, such as the time since grazing." Variability is discussed further in section 5.1.3 of this document.

An example of where experimental design may be appropriate for monitoring is provided by Duncan and Coates (2006, page 21):

Example: Consider the situation where an Officer has responsibility for monitoring a hypothetical population of the tree *Eucalyptus cadens*. The population contains approximately 500 individuals that are scattered over about 10 ha of uniform vegetation. Historical information about the site suggests that seedlings are very rarely observed and that the site is has not been burnt for more than 40 years. The key monitoring question was determined to be – Is the absence of seedlings due to grazing and/or the absence of burning?
In this case, experimental monitoring is the best way to answer the monitoring question. Following the process outlined earlier in this section, an experiment with 4 treatments (nil, fence only, burn only, fence & burn) is established in a randomised block design with 3 replicates. Treatments are then imposed – plots with a 'fence' treatment have grazing exclusion fences erected, and plots with a 'burn' treatment are burnt at an appropriate time of year. All plots are then monitored monthly, where the number, size and health of seedlings in every plot are measured for a 2 year period to determine trends through time.

It should be noted that both population monitoring and demographic monitoring can be experimental.

4.6.5 Selecting monitoring locations

Selecting locations for monitoring will again depend on the monitoring question, the nature of the species being monitored, and the monitoring design that has been developed. For example, if monitoring is experimental, monitoring sites may need to be established in the population in, for the example provided above, both fenced and unfenced areas, if assessing the impacts of grazing, or in both burnt and unburnt areas, if assessing the recruitment of a species after fire.

Monitoring locations may instead involve the whole population of a species, if the population is of a size for which this is feasible, if monitoring recruitment within the population. If, however, the population is very large and it is not feasible to monitor all individuals, selected samples (with replication) in sites typical of the population may be chosen to represent the population. However, depending on the type of monitoring planned, strategic locations may be required (for example deliberate placement of monitoring locations at the edge of populations to assess edge effects), rather than representative locations across the population.

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[2] From Department of Environment and Conservation (2009) - **Treatment:** subjection to some agent or action. In the case of a monitoring program, the treatment will be the management regime that is expected to cause some change in the condition of the site.

[3] See power definition in Section 5.1.2 below.

If there is a lot of variability in the population or vegetation, more monitoring locations are likely to be required to adequately sample this variability (see Section 5.1.3). This is because trends are more difficult to detect in variable populations, so more replicates are required to achieve a certain level of statistical power – if you are using significance testing[4]. For example, if your area to be monitored is relatively uniform, a low level of replication may be sufficient (such as the bare minimum of three or four samples). If, however, the area to be monitored is quite variable, for example contains microdunes and microswales or several different soil types, then the required level of replication will be much higher to sample as much of the variation as possible.

4.6.6 Monitoring frequency and timing

Monitoring frequency refers to how often monitoring will be undertaken, and is determined by the timing in which changes in the population are expected to occur. For example, if monitoring seeks to determine changes that occur after fire, monitoring may occur immediately after fire, and several months thereafter. If monitoring is related to recruitment of an annual species, monitoring may take place several weeks after rain to capture germination, and then again at expected fruiting times. Monitoring may be required in spring, or depending on the geographical region of the state after periods of significant rainfall (for example post cyclonic rainfall monitoring). Alternatively, monitoring may be required before and after a particular management action (for example, two weeks after spraying a weed species, then two months after, then annually for five years).

Population monitoring is often undertaken annually, with the biology of the species, and ultimately the monitoring question, dictating whether monitoring needs to be undertaken more frequently. Duncan and Coates (2006, page 10) discuss the frequency of demographic and experimental monitoring; "Demographic monitoring is usually undertaken at least annually, and depending upon the biology of the threatened species, may require multiple visits during important life history stages. Experimental monitoring will generally require frequent and intensive monitoring, but the exact timing of this monitoring will vary on an experiment-by-experiment basis."

4.6.7 Monitoring replication/sample size

Monitoring requires sufficient replication to ensure that physical and biological variation within the site is adequately sampled, and to ensure that sufficient data are collected to show the change that the monitoring is required to show. For monitoring involving significance testing[5], the number of monitoring units (replicates) required to answer the monitoring question will be determined by the degree of risk you are prepared to take in failing to detect a change when it is occurring[6], the variability of the measured variables, and the magnitude of change you want to detect. For monitoring using a threshold there are no firm recommendations for replication requirements, although from an ecological perspective, it would be desirable to have sufficient replicates to encompass the variability in your monitoring area. Replication is required so that the conclusions from monitoring can be applied generally across the spatial area of the monitoring program; results from monitoring can then also be applied outside of the specific sampling sites.

There are a few exceptions where replication is not required because extrapolating results to an area other than the sampling area is not required. An obvious example is a threatened species with just one occurrence – in this case replication will not be possible, nor required, as what happens within that specific occurrence is of interest. In most other cases, however, replication is critical for good monitoring design and "pseudoreplication"[7] must be avoided.

A pilot study may be necessary to determine whether the proposed monitoring design will provide sufficient data in order for the chosen analysis to show the changes/level of change required. Time and resources for a pilot study may need to be considered. A pilot study involves establishing monitoring units and undertaking monitoring to provide data for this analysis. Elzinga *et al.* (2001) notes that a pilot study can;

- provide estimates of standard deviation needed to plug into sample size formulas to determine an adequate sample size to meet your sampling objective;
- expose problems at an early stage; and

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[4] See Significance Testing in Section 5.1.4
[5] See Significance Testing in Section 5.1.4
[6] Beta level
[7] See Pseudoreplication reference below in this section

- demonstrate whether a monitoring design is feasible.

If using significance testing, Barker (2001, page 35) writes; "It is worth spending time determining the number of quadrats needed to give a precise estimate. The precision of the estimate is important for detecting any change due to the treatment. If the estimate is imprecise the power[8] of the analysis will be low…and only a very large change will be detectable. In these circumstances it may be very difficult or impossible to do anything meaningful with the data. The formula for calculating the required number of quadrats to be measured repeatedly is:

$n = SE\ s^2/d^2$

where:

n is the number of quadrats
SE = sd/sqrt n
s^2 is the variance of the sample at a particular time (the variance is the standard deviation squared)
d^2 is the squared percentage change that your sample needs to be able to detect (expressed as a difference in density). For example, if the estimated mean density is 6 individuals/quadrat and you want to detect a 10% change then d = 0.6 and $d^2 = 0.36$.

Example of evaluating precision of estimates versus number of quadrats
After collecting data from 50 quadrats in *Epacris barbata* heath, we can calculate the number of quadrats needed to detect a change in *Epacris barbata* density of ±10% and ±20%. The calculation indicates that the 50 quadrats is more than enough to allow us to detect a change of 20%. If we want to detect a change of 10% we need to increase the number of quadrats to at least 78. However, future precision will also be affected by the future variability in the data. In practice, the number of quadrats may be determined by the resources available. In this example the mean number of individuals for the 50 quadrats was 5.32 and the standard error was 0.75, so the sample variance is 29.

With 10% precision
$n = (0.75 \times 29) / (5.32 \times 0.1)^2 = 21.75/ 0.28$
78 quadrats
With 20% precision
$n = (0.75 \times 29) / (5.32 \times 0.2)^2 = 21.75 /1.13$
19 quadrats."

Pseudoreplication

Pseudoreplication can be an issue if your monitoring program contains different treatments (for example grazed versus ungrazed sites) and occurs when data are treated as independent observations, when in fact they are interdependent or correlated. This can occur when sampling sites are located too close together, or whenever observations at one sampling point are likely to be dependent on another. For example, when assessing points along one transect, each point along the transect is part of the data for the whole transect; and each point usually cannot be considered to be a separate data point unless it can be demonstrated that they are. Hurlbert (1984) describes pseudoreplication as "the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent" and notes that interspersion of treatments can safeguard against pseudoreplication..

There are three main types of pseudoreplication: temporal, simple and sacrificial. Temporal pseudoreplication is easy to identify; it occurs when the same sampling unit, for example a quadrat, is sampled more the once. If so, the data points from that quadrat are not independent, as they are likely to be similar to one another because they are both measurements from the same location. In this case the data points can not be considered independent and so must be analysed using methods that take this lack of independence into account (for example repeated measures analysis).

[8] See Power definition in section 5.1.2 below.

Simple pseudoreplication and sacrificial pseudoreplication are the other types of pseudoreplication. Simple pseudoreplication occurs when there is really only one independent sampling unit in each treatment of a monitoring study, but several sampling subunits within the larger one are treated as independent. Sacrificial pseudoreplication occurs when your monitoring program has several independent units within each treatment but again, smaller sampling units. For example, if a monitoring program involves counting the number of juvenile plants in ten 1m x 1m quadrats within a single 10 m^2 area in one ungrazed vegetation patch and one grazed patch. If you treated the data from each quadrat as a data point for analysis (thinking you have ten independent data points from each patch) then you would be committing simple pseudoreplication – in fact you only have two data points: the average of the ten quadrats in each patch, and the monitoring program does not actually have any replication. If you had a similar design, except two patches in each treatment, you would be committing sacrificial pseudoreplication if you thought you had 20 data points in each treatment. In fact, you only have two independepent data points in each treatment.

Determining if you are committing pseudoreplication is not always black and white, and there is a certain amount of 'grey area'. As a general rule, you need to ask "is this sampling unit more likely to be similar to that sampling unit in the same treatment, due to spatial proximity, than to another sampling unit in another treatment?" If the answer is yes, then you would probably be committing pseudoreplication if you treated the data from the sampling units in the same treatment as independent (rather than averaging them to obtain one value). However the issue is complex so you should read Hurlbert (1984) and seek the advice of a statistician/biometrician if you are unsure.

4.7 Developing the monitoring protocol

Once the monitoring approach has been developed, all components need to be clearly documented in a monitoring protocol. The monitoring question, custodians of the monitoring program, specific monitoring techniques, proposed data analysis, data collection sheet templates and any relevant information will need to be included in the monitoring protocol, to ensure that those continuing monitoring are aware of all specific requirements. This will also help reduce sources of error in the monitoring.

Oakley (2003) http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf) provides a template for a monitoring protocol, and monitoring protocols that have been developed previously can be referred to http://www.dec.wa.gov.au/content/view/5386/2238/.

5 Data

5.1 Data analysis/Statistical Considerations

Once the monitoring design has been developed, it will be necessary in many circumstances to discuss the planned monitoring approach and analyses with a statistician or biometrician. This is necessary for deciding on analyses for the data that will be collected and understanding the replication required in order to ensure that there is sufficient statistical power to detect the desired change, or to set benchmarks for management as a result of the monitoring. Discussing planned analyses with a statistician or biometrician is also necessary so it can be decided whether to proceed with the planned monitoring program; if an unfeasible level of replication is required, without which the monitoring program will not show the desired change, then you will be required to start from 'scratch' to develop a completely different monitoring program in order to answer the monitoring question.

A statistician can also provide advice on how to make the monitoring design as efficient as possible. An important part of any monitoring program involves dedicating sufficient time and resources to the design of the program. This will ensure future efforts are targeted and that the desired outcomes of the program can be met.

A brief discussion of analyses is provided below. However, as stated above, it is recommended that further assessment of appropriate analyses be undertaken and discussed with a statistician or biometrician.

5.1.1 Required sample size/replication

In order to determine the minimum sample size required for the monitoring, the following need to be determined;

- An estimate of the mean and standard deviation (i.e. the coefficient of variation or the variation of your counts) (obtained via a pilot study or using results of a similar study);
- The smallest number of years over which you would like to detect a change – this is not always necessary, but is useful in some circumstances;
- The smallest percentage change you would like to be able to detect over those years;
- An alpha (significance) level (section 5.1.2) that you will use to determine if a change is real and not simply normal variation;
- A power level (the proportion of the time you would like to detect a trend if one were occurring) (section 5.1.2); and
- An appropriate statistical test (section 5.1.4) (your analytical model).

The mean and standard deviation (a measure of the amount of variation of your counts) are determined by the traits of the plants being sampled and are best obtained from pilot data for your study. If this is not available you may use data from similar studies with an appropriate amount of caution. You can avoid problems when you calculate estimates of the variation of your counts by:

1. Using data from studies with similar counting techniques and sampling units to the ones you plan to use.
2. Use means that come from the same data you used to calculate the variance.

All other pieces of information required for setting sample size are decided based on your need for precision and the smallest amount of change you would like to detect. The more you want to be confident of detecting a trend, if one is occurring, and the smaller the change to be detected is, the more effort and cost will be involved in getting sufficient data to be able to provide the desired information. In general, higher expectations will mean that a larger number of samples will be required. In practice, large sample sizes are rarely possible with available resources. It is therefore useful to keep in mind that sample size requirements can be lowered by:

- Aiming to detect only long-term changes;
- Setting your analytical tests (alpha level) to 0.10 rather than the usual 0.05; and
- Lowering the variability of your samples using techniques such as standardising the time of year when data are collected or by using consistent observers to collect the data.

Any calculation of how many samples are required for a monitoring program should be treated as an educated guess. There are too many variables involved that cannot be accounted for or known at the beginning of a project. It is also recommended that the adequacy of the number of samples is reviewed at least every five years.

Note: Throughout this document the terms variance, variation, and variability have been used interchangeably and as a quick reference to the general concept of the variability of samples. It is important to understand that the actual mathematical calculation of variability could be any one of several measures such as standard deviation, standard error, variance, or coefficient of variation and each of these has a specific statistical meaning.

5.1.2 Detection of change/trend detection

Trend can be defined simply as change over time and usually includes a measure of the rate of change. The detection of a trend is usually associated with the goals and/or objectives of a monitoring project for significant native flora species which will often specify minimum or maximum rates of change over a specified time period. These in turn are associated with assessing the success of a recovery plan and also triggering the implementation of appropriate management or research actions. It is common, and important, to state the time period over which you want to detect trends. Trends are also important for assessing the conservation status of a species against IUCN criteria.

Rules of thumb: for detecting trends:

- The smaller the population change you would like to detect, the greater the number of samples you will need to detect it.
- The fewer the number of years over which you would like to detect a trend, the greater the number of samples you will need.
- The smaller the degree of change that is required to be detected over the shortest time frame, the greater the cost of implementing the monitoring project.

Another decision you must make is how much risk you are prepared to take in failing to detect a trend when one is occurring. The smaller the risk you are prepared to take, the more replicates you will need and the more expensive and time intensive your monitoring program will need to be. While it is impossible to specify a degree of risk for all situations (it is very similar to setting an alpha value, i.e. arbitrary), if your species or community is endangered then it is difficult to see how your risk of failing to detect a trend when one is occurring (and the species/community potentially going extinct) is any more desirable than detecting a trend when one isn't occurring (and implementing a management regime that is a waste of money). So, as a general rule, you probably want your Type II error rate (the rate of failing to detect a trend when one is occurring) to be low. As the type II error rate is 1 – power, your power needs to be 0.9 or 0.95. It is appropriate to consider your willingness to risk being wrong about the population change you are trying to measure with the relative costs and consequences of obtaining the data and making the decision.

Rule of thumb: The higher the risk you are prepared to accept of failing to detect a trend when one is occurring the lower the number of samples you will need. Conversely, the lower the risk you are prepared to accept of failing to detect a trend when one is occurring, the larger the number of samples needed.

This risk is controlled by using two statistical settings:

1. Alpha (significance) level; and
2. Power level (itself affected by variability in your data, the size of the trend you want to detect and risk of failing to detect trends).

Alpha Level

Species populations and their counts will vary for many reasons, some known and some unknown, and therefore monitoring results are unlikely to produce nice, clear linear graphs. Instead, you are likely to find a scattering of points that may or may not show a trend. From this scattering you may decide that a trend is present, and that action is appropriate, but there will always be a level of uncertainty. The level of uncertainty in your conclusions that you are willing to tolerate at the risk of being incorrect is the alpha level.

Conventionally, the alpha level is set to 0.05 or 5%. If the probability ('p-value') from a statistical test (such as the test of whether the slope of a trend line differs from zero) is less than this alpha level, we conclude that there is a significant effect. In 5% of cases we will conclude that there is a significant effect when, in fact, there is none (a type I error, or 'crying wolf').

The setting of an alpha level is a balance between not wanting to 'cry wolf' (saying a trend exists when it really doesn't) and missing an important trend by being too conservative. If the monitoring project is designed to provide information to trigger remedial action if, for example a threatened species declines below an acceptable population size, then you may want to increase the alpha level above the usual 0.05. This would increase the likelihood of falsely triggering action when it is not needed but would also reduce the likelihood of missing an important change that may not have been "statistically significant" at a lower alpha level. However, changing alpha from the conventional 5% level will require justification.

Rule of thumb: The less willing you are to be caught 'crying wolf' (or the smaller you set the alpha level) the more samples you will need to detect a given level of population trend.

Power

Power may be defined as your ability to (or the probability of) detecting a trend given that your population of interest is actually undergoing a change.

Rule of thumb: A power of ≥ 1-alpha, so 90 or 95% is reasonable for most monitoring programs.

If the species is critically endangered, you want to reduce the risk of missing a decline, rather than saying one exists when it doesn't. Barker (2001, page 36) provides a good level of detail on power, and should be referred to for further discussion of statistical power.

5.1.3 Variability

Variability is a measure of how your samples fluctuate between sites, between monitoring units (spatial variability) and between monitoring events (temporal variability). This variation is caused by three elements: the variability in the plant populations from year to year, the imprecision of the sampling technique itself, and the variability of population trends from site-to-site (if more than one site is being included) or plot to plot. The level of variation affects your ability to detect trends. Data that fluctuates greatly will mask the trends that you would like to observe.

Rule of thumb: The more variable your samples, the more samples you will need to detect a change or trend of a given magnitude.

To calculate an estimate of the sample size required you will need an estimate of variability. This can be obtained from your own pilot data (standard error, variance, or standard deviation) or from estimates taken from other similar situations.

Be careful when using counts from other studies because count variances are specific to the counting technique and how the original study pooled their samples. Sampling variances will differ between studies and between sites even if using the same sampling techniques on the same species in the same region. However for an individual site the variability in samples is usually reasonably stable over time. It is useful to check it is still consistent every 5 years or so. It is recommended that estimates of variability of counts from other studies are used only as a general guide at the beginning of a project and that this is reviewed when you have collected sufficient data to estimate the variability for your own study.

There are several ways of reducing count variation and these should be attempted wherever possible.

Rules of thumb for decreasing your sampling variability:

- Where there is discretion, choose species whose populations and associated monitoring methods have low variances;
- Use a precise monitoring technique (i.e. a technique that measures close to the 'true' value and this accuracy can be repeated);
- Ensure that the technique is used accurately and consistently on every occasion;
- Monitor during the season/timing that provides low variance;
- Measure other things during monitoring that might explain some of the variability (covariates); and
- Train the observers well and use the same ones each year.

Sampling Technique. Counting techniques vary greatly in their precision and accuracy.

Choosing When to Undertake Sampling. All species have optimum times and possibly conditions when they are more easily detectable and counts are less variable. Sampling should usually be taken when the features (for example flowers/fruits) or species detectability is highest and/or most consistent. Data included from less optimal time periods will increase the variation in the results and should therefore be avoided.

Covariates. Factors that might influence the detectability of the subject being sampled (e.g. season, habitat) that can be easily measured whilst conducting counts should also be recorded. These data can then be used during statistical analysis to adjust estimates to account for the influence of these factors on the results and thereby help extract the true trend from the overall variability in counts.

Observers. Observers can be one of the largest sources of variability of data within a monitoring program. If possible, the same observers should be used throughout the monitoring project but this is rarely possible for long term projects. When new observers are required, training is important to limit the variability. Training must be provided to ensure that all observers are undertaking counts the same way and with equal skill. It is recommended that observers are regularly tested, preferably in a field situation by an experienced observer. This may be done by setting a group of observers the task of counting plants at a particular site at the same time without communication and comparing the results. Differences in identification skills and counting skills will quickly be identified and remedial action can then be taken. It may also be possible to account for observer differences by including observer identity as a covariate. A well articulated monitoring protocol will also help to reduce observer variation.

Useful reference:

Seavy, N.E. and Reynolds, M.H. (2007). Is statistical power to detect trends a good assessment of population monitoring? Biological Conservation 140: 187-191.

5.1.4 Statistical testing

There are numerous methods and packages available for analysing monitoring data and so it is difficult to provide even a basic introduction.

However, if you have managed to set your goals and objectives for the monitoring of the species, have identified potential monitoring site/s, determined the most appropriate monitoring approach and determined which methods you plan to use to monitor your species of interest, then you should be in a good position to match this information to an appropriate statistical model. Ideally you should have considered what statistical models will be used throughout the design phase of the project but if not, then it may be necessary to make adjustments to the project design to ensure it fits the requirements and assumptions of the model.

It is very important to know how you intend to analyse your data **before** you begin collecting it. If you have already collected data without considering its analysis, you will more than likely find that it is only possible to undertake less powerful statistical analyses. This will therefore compromise your ability to detect trends and draw conclusions.

Department of Environment and Conservation (2009) states: “The objective of undertaking a statistical analysis of a dataset is to determine if a trend, or an observed difference, is statistically significant. In a monitoring context this means determining if any observed difference between the treatment and control site occurred by chance, or because those sites really are different. Such analyses will not be required in observational monitoring programs. In an analytical program, statistical significance is required if the monitoring hypothesis is to be accepted or rejected.

Statistics is a broad science and it is not feasible to present the array of available techniques in the current document. It is recommended that a statistician be consulted if a monitoring program is required to show statistical significance. It is critical that this consultation occur during the planning phase of the program in order to ensure that an appropriate program is designed. Statistical analyses cannot overcome the problem of collecting poor data due to an inappropriately designed monitoring program.”

While, as mentioned above, it is not possible to discuss the array of available statistics here, Elzinga *et al.* (2001) writes that two types of analyses “can be identified based on the nature of the management and sampling objectives: parameter estimation (with confidence intervals) for target/threshold objectives and significance test for change/trend objectives”, and these are described below. There are advantages and disadvantages of deciding to use either a trigger/threshold for management (the simpler method of the two), or significance testing to trigger management, and these are detailed below.

Pre-determined threshold:

Elzinga *et al.* (2001, page 150) states: "A parameter is a quantity that describes or characterizes a population. Examples of parameters are the population mean, population variance, population standard deviation, and population coefficient of correlation." Table 1 below shows a summary of statistics from Department of Environment and Conservation (2009), some of which may be used as parameters, or thresholds for triggering management. For example, if research has shown that 5 juveniles per quadrat are required for sustainable recruitment for the species, and burning has been shown to decrease germination[9] and recruitment, then once numbers of juveniles drop below a mean of 5 per quadrat, a change of management, for example altering fire regime by reducing the fire frequency will be implemented.

Another example may include monitoring of an aggressive weed, in which it is decided that once weeds on monitoring transects reach 10% density (our parameter), management (weed spraying) is initiated. Alternatively, in monitoring of a less aggressive weed species, when densities of 30% along a transect are recorded, management may be initiated.

Barker (2001) discusses the use of a threshold, noting that it "…may be the minimum population size needed to buffer a population of rare plants against fluctuations that may threaten its existence. Alternatively, it may be the maximum forest fuel load possible to ensure that the intensity of an unplanned fire does not cause extinction of a threatened species. We monitor to detect when thresholds have been broken."

Advantages of using a pre-determined threshold include that the trigger for management action is clearly defined, and a simple data analysis will reveal whether the trigger has been reached, and will indicate that management should be implemented. Disadvantages of using a pre-determined threshold include that a reasonable level of information will be required in order to determine the appropriate threshold level, however this may also be the case with other statistical methods. Thresholds also have a beneficial role in setting completion criteria for rehabilitation programs and may be linked to statutory conditions. Monitoring of the rehabilitation becomes a tool for the proponent and regulator to measure compliance with the conditions of approval.

Significance Tests:

An alternative to relying on threshold triggers for management involves an approach with a greater degree of analysis, referred to as significance testing. This may involve having an agreed level of certainty that the change observed in the data is a true change, rather than a result of random variation as a result of the sampling undertaken to estimate the parameter of interest. Elzinga *et al.* (2001) and Department of Environment and Conservation (2009) discuss this further. It is likely that, if you do not have a background in statistical analysis, you will need to consult a biometrician/statistician to determine the type of analysis you will need to undertake. Depending on the requirements of the monitoring program, determining whether a statistically significant change has occurred may be a necessary component of monitoring. Undertaking tests for statistical significance may in many cases take a long time to gather data and trigger management, which for some species may result in them declining drastically before a statistically significant change is detected. In such cases, use of a threshold to trigger management may be more appropriate, however every monitoring program will have different requirements, and because testing for statistical significance may be more complex, it does not mean it should not be considered if appropriate.

Table 1: Adapted from Table 15 Chapter 4, A guide to managing and restoring wetlands in Western Australia (Department of Environment and Conservation, 2009): Overview of statistical summary techniques.

[9] It is important to note here that this is an example only; in some circumstances fire may have been absent from the system too long, and may in fact be required to stimulate germination of some species.

Summary Statistic	**Definition**	**Calculation Method**
Mean	Representative of the values being summarised due to being intermediate between the extremes of the dataset.	Divide the sum of the values by the number of values. $\bar{x} = \sum x_i / N$ $\bar{x}$ is the sample mean x_i is each of the values in the set N is the sample size
Median	The value for which one-half (50%) of the observations (when ranked) will lie above that value and one-half will lie below that value.	List all values in ascending order and select the middle point of the list. If the dataset has an even number of values, sum the two middle values and divide by 2.
Mode	The most commonly occurring value in a dataset.	Count the frequency with which each value occurs n the dataset.
Range	The difference between the maximum and minimum value in a dataset.	Subtract the smallest value from the largest value in the dataset.
Standard deviation	A measure of how closely the values in a dataset are clustered around the mean.	$s = [\sum (x_i - \bar{x})^2 / N]^{1/2}$ where s is the standard deviation x_i is each of the values in the set $\bar{x}$ is the population mean. N is the sample size.
Standard error	A measure of how close the *sample* mean is likely to be to the *population* mean.	$se = s / N^{0.5}$ where se is the standard error s is the standard deviation N is the sample size
Percentile	The value below which a given percentage of the data values lie. The *p*th percentile is the value in the dataset which *p*% of values is less than. The 25th, 50th and 75th percentile are called quartiles.	List all values in ascending order and select the value that is ranked *p*% of the way through the list.

5.1.5 Data storage

Data storage is a very important part of the monitoring process, as from this monitoring data will flow analyses and changes to management. It is critical that data be entered into databases, so that those who will analyse the data can access it, and to ensure that data is not lost after investing much time in collecting it.

Data entry involves transporting raw data from field sheets/notebooks into an electronic form such as a database. Quality assurance and control are important during the data entry process. DeBacker *et al*. (2004) suggest that where electronic data forms and databases are used for data entry, features such as drop-down lists and value limits may ensure minimal errors. Only valid names or measures should be allowed to be entered and spelling mistakes must be eliminated. Databases for flora monitoring data should be capable of receiving updates from the WA Herbarium to ensure name changes are addressed.

Data collected according to this protocol should be entered as soon as possible after collection into databases (for example the Site Species database {which has capacity to store quadrat and transect data, community descriptions, soil information, coordinates, photograph information and many other environmental site details}, the Threatened and Priority Flora database, the TEC database, and monitoring partner group databases). Data should be saved and stored according to the naming conventions detailed in Standard Operating Procedure 1.4: File Management: Naming Convention, directory structure, storage and creation of metadata for spatial and aspatial data; (http://www.dec.wa.gov.au/content/view/5389/2239/), and copies of files should be sent to the Flora Administrative Officer at Species and Communities for backup storage.

Data should be entered by people familiar with the data, to help minimise errors, as familiarity with the data allows errors to be detected and easily corrected. Where edits to data are required, information can be replaced with the correct detail on hardcopy datasheets, in order to document decisions made about the data.

GPS points for quadrat and transects locations should be entered into the databases and converted into a GIS layer for use (for example in ArcMap9) using available linking tools. Location data can be verified for accuracy in relation to survey area boundaries.

As noted in DeBacker *et al*. (2004), data verification should immediately follow data entry and involve checking the accuracy of electronic records against the original source (eg. paper field records). Once the electronic data have been verified as accurately reflecting the original field data, the paper forms can be archived and the electronic version used for all subsequent data activities.

It should be noted that storage of data in local databases alone may prevent access to data by those who may, for example, require access to the data years after a monitoring program has been completed. Monitoring data should where appropriate be stored both locally and in a central database to ensure that Departmental information is backed up, is accessible and able to be utilized and analysed.

5.2 Reviewing and refining monitoring

The monitoring program or plan that is developed should be subjected to peer review, by a statistician or biometrician, by DEC experts with a good understanding of monitoring and, where applicable, by relevant experts at universities. In particular, proposed monitoring design and data analysis (see section 5.1) should be peer reviewed prior to establishing monitoring. Peer review will allow the incorporation of expert input, and can assist in producing a more effective and successful monitoring program. Small adjustments to methodology at the planning stage of a project can prevent larger problems later in the project. Sufficient time should be provided for review, so that modifications can be incorporated ahead of field work, and documented in the associated monitoring protocol.

6 Preparation for field work

Preparation for field work may involve gathering or producing site specific maps, discussing monitoring with local DEC staff, landholders and local government, to provide site specific knowledge. Field reconnaissance is also likely to be required when developing the monitoring program.

6.1.1 Collecting permits and licenses

Various licences that may be required prior to establishing monitoring in the field may include those detailed at http://www.dec.wa.gov.au/management-and-protection/plants/flora-licensing/taking-or-collecting-flora.html. Permits and licenses may include:

- Scientific of Other Prescribed Purposes License for undertaking Research;
- Permit to Take Rare Flora if sampling or disturbance of Rare Flora may occur;
- Permission to enter the land from the relevant land owner or manager (for non-DEC staff, a CALM Regulation 4 Permit is required to undertake research under the CALM Act);
- Fire permits (if undertaking burning trials); and
- Permit to enter Disease Risk Area (DRA) subject to dieback quarantine. This should be

discussed with the district DEC office for the subject area prior to access to the site.

6.1.2 Site access

Where monitoring sites are on private land, landholders need to be contacted well in advance of monitoring, and prior to any reconnaissance visits, to approve access to sites.

Site access issues, such as dieback restrictions, lack of suitable tracks, muddy sites after rain, sandy sites need to be considered.

If remote, the distance of accommodation from the site(s) needs to be considered, as this can greatly affect the time available for field work.

6.1.3 Reconnaissance Survey

Field reconnaissance visits to potential monitoring sites need to be undertaken, to confirm suitability for of sites, and to determine any potential issues that may need to be resolved (for example site access issues or lack of suitable habitat for survey).

6.1.4 Communication and Safety

Appropriate spare equipment (tyres), recovery gear, hydraulic pump, shovel, water and fuel jerry cans, communication equipment (Next G phone, UHF/VHF radio or satellite phone and car chargers) and safety equipment (first aid kit, fire extinguisher) may be required. A complete list of all safety equipment required should be prepared and appropriate equipment sourced and checked prior to field work.

6.1.5 Field equipment

Depending on the agreed monitoring method, some of the following suggested field equipment may be required for field work when establishing/undertaking monitoring:

- Printed maps with directions and proposed sites delineated;
- Smaller detailed maps for use in the field and for discussions with landholders;
- Plant collection and other permits (refer SOP Collection of Herbarium Specimens (in draft));
- Secateurs;
- Plant tags;
- Small paper bags/envelopes;
- Plants presses;
- Newspaper and cardboard corrugates;
- Pens, pencils, permanent thick black marker pens;
- Survey recording sheets (if not using Personal Data Assistant {PDA});
- Threatened and Priority Flora Report Forms (TPRF);
- TEC Occurrence Report Forms;
- Bushland Plant Survey recording sheets;
- Transect/quadrat data recording sheet;
- Digital camera, memory card, batteries;
- PDA with GPS (note if using PDA, electronic data sheets should be loaded);

- GPS (ideally DGPS);
- Survey pegs (1 metal and 3 plastic for quadrats, 2 metal for transects);
- Hammer;
- 50m measuring tapes;
- Optical square;
- Small blackboard and chalk;
- Point intercept device (long metal pin);
- Plant specimen books (for the collection of small pieces of plant material for each quadrat/transect); and
- 3M 'breathable' sticky tape for specimen books.

6.1.6 Relevant Standard Operating Procedures

Several Standard Operating Procedures have been developed that may assist with flora/vegetation monitoring; http://www.dec.wa.gov.au/content/view/5389/2239/

7 Monitoring in Western Australia

Much monitoring of flora and vegetation occurs in Western Australia, some references for which are provided below. These may be of relevance when developing flora or vegetation monitoring in Western Australia.

Flora/vegetation monitoring

- Barrett, S. 2001. *Monitoring of aerial phosphite applications for the control of Phytopthora cinnamomi in the Albany district.* Phytopthora in Forests and Natural Ecosystems. 2nd International IUFRO Working Party Meeting 7.02.09 Meeting, Albany, W. Australia 30th Sept – 5th Oct 2001.

- Gibson N, Keighery GJ, Lane JAK (2004). *Five years monitoring of the Lake Muir-Unicup wetland system, south western Australia*. Journal of the Royal Society of Western Australia 87, pp. 29-33

- Lyons MN, Halse SA, Gibson N, Cale DJ, Lane JAK, Walker CD et al. [Mickle DA] (2007). *Monitoring wetlands in a salinizing landscape: case studies from the wheatbelt region of Western Australia*. Hydrobiologia 591, pp. 147-164

Effectiveness of weed control

- Brown, K and Clarke, V.T. (2009). Monitoring Protocol: Weed control within Brixton Street Wetlands Herb Rich Shrublands in Clay Pans (FCT 8) Threatened Ecological Community. Version Number 1.0.(June 2009). Prepared for the Resource Condition Monitoring – Significant Native Species and Ecological Communities Project, Department of Environment and Conservation. http://www.dec.wa.gov.au/content/view/5386/2237/

Population characteristics;

- Harris, A and Yates, C. 2003. *Population characteristics of Grevillea batrachioides (Mt Leseur Grevillea).* Unpublished report to Western Australian Threatened Species and Community Unit (WATSCU), June 2003. Department of Conservation and Land Management.

- Harris, A and Yates, C. 2003. *Population characteristics of Grevillea humifusa (Spreading Grevillea).* Unpublished report to Western Australian Threatened Species and Community Unit (WATSCU), June 2003. Department of Conservation and Land Management.

- Harris, A and Yates, C. 2003. *Population characteristics of Eremophila scaberula (Rough Emu Bush).* Unpublished report to Western Australian Threatened Species and Community Unit (WATSCU), June 2003. Department of Conservation and Land Management.

- Harris, A and Yates, C. 2003. *Population characteristics of Gastrolobium hamulosum (Hook Point Poison).* Unpublished report to Western Australian Threatened Species and Community Unit (WATSCU), June 2003. Department of Conservation and Land Management.

Guidelines for Terrestrial Vascular Flora and Vegetation Surveys for Environmental Impact Assessment are also currently being drafted by the Department of Environment and Conservation. The guidelines are related to EPA Guidelines for Flora and Vegetation Survey which can be found here http://www.epa.wa.gov.au/docs/1839_GS51.pdf. and will contain detail on requirements for flora and vegetation survey. Although these have been developed for flora and vegetation survey, they may contain information relevant to flora and/or vegetation monitoring (for example timing of field work, sampling methods) and may need to be consulted prior to development of monitoring design.

Threatened Ecological Community monitoring

Monitoring protocols have been developed for a number of Western Australian Threatened Ecological Communities (TECs) and are available at http://www.dec.wa.gov.au/content/view/5386/2237/. These include monitoring protocols for predominantly plant based TECs (involving monitoring of, for example *Phytophthora* dieback, or effectiveness of weed control in a TEC), and a number of monitoring protocols for TECs that are not plant based (for example monitoring of tufa formations, and of mound spring invertebrate communities).

Wetland Monitoring

Guidance and instruction for monitoring wetlands is provided in Chapter 4 - 'Monitoring wetlands', prepared by G. Daniel, in 'A guide to managing and restoring wetlands in Western Australia., Department of Environment and Conservation (2009), Western Australia. (http://www.dec.wa.gov.au/content/view/2963/1946/).

8 References

Anzecc. 1999. National framework for the management and monitoring of Australia's native vegetation. Australian and New Zealand Environment and Conservation Council, Department of Environment and Heritage, Canberra.

Barker, P. 2001. *A Technical Manual for Vegetation Monitoring*. Resource Management and Conservation, Department of Primary Industries, Water and Environment., Hobart.

Brown, K. and Brooks, K. (2003). *Sparaxis bulbifera* (Iridaceae*) invading a clay based wetland on the Swan Coastal Plain – control methods and observations on the reproductive biology*. In: Plant Protection Quarterly Vol. 18(1).

DeBacker, M.D., A.N. Sasseen, C. Becker, G.A. Rowell, L.P. Thomas, J.R. Boetsch, and G.D. Willson (2004) *Vegetation Community Monitoring Protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program*, Wilson's Creek National Battlefield, Repubic, Missouri. 40 p. plus appendices.

Department of Environment and Conservation. 2009. 'Monitoring wetlands', in *A guide to managing and restoring wetlands in Western Australia*, Prepared by G. Daniel, Department of Environment and Conservation, Western Australia.

Duncan, M. and Coates, F. 2006. Monitoring Nationally Threatened Flora in Victoria. Published by the Victorian Government Department of Sustainability and Environment (DSE) Melbourne, December 2006.

Elzinga , C.L., Salzer, D.W. , Willoughby, J.W. and Gibbs, J.P. 2001 *Measuring and Monitoring Plant and Animal Populations.* Published by Blackwell Science Pty, Ltd. Carlton, Victoria.

Field, S.A., O'Connor, P.J., Tyre, A.J. and Possingham, P.P. 2007. *Making monitoring meaningful*. Austral Ecology. 32, 485–491

Given, D, R. 1989. *Monitoring of Threatened Plants.* In Craig, B., ed. Proceedings of a Symposium on Environmental Monitoring in New Zealand with emphasis on Protected Natural Areas. Published by Department of Conservation, Wellington.

Harris, A and Yates, C. 2003. *Population characteristics of Eremophila scaberula (Rough Emu Bush) A framework for monitoring change*. Unpublished report to the Western Australian Threatened Species and Communities Unit, Department of Conservation and Land Management.

Hurlbert, S.H., 1984. *Pseudoreplication And The Design Of Ecological Field Experiments*. Ecological Monographs, Vol. 54, No. 2. (Jun., 1984), pp. 187-211.

Oakely, K.L., Thomas, L.P. and Fancy, S.G. 2003. *Guidelines for long-term monitoring protocols*. Wildlife Society Bulletin 31(4): 1000-1003.

Stack, G. 2009. Threatened and Priority Flora Report Form Field Manual. Version 1.0 (December 2009). Prepared for Significant Native Species and Ecological Communities – Resource Condition Monitoring Project, Department of Environment and Conservation.

9 Appendices

Appendix A: Pre-monitoring development considerations

Appendix B: Example checklist template for monitoring

Appendix C: Threatened and Priority Flora Report Form

Appendix A: Pre-monitoring development considerations

Examples of information that may need to be gathered, or results of research provided prior to or during development of monitoring and definition of the monitoring question are provided below - note these are *not* monitoring questions;

- How many populations of the species/taxa are known to occur?
- What phenological data is known about the taxa/species (for example, is the season and specific timing of flowering/fruiting known, does the plant has active growth stages or experiences dormancy, how long does the plant live)?
- What is the reproductive method of the plant? (for example, does the species resprout from tuber, or does it germinate from seed)?
- What is the life cycle of the plant (perennial/annual)?
- What is the growth form of the plant (shrub, tree, grass, herb etc)?
- Is mapping (using GPS/DGPS) of the location of individual plants required?
- Is demographic data (height, fruiting/flowering/plant age) known/required for the population?
- Would quadrats/transects/traverses be the appropriate for monitoring the features of interest in the subject species?
- Would tagging of individual plants be feasible/assist in collection of data necessary for monitoring this species?
- What is the soil type(s) of the monitoring area(s), and is detailed soil analysis required prior to/as part of monitoring?
- What is the vegetation type and plant community description, and what NVIS level http://www.environment.gov.au/erin/nvis/publications/avam/section-2-1.html is the vegetation described at?
- What is the vegetation condition, and how does it relate to the VAST http://www.daff.gov.au/__data/assets/pdf_file/0007/96982/vast_report.pdf system?
- Does the species vary between populations (for example in morphology, in distribution - sparse/dense clustering?)

Susceptibility to plant pathogens

- Is the species/taxa known to be susceptible to plant pathogens?
- Has the species/taxa responded to phosphite or other spraying/injection trials, and if so, how?
- Are juveniles known to more susceptible to the pathogen than adult plants?

Hydrology

If the monitoring question is thought to be related to altered hydrological regimes, bore data from existing bores will need to be gathered to understand hydrological (surface and ground water) flows, and water quality. New bores may need to be established, the timing, placement and costs of which need to be carefully considered, after consulting with a hydrologist. Hydrological expertise can be provided by hydrologists in the department, either in the regions or in Natural Resources Branch (NRB), or by the Department of Water.

Questions that may need to be considered prior to establishing flora monitoring with hydrological considerations include;

- What are the water quality and quantity requirements of the taxa/species?
- What bores exist within the site, or in proximity
- What water quality information exists?
- What hydrologically pertinent activities occur in or near the site that may be of influence?
- What type/how many/location of bores might be required to answer the monitoring question?
- Is medium or long term climate data available?
- Is increasing salinity thought to be negatively impacting the species?

The link to Department of Water hydrological information is:

http://www.water.wa.gov.au/Tools/Monitoring+and+data/default.aspx and the contact address is waterinfo@water.wa.gov.au and the Department of Agriculture and Food contact regarding Agbores is dbennett@agric.wa.gov.au. NRB is in the process of setting up a hydrological database, and expect it to be functional by the end of 2010.

Recruitment

If the monitoring question is related to, for example recruitment of a species, monitoring may need to include mapping of individuals at certain times (for example at expected germination and fruiting times). Collection of seed for viability testing may need to occur prior to monitoring.

With reference to the absence of younger plants in the population, Keith *et al*. (2002, cited in Harris and Yates, 2003) state that "In many plant taxa germination and recruitment occurs predominantly in the first few years following a fire and very rarely in inter-fire periods". From Witkowski & Lamont (1997); Bond and Midgley (2001) (cited in Harris and Yates, 2003, page 6) "Persistence of non-sprouting species killed by fire is entirely dependent on the recruitment of seedlings from a soil or canopy seed bank. In sprouting species the seed bank is not as vital to persistence in the short term."

- Does the species/taxa resprout from a tuber?
- Does the species/taxa germinate from seed?
- What germination/resprouting events have been recorded?
- Does the species reproduce by underground runners etc? (Given 1989)
- What phenological data is known about the taxa/species (flowering/fruiting time)?
- Are pollination processes known and are these likely to have been inhibited/disturbed?
- What species demography data is available?
- Are particular aged plants of the species/taxa absent in the population?
- Does the plant store seed in the soil/plant?
- Have seed been collected/stored/subjected to germination tests?
- Is there evidence that suitable pollinators have been active, or are absent?
- Does each plant produce many/few inflorescences?
- Is the species known to have dormancy mechanisms, and has research on breaking this dormancy been undertaken?

Grazing

- Is the species subject to grazing from introduced species?
- Have grazing exclusion plot trials been established?
- Have other potential causes of plant absence/decline been considered (that is, is it possible that grazing is not impacting on the species?)
- Have juvenile plants been observed to have germinated/sprouted?

Competition with weed species

The monitoring question may involve the assumption that invasion of weed species are out-competing a significant native species, and therefore decreasing its density.

- What weed controls have previously been used, and what was the effect?
- What is known about the weed species and how it can be killed/removed?

Fragmentation

- Is the species/population fragmented (ie non continuous habitat) and is this fragmentation natural or the result of land clearing?
- Is there likely to be loss of genetic diversity/increased inbreeding?
- Might edge effects/altered disturbance regimes (fire) be resulting in changes to pollination/predation/competition/herbivory/pathogens?

Changes in vegetation cover

- Is a health measure for individual plants required?
- Are length, width (and height) measures required?

- Would establishing a vegetation quadrat help answer the monitoring question, or would tagging individual plants be more suitable?
- What quadrat size is appropriate to measure the desired change?
- Would GPSing/DGPSing plants and/or drawing a mud map help answer the question?
- Would photographic monitoring be suitable?
- If measuring plant foliage cover within a quadrat, what method of cover classification will suit the type of analysis planned? (Braun-Blanquet etc)?

Fire frequency

- How does the species/taxa respond to fire?
- When does the species reach reproductive maturity?
- Does the species/taxa resprout from an underground organ, such as a tuber or corm?
- Does the species/taxa germinate from seed?
- What germination/resprouting events have been recorded?
- What is the known fire history of the site (including frequency, intensity, season and patchiness)?
- Is there existing data about the response of the species/taxa to timing of fire, and intensity of fire?
- How does associated species/community respond to fire?

Barker (2001, page 61) details the considerations for monitoring of burning, including:

- Time since last fire
- Fuel loads
- Fire intensity
- Plant populations
- Soil seedbank
- Meteorological data

Remote sensing

- What remote sensing data is available?
- Is the subject species thought to be being affected by a factor that can be monitored using remote sensing? (See Chirici, G. and Corona, P. (2005) http://www.sisef.it/forest@/show.php?id=305&action=full with regard to post-fire monitoring using remote sensing).

Plant Interactions (from Duncan and Coates, 2006).

- What is the species relationship with pollinators?
- Is natural pollination occurring?
- What is the species relationship with predators?
- Is predation of leaves, flowers, seed pods, new growth, or whole plants occurring?
- How abundant are pests, predators and competitors?
- Does the species have a symbiotic relationship? for example mycorrhizal fungi

Appendix B: Example checklist template for monitoring

An example of a checklist template for required elements that need to be considered when developing a monitoring project, from Barker (2001, page 9)

Table 3.1: A project proforma containing the fields that are mandatory for a monitoring project.

Project title				**Project leader**		
Date						
Tenure			**Land manager**			
Who knows the location and details of this project?						
Monitoring question?						
Treatment(s)?						
Date applied			Location of datum			
			Easting		Northing	
Number and size of quadrats						
	Number	Size	Number	Size	Number	Size
Control						
Treatment						
Distribution of quadrats						
Random	How and why stratified?			How and why systematic?		
Arrangement of quadrats (diagram: include distances and directions to numbered quadrat marker pegs). For transects, specify whether quadrats are to left or right of transect line.						
Re-measurement (annual, 5 years?)						
Where is the data stored?						
Where are back up data?						
What is it stored on?						
Description of intended analysis						
Name of the statistician who looked at the design						
Description of the anticipated trigger for a management response						
**Attach the decision support system to this hardcopy						

Appendix C: Threatened and Priority Flora Report Form

Department of Environment and Conservation
Our environment, our future

Threatened and Priority Flora Report Form

Version 1.0 April 2009

Please complete as much of the form as possible, with emphasis on those sections bordered in black.

TAXON: ______ **TPFL Pop. No:** ______
OBSERVATION DATE: / / ______ **CONSERVATION STATUS:** ______ New population ☐
OBSERVER/S: ______ **PHONE:** ______
ROLE: ______ **ORGANISATION:** ______

DESCRIPTION OF LOCATION (Provide at least nearest town/named locality, and the distance and direction to that place): ______

Reserve No: ______
DEC DISTRICT: ______ **LGA:** ______ Land manager present: ☐

DATUM: GDA94 / MGA94 ☐ AGD84 / AMG84 ☐ WGS84 ☐ Unknown ☐

COORDINATES: (If UTM coords provided, **Zone** is also required)
DecDegrees ☐ DegMinSec ☐ UTMs ☐
Lat / Northing: ______
Long / Easting: ______
ZONE: ______

METHOD USED:
GPS ☐ Differential GPS ☐ Map ☐
No. satellites: ______ Map used: ______
Boundary polygon captured: ☐ Map scale: ______

LAND TENURE:
Nature reserve ☐ Timber reserve ☐ Private property ☐ Rail reserve ☐ Shire road reserve ☐
National park ☐ State forest ☐ Pastoral lease ☐ MRWA road reserve ☐ Other Crown reserve ☐
Conservation park ☐ Water reserve ☐ UCL ☐ SLK/Pole ______ to ______ Specify other: ______

AREA ASSESSMENT: Edge survey ☐ Partial survey ☐ Full survey ☐ Area observed (m²): ______
EFFORT: Time spent surveying (minutes): ______ No. of minutes spent / 100 m²: ______
POP'N COUNT ACCURACY: Actual ☐ Extrapolation ☐ Estimate ☐ Count method: ______ (Refer to field manual for list)
WHAT COUNTED: Plants ☐ Clumps ☐ Clonal stems ☐

TOTAL POP'N STRUCTURE:	Mature:	Juveniles:	Seedlings:	Totals:
Alive				
Dead				

Area of pop (m²): ______
Note: Pls record count as numbers (not percentages) for database.

QUADRATS PRESENT: No. ______ Size ______ Data attached ☐ Total area of quadrats (m²): ______

Summary Quad. Totals: Alive				

REPRODUCTIVE STATE: Clonal ☐ Vegetative ☐ Flowerbud ☐ Flower ☐
Immature fruit ☐ Fruit ☐ Dehisced fruit ☐ Percentage in flower: ______ %

CONDITION OF PLANTS: Healthy ☐ Moderate ☐ Poor ☐ Senescent ☐

COMMENT: ______

THREATS - type, agent and supporting information: Eg clearing, too frequent fire, weed, disease. Refer to field manual for list of threats & agents. **Specify agent** where relevant. Rate current and potential threat impact: N=Nil, L=Low, M=Medium, H=High, E=Extreme. Estimate time to potential impact: S=Short (<12mths), M=Medium (<5yrs), L=Long (5yrs+)	Current impact (N-E)	Potential Impact (L-E)	Potential Threat Onset (S-L)
•	____	____	____
•	____	____	____

Please return completed form to DEC, Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983
RECORDS: Please forward to **Administrative Officer, Flora,** Species and Communities Branch.
Record entered by: ______ **Sheet No.:** ______ **Record Entered in Database** ☐

Department of Environment and Conservation
Our environment, our future

Threatened and Priority Flora Report Form

Version 1.0 April 2009

HABITAT INFORMATION:

LANDFORM:	ROCK TYPE:	LOOSE ROCK:	SOIL TYPE:	SOIL COLOUR:	DRAINAGE:
Crest ☐	Granite ☐	(on soil surface; eg gravel, quartz fields)	Sand ☐	Red ☐	Well drained ☐
Hill ☐	Dolerite ☐		Sandy loam ☐	Brown ☐	Seasonally inundated ☐
Ridge ☐	Laterite ☐	0-10% ☐	Loam ☐	Yellow ☐	Permanently inundated ☐
Outcrop ☐	Ironstone ☐	10-30% ☐	Clay loam ☐	White ☐	Tidal ☐
Slope ☐	Limestone ☐	30-50% ☐	Light clay ☐	Grey ☐	
Flat ☐	Quartz ☐	50-100% ☐	Peat ☐	Black ☐	
Open depression ☐	Specify other: ________		Specify other: ________	Specify other: ________	
Drainage line ☐					
Closed depression ☐					
Wetland ☐					

Specific **Landform** Element: ________
(Refer to field manual for additional values)

CONDITION OF SOIL: Dry ☐ Moist ☐ Waterlogged ☐ Inundated ☐

VEGETATION CLASSIFICATION*:
Eg: 1. Banksia woodland (B. attenuata, B. ilicifolia); 2. Open shrubland (Hibbertia sp., Acacia spp.); 3. Isolated clumps of sedges (Mesomelaena tetragona)

1. ____________________
2. ____________________
3. ____________________
4. ____________________

ASSOCIATED SPECIES:
Other (non-dominant) spp ____________________

* Refer to field manual for NVIS Structural Formations. The TPFL database will accommodate data for up to four vegetation layers with up to two dominant species in each.

CONDITION OF HABITAT: Pristine ☐ Excellent ☐ Very good ☐ Good ☐ Degraded ☐ Completely degraded ☐

COMMENT: ____________________

FIRE HISTORY: **Last Fire**: Season/Month: ________ Year: ______ **Fire Intensity:** High ☐ Medium ☐ Low ☐ No signs of fire ☐

FENCING: Not required ☐ Present ☐ Replace / repair ☐ Required ☐ Length req'd: ________

ROADSIDE MARKERS: Not required ☐ Present ☐ Replace / reposition ☐ Required ☐ Quantity req'd: _______

OTHER COMMENTS: (Please include recommended management actions and/or implemented actions - include date. Also include details of additional data available, and how to locate it.)

____

SPECIMEN: Collectors No: ________ WA Herb. ☐ Regional Herb. ☐ District Herb. ☐ Other: ________

ATTACHED: Map ☐ Mudmap ☐ Photo ☐ GIS data ☐ Field notes ☐ Other: ________

COPY SENT TO: Regional Office ☐ District Office ☐ Other:

Submitter of Record: ________________ Role: ______________ Signed: ____________ Date: / /

Please return completed form to DEC, Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983

RECORDS: Please forward to **Administrative Officer, Flora,** Species and Communities Branch.

Record entered by:____________________ **Sheet No.:**__________ **Record Entered in Database** ☐