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Native Vegetation Condition Assessment and Monitoring Manual for Western Australia

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CONTENTS

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FORWARD TO THIS VERSION

This is both the first draft and the first iteration of a document that may form a general template. It makes a first pass at gathering disparate components in a manner that has regard for the way that much assessment of vegetation has been conducted in WA to the current date. It will undoubtedly benefit from subsequent iteration, and editing, and clear, and constructive contributions based on verified processes and/or related field experience and field use. In particular the list of attributes, some internal descriptors within each attribute, and the inter-relationship and arrangement of attributes into groups or attribute clusters, may be better refined to suit general use.

Some parts are rudimentary, others are better refined.

This version has been compiled to:
1) emphasize polarities or extremes within attributes, so that these form basic reference points. This suits assessment of trends in processes or threats. In addition some aspects of patchiness are incorporated. This may need to be better developed, so that within an attribute in a given state there is a fundamental question - “although the site is mainly like this is there an element of its antithesis?” (That is, in burnt is there unburnt, amongst litter is there bare surface, with thicket is there open space, or with senescence is there young growth?).
2) have a uniform, familiar, arrangement to the scales
3) align with two existing scales (one state, one national) in order to:
i) accommodate a degree of cross-comparison or compatibility with much existing data ii) allow a single basic attribute scale to be used where it is felt this is expedient or less daunting. This helps accommodate different levels of experience
4) incorporate most of the attributes that commonly arise in such schemes consequently it can be viewed as:

- *a checklist of broad ecological factors or their dysfunctional expression as threats*
- a means of hedging bets so that options are left open in terms of available attributes^
- a resource to help supplement other work in a selective fashion if required

5) allow supplementation with attributes where found necessary
6) *the two preceding points decrease the risk of focusing on a select set of attributes which may not cover those factors that change and/or may not provide sufficient early warning of adverse trends and potential harmful impacts*. This is important in the case of a single visit to assess state and likely trend, and for repeated monitoring visits to assess actual trend.
7) benefit from further refinement (especially in terms of operation, and of further review and incorporation of ecological processes as better foundation). Some of the more rudimentary attributes require augmentation they are little more than pigeon holes at present.
8) have an open arrangement so that the attribute’s components are self-evident

9) rely on a minimum of "weighting" and for such weighting as there is to be openly reflected in the descriptions of attribute components. This stands in contrast to formula-based weightings that tend to compound and are consequently less obvious.

> ***A descriptive account of the attribute has one fundamental advantage over anything that is based on densities and cover namely it can be applied over large areas because it is relative. This approach side-steps the problem of variation in such measures between vegetation types and regions***.
> ***In other words a small set of absolute measures is unlikely to be widely applicable***.
> However, because the layout is explicit it may be possible to construct formula-based weightings should it prove essential though this is not advocated here. This may also leave options open^.

10) probably benefits from an element of double accounting where aspects of ecological processes overlap, as they do in nature, eg the concept of patchiness links fire, and thickets or open areas. There is some merit in this approach, which is used to advantage in psychometric testing, where different ways of re-presenting the same question helps to ensure that underlying traits rather than a premeditated or biased answer is given.
11) because it can potentially take into account multiple attributes (or factors) is able to express a sense of cumulative load to some degree. For example although there may be one strong factor contributing to Woylie decline it is the net load from drought (cum "climate change"), fragmentation of landscapes and habitat (especially removal of prime habitat disruption to food source cycles and networks), altered predation, altered fire regimes, and likely other factors, that ultimately takes its toll.
11) may potentially be rated at a number of scales if so desired (viz. quadrat, array, locality & (with inclusion of the requisite attributes) landscape/catchment scales)
12) provide some substantiation to most attributes and a *basic introduction to the ecological aspects*, in other words it recognizes that the levels of experience of the assessors may vary.
13) encourage some consistency of assessment. That is because the components under each score are listed and tend to rely on more than one character. Consequently, if it is used strictly, a degree of individual variation *may* be constrained. This will tend to require time. This has the consequence that the descriptive guide is relatively large, and may be best suited to a flip chart arrangement. On the other hand the score sheets only amount to a few pages in full.

The main requirements include:
Time: Please note that no means of assessment can bypass the simple fact that an assessment takes time. The more time that is put into the process the better the result.
Similarly the more time devoted to training and to getting experience of and exposure to reference points the better.
Willingness: It is essential to carefully examine the site and then to consider every sub-point in an attribute. The observer needs to diligently observe and critically appraise the site.

RECOMMENDATIONS:

The next steps are:
A) to refine the document
B) to develop supplementary field or resource sheets for attributes where these are necessary, or where it may help in the early stages of training and orientation. These would be along the lines of those accompanying feral animals or fire.
C) a year of selective use in a region for refinement of procedure and consolidation of sites based on themes. Then extend to a couple of regions for a couple of purposes, then review, over *at least* two years. This can then gradually dovetail into extension in select areas. In the latter stages workshops will help this process.
D) compilation of support/ resource documents at a sub-region level. Such material needs to include: weeds focal species and vegetation type (“communities”) basic structure types (using Beard as a rough guide and not a benchmark) vegetation habitat that requires fire exclusion and current general threats. Much of this material may well exist and may just require linking, abridging, or compilation.
E) better linkage of condition attributes to ecological principles by further review of the literature and departmental findings.

Note that the contemporary selection of attributes is fairly arbitrary:

- Substantiation is very limited and their linkage to ecological principles is not explicit
- The notion that attributes are surrogates for biodiversity seems to be embedded as dogma and jargon, and this is a concern as most attributes seem to more directly or better represent ecological processes or factors.

F) regardless of the final format it is likely that occasional calibration sessions will help ensure that drift from an agreed interpretation is moderated.
G) a pivotal element, and the point where many initiatives fail, is a failure to promote ownership and engagement. In this regard aspects such as C) & F) above are important because they serve as an introduction and a means of developing familiarity with the overall initiative.
H) to refine and possibly devolve an abridged attributes guide to support the rating tables and with more informal text that highlights things to look for (most of the elements exist in this text);
I) to (in support of step H) incorporate many of the photos from the trial sites that help inform the attributes. The photos are a valuable resource because they were taken with such use in mind, and many will help give an idea of the spectrum of state for some attributes. They do not fully cover all aspects of all attributes and ideally supplementary photos from equivalent bioregions would be acquired or taken;
J) to concentrate on assessment of one area with one major vegetation type in order to afford the best opportunity of gradually coordinating assessment of groundwork & remote-sensing & commencing the process of finding measures that correlate and better link the two procedures. Conversely changing the area of focus will likely create more noise & uncertainty.

The selection of an interim basic set of site attributes.

A) In section 5.6.1 an interim basic set of site attributes is highlighted in green. This comprises 10 firm (including a general disturbance attribute) or up to 21 likely (excluding a general disturbance attribute).
B) The range of candidate attributes comes from multiple sources including an identification of the components in the Keighery and VAST scales.
C) The selection is significantly informed by a few key sources as shown in the interim site attribute table. There is no simple perfect agreement. Condition schemes tend to have their foundations in non-disturbance attributes. Consequently VAST and the Southern My Lofty Ranges scheme rely on: i) composition ii) architecture iii) maintenance iv) regeneration/resilience and then iv) disturbance. While the threats which face management at community and regional levels first emphasize disturbance (TEC/PEC threats, and DEC Regional Plans threats).
D) Without using almost all available and applicable attributes the selection of attributes will remain to some degree arbitrary. This is for a number of reasons including the:
i) exclusion of some attributes by default due to the conceptual difficulty of making some environmental and habitat factors amenable to qualitative assessment (this may be part of the reason that some have been avoided to date). A larger set of attributes may help in this regard because it captures some of the less tractable attributes by virtue of a modicum of overlap
ii) bias towards the topical parts of the ecosystem (especially forests - forest specific attributes are unlikely to translate to general application without adaptation)
iii) the question of scale - to be truly meaningful assessment may need to be at the site, locality and landscape scales. This implies associated costs, for instance incorporating the first two scales requires time, diligence and orientation in its own right and
iv) the state of knowledge of the ecology.
E) Ideally the attributes and the choice of attributes would be purely founded on ecological principle. In which case it could firmly reflect and honour the steady and progressive advance in the state of knowledge of the ecology (from integrative initiatives such as fungal biodiversity survey and the Forestcheck multidisciplinary monitoring). Elements of these have been given some regard in devising attribute scales, but with time this may need to be revisited and further developed.
F) Provisional attributes are included to see if they are workable - for example fire and stability (which may need a counterpart in the form of an overall disturbance scale). *Both require the assessor to develop a sense of process and pattern - <u>strong recurrent themes</u> that emerge the more one investigates the range of potential attributes, and the underlying ecology*.

QUALIFICATION: the selection of attributes nominated above does not imply comprehensiveness, or that other attributes (including some not covered by the broader list), do not have merit or current application in specific or broad circumstances. Every effort has been made to create *draft* attribute scales that are broad in nature however, there is no guarantee that they will be applicable in every situation.

1) INTRODUCTION

1.1) MAINTENANCE OF VEGETATION - CYCLICAL VERSUS DIRECTIONAL (OFTEN ADVERSE) CHANGE

A good introduction is provided in two existing references as follows:

Change is a natural feature of native vegetation. "Individual plants grow, flower and shed seed. Plants age and die, to be replaced by others, either from seed or by vegetative growth. Changes in a plant community may be cyclic or directional. Broadly speaking, natural cycles in the plant community may be maintained by recurring events such as fire or flood. After these, species already in the habitat, perhaps as soil-stored seed, are recruited and the vegetation gradually regains its former structure. Depending on the sequence of events and weather conditions, slightly different combinations of species may be favoured, but the plant community is essentially self-maintaining. Directional change may be induced by habitat disturbance which alters soil and water properties, and allows recruitment of species not native to the habitat, in particular, exotic weeds. Such changes generally lead to bushland deterioration." (Benson and Howell 1990). The extent of the change will be dependent on the nature, extent, and duration, of the disturbance, and the associated pace of change.

"Activities that adversely affect the self-maintenance of bushlands are commonly called disturbance factors. Such factors include partial clearing, fragmentation, selective removal of species (for example, timber cutting, wildflower picking, mowing), dieback, fire regime, 'enrichment planting' (that is planting of species not found in that plant community), weed invasion, animal impact (horses, foxes, rabbits, cats, dogs), soil movement (both removal and dumping), changes in water regimes (flooding, drainage and watering), rubbish dumping, mining (particularly mining for roadworks, grazing (stock, overgrazing by native mammals), proliferation of tracks (fire-breaks and walk trails), off-road vehicle use, use of service corridors (for electricity, gas, roads and water), fertiliser drift and pesticide or nutrient influx along waterways."

"Not all of these factors have the same level of impact but generally they are interrelated, the presence of one type of disturbance leading to further disturbance. The observed disturbance is most often the cumulative result of a series of compounding disturbance factors."

"An assessment of disturbance, in relation to the ability of the bushland to self-maintain, has been used as the basis of defining condition ratings for plant communities. …" Department of Environmental Protection (2000).

1.2) ISOLATING THE SIGNS AND SYMPTOMS OF CHANGE

This sets the stage for the central conundrum/s in condition analysis - 'How is condition and especially directional change (or an adverse trend) in condition to be separated from characteristics of a vegetation type that have little to do with condition in other words how are symptoms of adverse change to be *separated from characteristics of identity (and the usual processes which maintain identity)?*'

There is no easy answer to this. It *requires due diligence* in terms of assembling sufficient background (including the current & historical context) on the vegetation type in question to be able to make an *informed judgement* of how it fits into a spectrum of states. Where the vegetation type is very small the next closest equivalent type may have to suffice.

Overall this can be approached in a number of ways. They all have to do with building a strong context for the vegetation and a strong sense of its identity. The most objective is to assess full plant diversity from many sites roundabout and then look at the balance of native species and weeds in light of disturbance (ideally this would be assessed numerically). There are other ways of establishing context and achieving reference points. Many national systems use a benchmark system with information on reference states for set vegetation types (however, this has its limitations, especially in light of the high diversity of species and communities in W.A. and the logistics of setting up such a system, but also due to an incomplete state of knowledge, flux in taxonomy, and differences in scale and voracity of information). There is much value in many years experience of vegetation survey and assessment which can clearly help inform an understanding of condition (but this does not mean that this comes without individual bias).

An intermediate approach shadows the sort of approach that those with long-standing experience of vegetation assessment would use. It employs a mixture of: i) reference material ii) preliminary reconnaissance and observation and iii) cultivating a sense of the polarities of state and whether these are due to resident processes or imposed disturbance. It takes time to develop a sense of ecological pattern and process. Unfortunately the whole exercise is likely to get progressively more difficult for each generation as the drift in condition continues.

1.3) A PLETHORA OF FACTORS

This endeavour is like making a diagnosis. Signs and symptoms are checked and the quality of the assessment generally improves as the checklist, and the context and history are refined. As the quality of the picture so drawn rises so the risk of a miss-diagnosis falls. Consequently the prospect of correct treatment and a better long-term prognosis is also enhanced. Alternatively a meagre collection of symptoms may be attributed to the wrong cause/s then mistreatment may follow misdiagnosis.

In practice the ecology of an individual (autecology) is similar in many respects to that of systems (synecology) and the same cautionary principles apply. The risks of basing management on a poor diagnosis of the current state, likely trend, and the underlying causes, are similar. That is greater exposure to the risk of ineffective treatment/management and poor outcomes.

In both cases there is a trade-off. In dealing with highly complicated systems the more time and other resources that are applied to assessment and critical analysis the better the resultant picture of the subject.

The trick lies in finding a compromise. A simple assessment is easy – but delivers little information. A detailed assessment is difficult right through to analysis and interpretation. Ideally, somewhere in the middle ground, may be approaches that reflect real, underlying and interacting, factors with moderate expenditure of effort.

The subsequent quality of the decision making based on the evidence so gathered, while crucial, is a matter beyond the scope of this document.

1.4) PURPOSE AND SCOPE

This manual has vegetation condition at its core.

It has regard for a number of recognisable factors that may influence vegetation condition, or the perception of vegetation condition.

It also has regard for how this inevitably interacts with other, inter-related, facets of vegetation assessment, and with how they may be distilled and incorporated as required.

Consequently it is meant to be used incrementally.

The extent to which the various elements are deployed will depend on the task at hand and the intent of the assessor.

It is possible to collect only minimal information and build a simple picture, or to start from that point and progressively add more parts and build a better picture of the target area especially if time and other resources are limited. This applies to both the: i) level of assessment of condition and ii) the addition of complementary and inter-related means of assessment.

It is broad in scope. So it provides an element of common structure and standardization, and draws on ecological processes and themes as much as possible. But ultimately it is limited in its capacity to provide specific details suited to a given sub-region and locality – rather it foreshadows development and/or collation of existing sub-regional resource information that supports such assessment work.

2) HOW TO USE THIS MANUAL

This manual may be used incrementally.

Its use depends upon your requirements.

The areas that can be addressed can be combined in various ways, as illustrated in the following table.

ASSESSMENT ACTIVITY >		**Condition**	Condition + **Plant Diversity**	Condition + Plant Diversity + **Remote Sensing**	Condition + Plant Diversity + Remote Sensing + **Other**
SELECTION OF TASKS FOR THE ACTIVITY \/	**SECTION NUMBER**				
Orientation	(3)	X	X	X	X
Site Selection	(4)	X	X	X	X
Condition	(5.1 - 5.4 (short) or 5.6.1 (basic) or 5.6.2 (extended))	X	X	X	X
Plant Diversity	(6)		X	X	X
Remote Sensing	(8.2)			X	X
Other forms …	(8.1)				X

2.1) ORIENTATION AND SITE SELECTION
Orientation and site selection are common to all combinations (see sections 3 & 4).

2.2) BASIC ASSESSMENT
It is possible to focus upon vegetation condition in "isolation", *provided it is understood that this is not a direct surrogate for plant species diversity* (that is the uniqueness of vegetation and identification of its component species – which requires specific additional assessment) *or for biodiversity per se*, rather it is better viewed as a qualitative substitute for a range of ecological attributes.

By and large vegetation condition assessment schemes rely on *qualitative measures* and consequently it is important that the approach is as consistent and standardised as possible (see sections 5.1 - 5.4 (short) or 5.6.1 (basic) or 5.6.2 (extended)).

2.3) STANDARD ASSESSMENT
It is recommended that vegetation condition and plant diversity are assessed together as they are strongly inter-related and integral to many administrative

requirements and to extending the state of knowledge of the ecology and biota.

It is desirable that plant diversity is formally assessed, especially in an exploratory situation. Although this attribute is rated within a condition assessment procedure such an approach tends to provide a limited sense of the uniqueness of particular vegetation or its components. In order to incorporate plant diversity see section 6.

2.4) LINKING REMOTE SENSING

Condition scores tend to be both qualitative and an amalgam of various components, which is another way of saying that for the purposes of remote sensing they may be somewhat noisy and/or not readily linked to measurable features on the ground. While it may be possible to establish a reasonable correlation between remotely sensed images and qualitative condition scores, this is unlikely to cover all contingencies and complementary remote-sensing groundwork measures may need to be taken concurrently. For remote sensing see sections 7 & 8.2.

2.5) QUANTITATIVE ASSESSMENT FOR VARIOUS PURPOSES

Complementary quantitative measures can be taken at the same time as qualitative condition assessment is made. It is just a matter of adapting the sampling format to suit statistical or remote sensing purposes.

A general idea of how some other forms of assessment may be coordinated with the condition procedure is indicated above (other measures …8.1 & 8.2). For example if it is intended to include trial work, case-studies, Adaptive Management Programs, or equivalents, *likely* additional points of coordination are indicated in section 8.1.

2.6) MONITORING

Monitoring is readily brought into many aspects of assessment (except orientation and site selection). The act of a single visit establishes a reference point in time. Any subsequent acts that involve returning to the same place at a different time and reassessing the same measures can monitor changes or trends or the lack thereof.

2.7) LIMITATIONS

The main purpose of including limitations here is to encourage these things to be held in mind during either assessment or refinement of procedures. Limitations can be mitigated to varying degrees by means such as standardisation, calibration, more resources and training in critical appraisal. Some of these mitigating elements have been incorporated into the procedures outlined here.

Limitations can be categorised as those that:

a) are linked to the focus, such as:

i) the primary emphasis on vegetation condition attributes
ii) how information generated might be interpreted or applied.

b) are linked to the version of the procedure, such as:

i) the early stage of development, based on finite time and other resources
ii) the requirement for incremental application, refinement and extension
iii) the degree to which the attributes that are available reflect an ideal set of attributes
iv) the degree to which basic condition assessment can be coordinated with related assessment activities.
v) the quality and quantity of available background and reference material that is included in assessment
vi) the way attribute scales are constructed, and weighted and
vii) the number of attributes that are assessed

c) are operator related, such as:

i) the training, experience and background of the assessor
ii) the biases of the assessor
iii) selective use of parts of the procedure and
iv) inappropriate use of selected parts of the procedure.

2.8) USE OF TERMS

Process is exclusively reserved to refer to an ecological process in its un-impacted state. A disturbance, which gives rise to an adverse trend or threat meaning that the community may not be self-sustaining, is viewed as equivalent to a pathologic expression of a process.

Plant diversity applies to the total diversity expressed by vascular plants. This underlies much work on the flora referred to as “Floristic Community Type” or FCT.

Disturbance of post-settlement origin may be referred to as man-made, intervention or anthropogenic.

An array refers to a group of neighbouring, continuous, quadrats at one location arranged in a square. In the remote sensing literature this may be referred to as a cluster.

A quadrat is applied to a rectangular plot (commonly square) at one site. The term plot is not quite interchangeable because any shape of bounded area might be a plot.

Refuge within vegetation is taken in a broad sense to cover a clump (or tussock or hummock), a grove or a thicket. This broad sense of a refuge is primarily meant to encompass the concept of a faunal retreat, although it tends to also apply to flora. Alternative terms might be applied such as: shelter, haven, and sanctuary. For example, in spinifex country, mala shelter in squats under spinifex hummocks (Dunlop & Morris 2009). Thicket may be the best general word to describe such refuge at a range of scales, provided it is clear that it is being used in a broad sense, and that it is not confined to those select vegetation types that are typically thickets in their mature state (eg Agonis, Melaleuca, or Pericallyma thickets in low-lying damp areas). Rather it is taken to have a broader application to the state of (mainly) the understorey within vegetation types. This is in order to have the latitude to describe where there are areas within vegetation which are providing continuous, relatively impenetrable cover, at a range of scales. Although the presence or complete absence of such features provides some information, it will help if the extent and arrangement within the vegetation type are observed and recorded. The intent is to be able to describe pockets or patches at different stages of development within vegetation types, especially such as arise due to differences in the age of the vegetation since key events such as fire or other cues.

Heterogeneity is one of the most consistent themes within vegetation condition and associated ecological processes. Factors that underwrite heterogeneity affect vegetation condition. For instance heterogeneity is strongly reflected in the high diversity of plant species at the site, locality and landscape scales (Havel 1975 Gibson et al 1994 Hopper 1992), and to matching small-scale variability in topography and soils, variability in litter and debris, and an overlay of patchiness due to factors such as fire and inter-related factors such as drought.

Three forms of diversity are recognised that reflect such heterogeneity, namely:

i) Alpha diversity - applies to the number of species in a homogeneous community (e.g. Cowling et al. 1992). Essentially this applies diversity at a site.

ii) Beta diversity - applies to species turnover along a habitat or environmental gradient (Cowling et al. 1992). Essentially this applies to diversity between sites at the wider locality.

iii) Gamma diversity - species turnover in equivalent habitats along geographic gradients, also called delta diversity (Cowling et al. 1992). Essentially this applies diversity at landscape or regional scales.

The present the definitions of condition and of integrity associated with this project are from the "Resource Condition Monitoring – Native Vegetation Integrity Project Literature Review: Vegetation Condition Assessment, Monitoring & Evaluation. Version 4."

The definition of condition has not been revisited or refined in light of field work and verified ecological studies and their findings drawn from the literature, so it is possible it may need amendment.

Condition is defined as follows:
A measure, for the purpose of biodiversity conservation, of indicators of vegetation composition, structure and function relative to a reference state (i.e. within the context of the presence or absence of threatening processes) at a patch or landscape (community or ecosystem) scale.

This measure needs to feed into regional or State maps of vegetation condition for strategic planning and natural resource management planning and the satisfaction of national targets.

Reference states may be defined as:

- Benchmarks
  - Largely unmodified by humans - notionally pre- European (taking into account the long term impacts of Aboriginal people);
  - Relatively unmodified by humans compared to what still exists (i.e. the best –on-offer; Low Choy et al. 2005);
  - The average characteristics of a mature and apparently undisturbed state;
  - A realistically desired functional State (ie a virtual benchmark).
- Baseline - current state
- Predicted - the state aimed for by management.

The National Natural Resource Management Monitoring and Evaluation Framework (2003) defines the 'integrity' of native vegetation as (i) the extent and distribution of vegetation communities; and (ii) their condition, for designated purposes (e.g. provision of habitat). 'Extent' is inherent in 'condition' in that 'extent' refers to the abundance and distribution of vegetation types, while condition refers to the quality of that vegetation. Vegetation condition assessment methods are tools that quantify the 'value' of a patch of vegetation for biodiversity. They are based on the assumption that vegetation structural attributes act as a surrogate for the habitat requirements of all indigenous plant and animal species (Gorrod, 2006b). *However, there is evidence in the literature that the use of vegetation data as a surrogate for habitat requirements of other species or biodiversity have many shortcomings (e.g. Burgman and Lindenmayer 1998; Doherty et al. 2000; Mac Nally et al. 2002; Williams 2005)*.

The Resource Condition Monitoring – Native Vegetation Integrity Project has been developed to facilitate the delivery of State-wide (surveillance) monitoring of native vegetation condition, and is part of Resource Condition

Monitoring as required under the Bilateral Agreements between the Australian and Western Australian Governments. The overarching aim of this project is to develop the basis for a long-term, large-scale, strategic approach to monitoring and evaluation of native vegetation integrity in Western Australia through provision of suitable evaluation tools and establishing a suite of reference areas[1]. For this project, 'integrity' is defined as both the extent and condition of native vegetation.

This manual primarily deals with assessment of the condition of native vegetation. It is compatible with assessment of integrity because, with time and the assessment of progressively more sites, the information generated should augment a database that focuses on vegetation extent. However, extent is not its primary purpose.

[1] *The latter is perhaps better taken as progressive condition assessment at a growing number of sites based on relativities within local vegetation types, and the creation of background resource material with a regional or sub-regional scope, and less as establishing specific reference areas. This avoids the extreme difficulty of establishing representative benchmarks for each of the plethora of diverse vegetation types and possibly also assumptions of equivalent quality, and resolution in diverse supporting information.

3) ORIENTATION – BACKGROUND, RECONNAISSANCE & OBSERVATION

KEY INGREDIENTS

A willingness to engage with the assessment process before, during, and after fieldwork is integral to this work.

It is intended that assessors will compensate for limited experience in this field of endeavour and/or limited experience in a specific area, by a mix of background research and preliminary field observation.

If condition assessment is conducted in isolation - it is important that the assessor access and come to terms with resource material on species composition (at least common weeds to genus level and preferably also the typical faithful species of the vegetation type/s of interest if such information exists), and the collective structure that arises within such vegetation, and that they understand or can locate information on the sub-regional processes and threats applicable to the area of interest.

If condition assessment is conducted in tandem with assessment of plant species diversity (the preferred option) – there is scope to also draw on the more detailed information generated by the more rigorous nature of such work, as well as taking the core steps outlined above.

This is an integral part of building up a core skill set for a career in natural resource management.

The two broad aims at this stage are to sub-divide (or partition or stratify) and characterise the area in question on the basis of field observation and background information, in the process recognising:
i) vegetation types or zones present;
ii) various states the vegetation types are in at present (cleared/un-cleared; recently burnt/not recently burnt/long-un-burnt; etc)

The first accounts for features in the vegetation that might be considered to represent identity and to a certain extent be fixed or strongly related to geology, soils and climate over long time frames.

The second reflects those features that are more likely to reflect vegetation state and to fluctuate in the short to medium term and that may be overlaid on the vegetation in a way that may often be independent of type.

3.1) LITERATURE-BASED APPROACH - FINDING BACKGROUND INFORMATION

The process of assessment can be augmented and potentially enhanced if resource material is able to be gathered beforehand.

Helpful resource information for the locality or subregion includes:
i) <u>the basic range of strata encountered.</u>
That is the number of layers and preferably some identifying species.
Ideally the sources & quality need to be qualified; see below.
ii) <u>the basic range of species encountered</u>
That is the number or composition of species and preferably their identities.
The sources & quality need to be qualified; see below.
iii) <u>the typical list of predominant weeds</u> (ideally divided by characteristics into a) disturbance opportunists; b) aggressive invaders.);

For the Swan Coastal Plain, Darling Scarp and Plateau sources are the:

- publications “Bushland Weeds: A practical guide to their management with case studies from the Swan Coastal Plain and beyond.” (Brown, K. & Brooks, K., 2003, Environmental Weeds Action Network, Perth.) and “Western Weeds, a guide to the weeds of Western Australia” (Hussey, B.M.J. & Keighery, G.J., 2007, 2nd Edition, Weeds Society of Western Australia, Victoria Park, W.A..); and
- the database “Swan Weeds” (http://florabase.dec.wa.gov.au/weeds/swanweeds/)

iv<u>) summaries of other threats including</u>:

a) key feral animals and pests including invertebrates;
b) disease;
c) hydrological change;
d) nature of landuse change;
v) typical local fire-cycles and/or imposed regimes;
vi) indicator species (autecology);
vii) ecological case studies (synecology);

viii) historical background – a synthesis (synecology).

The main sources that will help with orientation with regard to composition and strata include:

• Previous detailed survey work conducted at the local scale in the same vegetation type and in the same general area. Much of this will have been conducted for government agencies, local government and a range of private proponents, and may be located via libraries or a search of the relevant bodies.

Such work is likely to provide:

a) species lists for vegetation types which can help provide an idea of the range in species numbers expected.

b) some treatment of condition – in many cases the "Keighery Scale' This may indicate what vegetation in good-or-better condition will contain. Take care – consider how many examples the reports authors visited and that they may have tended to be sparing or generous with their ratings, both of which will affect the outcome.

Examine any photographs, and ideally visit a site or sites from the report. In many cases there will be maps to aid this. The photographs may be a useful guide to the appearance of vegetation types and the layers to be found within them. The maps may help with orientation with regard to types and as an aid in delineating their boundaries

Take care with regard to mapping - there will be some variability between sources. Those assessors with long-standing experience tend to have a better appreciation of boundaries. In addition mapping that does not reflect fine-scale details will be of limited assistance. That is it should be at the locality scale and reflect changes in local topography, soils and geology).

Take care –consider whether the work appears thorough, most work should meet a general standard (see EPA Guidance on terrestrial survey).

c) information on strata in the form of:

- a basic vegetation description (from a descriptive scheme such as Muir 1977);
- heights and covers of plants.

d) the time of sampling which should be given in the methods. Take care - appreciate that at certain times of year species of plants may not be evident. Refer to the general guide given here relative to the bioregion and to EPA Guidance for terrestrial survey.

• Government agency sponsored regional survey work. In W.A. this follows a "Floristic Community Type" approach that often shows relatedness of vegetation types at the regional level (eg Gibson et al 1994). A key strength of this source is that usually the sites were revisited on two or more occasions during a year.

Such work is likely to provide:

a) Species lists – though individual sites may vary in terms of number and composition this provides a general, ballpark, guide. (Take care - the full number of plants species present is stated in the community description and listed in the major appendix; an intermediate listing in table form is likely to be provided and although this will give a very good idea of most of the species present, some of the least common species may not be listed - that is the table is an underestimate. It provides a very good idea of the common faithful species.)

b) Strata may be outlined in the description of each vegetation type.

• Broad mapping and description at a state level (such as that of J.S. Beard or recent amended versions of this work) can be used to provide a basic idea of first the strata and then a more basic entry-point to expected species.

Take care - these lists are helpful and a good starting point, but they have their limitations. The species lists so presented are summaries or simplifications based on common dominants. They also cover a range of more detailed vegetation types, are unlikely to be exhaustive for the vegetation types they most closely represent, and are also a product of the state of plant taxonomy when they were recorded, in the case of Beard the lists were composed several decades ago. Similar considerations apply to the mapped Vegetation Complex/es of Heddle, Loneragan and Havel (1980) or Mattiske & Havel (1998).

NOTE: As a general rule increasingly more species and infra-species have been found in the state as understanding of the flora has advanced. So the date of the survey work will have some bearing on the number of species found.

• Online sources. Government agencies are likely to provide some material. For example the Western Australian Local Government Association has a link to the Perth Biodiversity Project which has photo reference points that give an idea of the appearance of some Swan Coastal plain vegetation types.

Note that for the purposes of vegetation condition assessment it is desirable that sub-regional resource documents (and possibly specific manuals) are gradually compiled made available to help provide some of the requisite material.

3.2) FIELD APPROACH - FINDING REFERENCE POINTS

This approach is a strategy for the application of local reference points rather than benchmarks.

There are distinct steps to getting orientated in a new area for the purposes of vegetation assessment; they are outlined below.

3.2.1) TIMING OF FIELDWORK

The time of year that the assessment is made can have bearing on findings.

In terms of plant species diversity a better assessment is likely to result if it is conducted at the time of year when most plant species are easily found, usually when they are actively flowering and reproducing following the main rain bearing periods. There will be some species that do not conform to this pattern and if assessment is being combined with full floristic work there will be a requirement to sample at other times of year. Only a brief guide is provided here; see the EPA Guidance on terrestrial flora and vegetation survey for further information.

	DRY PERIOD	WET PERIOD	MAIN PERIOD OF FLOWERING & REPRODUCTION
South-West - Mediterranean	SUMMER	WINTER	SPRING
Semi-arid & arid areas - capricious rainfall	MOSTLY	RARELY LARGE EVENTS ARE KEY	2-3 MONTHS AFTER MAJOR RAIN
North/Kimberley - wet/dry tropics	WINTER	SUMMER	SUMMER

Such timing does not necessarily suit the assessment of all condition attributes. For instance it may be better to assess plant health or grazing at the end of the hot, dry, season as this reflects peak stress. That is because plant health will be most affected where there is drought or a falling watertable at this time, similarly grazing pressure is more likely to be amplified at such times, rather than when fodder is bountiful.

There is some risk that a single visit may completely miss key events that have a great effect on condition, for example the reach and extent of late summer dust storms

If return visits are made in successive years this will become a monitoring exercise and for the sake of comparison it will be important to return at the same time/s of year.

3.2.2) LOCAL RECONNAISSANCE

A brief account of site selection is given here see section 4 for more detail.

Within the locality, conduct reconnaissance (preferably in tandem with appraisal of aerial imagery[1]) and:

a) delineate the zones corresponding to local/small-scale vegetation types, in other words stratify the site;

- A similar vegetation type will tend to have one to several of the main overstorey species and several understorey species present in roughly similar proportions at a site scale. They will remain faithful to the type and be recognisable from place to place in a characteristic combination.

b) determine which of these types are to be studied[2];

- For purpose of comparison it is important to try to pick *both* similar vegetation *and* similar landform to the extent that it is practicable. That is compare mid-slope with mid-slope, and flat with flat.

- Take into account very recently burnt sites and at least make allowance for the fact that they may remain relatively bare or even fallow for quite some time (especially in arid areas). At such times there will be few cues to reflect the plant species diversity or general state. Consider re-assessing such areas a couple of years after fire (or even several years later in drier areas). Signs to look for at this stage include: less bare soil and little evident charcoal, few remaining dead leaves from leaf-scorch on trees, less vigorous green regrowth on trees and shrubs, and signs that the leaf litter is no longer a 'monolayer' largely made up of leaves shed after the trauma of fire – that is the litter layer is becoming more irregular in dispersal and accumulation.

c) within the target types look for factors that can bias assessment; and make allowance for these. Two of the most common such factors to recognise and allow for are:

- areas that are effectively neutral in terms of condition assessment; namely:
    - naturally outcropping, rocky, areas where underlying rock is exposed. For future reference consider whether they are arranged at random or have they a fairly consistent pattern (eg vertical & horizontal stepping); only in some cases may it be possible to assign a consistent value for the cover of such occurrences.
    - Other naturally bare areas; such as:

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[1] This is a good point to appraise parameters such size, shape and proximity of remnants, in order to be able to verify their status and makeup on the ground and to also apply such information to condition assessment if required.

[2] This is a good point to create a map that will help re-locate the site and as a backup to coordinate records which can be incorrect for a number of reasons.

littoral and riparian areas (eg riverbanks and claypans); wind-borne sand deposits or blowouts; rocks that have separated from their source, such as detrital rock or ‘gibber’ plains.

It is not informative to arbitrarily assign these a score and the condition assessment process, without qualification, might *be best considered not applicable to such areas*.

- areas that are mosaics; such as: mulga groves and the ‘inter-groves’, and cracking clay soils of undulating, small-scale’ relief.

Depending on the scale *mosaics* may influence condition in as much as they *may demand two condition assessments to be conducted, and conceptually require two cover scales*. It may also be best practice to assess more than one site in order to cover the range of variation of the mosaic in a representative way.

3.2.3) OBSERVE THAT COVER VARIES & FLUCTUATES

In terms of condition assessment percent cover poses a particular dilemma because it is dependent upon the nature of the vegetation type, its current state, and the timing of assessment.

Cover needs to be carefully qualified and put into context in order to be considered for the purposes of condition assessment.

This is because cover is not uniform in the dimensions of time or space. Typical upper limits to cover are idiosyncratic, so it is a gross, and erroneous simplification to set 100% as the limit in all situations. The table illustrates this.

ILLUSTRATIVE EXAMPLES	%
Granite outcrops;	0-6
Cliff faces; rock strew; gibber plains;	
Mulga inter-grove;	
Granite outcrops;	0-15
Cliff faces; rock strew; gibber plains;	
Granite outcrops;	0-30
Cliff faces; rock strew; gibber plains;	
Mature areas of: blue-bush; salt bush; spinifiex;	0-45
Some semi-arid tussock grassland;	0-75
Coastal dunes;	
Mulga groves	
Much of the south-west;	0-100
Water-gaining areas with developed soils at large;	

Such considerations are generally embedded in vegetation description schemes such as that based on Muir (1977; see structure & table below). Cyclic influences such as fire and drought mean that it is possible for the description at one location to vary from one time to another.

It does not always follow that a bare area (*in the absence of other cues*[3]) is a sign of disturbance. For instance Spearwood dune areas in excellent condition typically have bare sand. Hence it is important to try to separate such features that reflect vegetation type identity from other pattern and process cues (Department of Environmental Protection 2000).

3.2.4) EVALUATION OF ATTRIBUTES AT REFERENCE AREAS.

Consider the attributes to be assessed at the reference areas. At each reference area it will be necessary to examine and establish the range for the attributes outlined below (and listed in the table*** and laid out in the accompanying field data sheet). It can be seen from the table that four of these are generally considered core attributes.

ORDER	ATTRIBUTES TO USE IN ORIENTATION	CORE ATTRIBUTES WITHIN CONDITION SCHEMES (eg VAST & Keighery scale).
a)	Forms of disturbance (and/or threats).	Disturbance from land-use and management practices.
b)	Number of weeds	
c)	Soil stability	
d)	Number of native plant species	Species composition (and a sense of whether there has been a loss of components)
d)	Number of strata	Vegetation structure (and a sense of whether there has been a loss of components)
e)	Seedlings and sapling presence	Regenerative capacity (or resilience)
f)	Vegetation health	

Progressively fill in the following field orientation sheet in the given order a) to f).

[3] Part of the process is to ask whether signs tend to corroborate each other or not.

ORIENTATION SHEET -

	# SPECIES (APPROX) (d)	HEIGHT RANGE (d)	COVER (d)	SEEDLINGS OR SAPLINGS (e)	HEALTH 0, 1, 2, 3, 4 (f)
UNDISTURBED AREA (a) EXTENT: _ _ _ _ _ _ _ _ _ _ _ _					
SOIL BINDING* (c)					
BARE					
LITTER					
Trees_ _ _> 30m			O/S		
Trees_ _ _10-30m			O/S		
Trees_ _ _< 10m			O/S		
Mallees _>8m			O/S		
Mallees _<8m			O/S		
Shrubs_ _>2m			U/S		
Shrubs_ _1-2m			U/S		
Shrubs_ _<1m			U/S		
Herbs			U/S		
Sedges/Rushes			U/S		
Grasses			U/S		
Other (eg climbers)			U/S		
TOTAL					
# WEEDS (b) (RECORD SP)					
DISTURBED AREA 1 (a) TYPE : _ _ _ _ _ _ _ _ _ _ _ _ EXTENT: _ _ _ _ _ _ _ _ _ _ _ _					
SOIL BINDING* (c)					
BARE					
LITTER					
Trees_ _ _> 30m			O/S		
Trees_ _ _10-30m			O/S		
Trees_ _ _< 10m			O/S		
Mallees _>8m			O/S		
Mallees _<8m			O/S		
Shrubs_ _>2m			U/S		
Shrubs_ _1-2m			U/S		
Shrubs_ _<1m			U/S		
Herbs			U/S		
Sedges/Rushes			U/S		
Grasses			U/S		
Other (eg climbers)			U/S		
TOTAL					
# WEEDS (b) (RECORD SP)					

*Soil binding includes: humus; root matts; plant stems; bulbs, tubers, corms & rhizomes; duricrust; & cryptogams.
(a) - brackets show suggested order. U/S - understorey. O/S - overstorey.

Note on how the growth forms listed in the sheet may be combined in order to work with fewer groups.
This may be in order to help score the composition attribute or especially for cover assessment in the quadrat or the diagonal quadrat transects.
It may help to conceptualise this into basic categories, for instance:

- overstorey [O/S]
  - the tallest stratum;
  - typically trees & mallees, usually several metres or more high;
  - that may range from a major form of cover to only a few scattered emergents;
- upper understorey [U/S-U]
  - the next tallest stratum;
  - typically larger or taller shrubs that are mainly above 1m tall;
- mid understorey [U/S-M]
  - typically those growth forms that are mainly 1m high or less (the occasional plant may be taller):
    - medium to small shrubs; and/or
    - sedges and rushes; and/or
    - grasses;
- lower understorey [U/S-L]
  - includes
    - ground hugging, near flat, “groundcovers”; and
    - herbs (non-woody, short-lived plants) of about 0.5m or less; such a category accounts for the large ephemeral flora in some major regions.

TABLE : suggested basic grouping of layers compared to two approaches used in the field; this may be able to be applied widely for summary purposes.

Layers as outlined in Keighery 1994.	Suggested use here	Former use for transect	Gibson et al 1994		
Trees_ _ _> 30m	O/S	O/S	Trees		
Trees_ _ _10-30m	O/S	O/S	Trees		
Trees_ _ _< 10m	O/S	O/S	Trees		
Mallees _ >8m	O/S	O/S	Trees		
Mallees _<8m	O/S	O/S	Trees		
Shrubs_ _>2m	U/S-U	S	(Shrubs)		
Shrubs_ _1-2m	U/S-U	S	(Shrubs)		
Shrubs_ _<1m	U/S-M	SS	Shrubs		
Herbs	US-L		Herbs		
Sedges/Rushes	US-M	GS	Herbs		
Grasses	US-M	GS	Herbs		
Other (eg climbers)	US+				

a) Disturbance Attribute
Identify disturbance and pick two locations, one that appears relatively undisturbed and one that is disturbed. In particular:

◇ Look for signs of the main form of disturbance/s in the general local area that influence the vegetation directly and note their nature where possible. Road verges, especially those that are subject to regular maintenance, such as grading are a good example.

> Imposed disturbances include: erosion, sediment deposition, flooding, water pumping (‘abstraction’), salt deposition; clearing; soil removal; quarry-based extraction; land-fill; soil dumping; construction of all forms of infrastructure; machinery and material lay-down areas; rubbish dumping; pollution, especially nutrient input via fertilizer, soil drift, animal faeces, drainage and sewerage; heavy grazing; heavy stock movement and trampling; plant diseases; plant pests, mainly insects; and feral animal pests.

◇ *Sites which are recently or long unburnt may need to be allowed for (see fire below*).

◇ Take a moment to reflect on the nature and extent of the disturbance. This may help in clarifying the impacts of such disturbance when the study sites are later examined, and compared and contrasted.

◇ Get a feel for the range of strata and species present in both sorts of areas. What strata are diminished or missing in the disturbed area? Species are not always evenly distributed even in vegetation in good condition. Pick a representative (medium, typical or modal) patch for each state of about 25mx25m. (It may also help to record high and low ranges). Make allowance for underlying zones within a vegetation type, such as naturally bare areas or mosaics as outlined above.

b) Weed Attribute.
Weeds may be divided on the basis of how disturbance can assist in their recognition; some utilise major disturbance, some are carried by vectors, and some are aggressive invaders even in the absence of disturbance.

The seasonal timing of assessment will influence the presence and/or reproductive state of many weeds, and so it is best to conduct orientation following the main period of rainfall. Most intensive landuse occurs in the south-west of the state and so the appropriate timing will be late winter/early spring. Some perennial weeds persist through the year and act as markers (eg in the south-west some grasses (such as *Panicum effusum*) compared to annual grasses and broad-leaf weeds, and in the north-west grasses and shrubs (such as buffel grass and kapok bush) compared to annuals such as ruby dock).

It will help to become familiar with weed genera in the region. On the Swan Coastal Plain useful sources include: i) bioregional survey (eg Gibson et al 1994); ii) locality-based survey work (a state government agency and local government library search may be required); iii) the weed database on the Department of Environment & Conservation web site; and iv) publications on weeds (as outlined above).

❖ Weeds utilising major disturbance.

Find a disturbed area where there have been activities that have altered or removed the vegetation and/or soil surface like partial clearing for earthworks for: extraction, construction, other infrastructure, or other purposes such as agriculture and horticulture.

In this regard road verges, infrastructure corridors, pasture, and firebreaks adjoining roads and cleared areas may prove most helpful. (In south-west rural areas road verges and remnants that are relatively congested with grasses are likely to have also been repeatedly disturbed by fire at a relatively high frequency and to be dominated by introduced grasses and other weed species. For contrast it is possible to find such patches interspersed with patches in better condition that still retain dryland sedges and woody understorey. In south-west rural areas few native species of grasses make thick tussocks, or are still dominate an area; though to save a slight chance of confusion becoming familiar with Triodia “hummock grass” and kangaroo grass will help.)

Identify the individual weeds that are characteristic in such areas, namely those that are repeatedly present and/or common to prolific. It may be helpful to collect samples and make up a field specimen book.

Such species are likely to be those utilizing disturbance.

Examine the edges of any blocks of native vegetation adjoining these areas. Look to see if there is evidence of the spread of weeds from the verges into any blocks of vegetation. Is there a gradient where weeds thin out with distance into the block?

Most mine sites (operating or closed) are also good places to use to get orientated for weeds. (Note that shallow deposits that have had the original, and formerly vegetated, soil returned within a short time-frame are less likely to have a high number of weeds). Otherwise in mined areas and waste dumps, wherever the subsurface, or rubble and coarse particles, and/or an altered mineral composition, are exposed the likelihood that weeds will predominate is high. Weed incidence will be higher after rain and around water-gaining or retaining areas in arid or semi-arid areas. In arid areas a weed that illustrates the combined effect of altered substrate and water is ruby dock. Similar effects can be seen near rail lines in the southwest where Watsonia or related plants can abound.

❖ Weeds utilising vectors.

Some weed species enter an area in animal droppings.

The most reliable indicators in the south-west are rabbit droppings which are easiest to locate given a tendency for animals to defecate in the same spot. Usually near diggings or warrens. The disturbance and raised nutrient levels favour the establishment of the weeds. Such spots are likely to have patches of weeds associated with them (pigface and dandelions are common examples on the coastal plain, and capeweed and wild oats in rural areas), especially if the animals are accessing surrounding areas.

Other animals such as emus, pigs and kangaroos may also spread weeds but in the former two cases locating droppings can require intense searching, while in the latter case the frequency of such transmission appears to be quite low if not negligible.

❖ Weeds that are aggressive invaders.

Many such species will be harder to differentiate than those associated with disturbance or droppings.

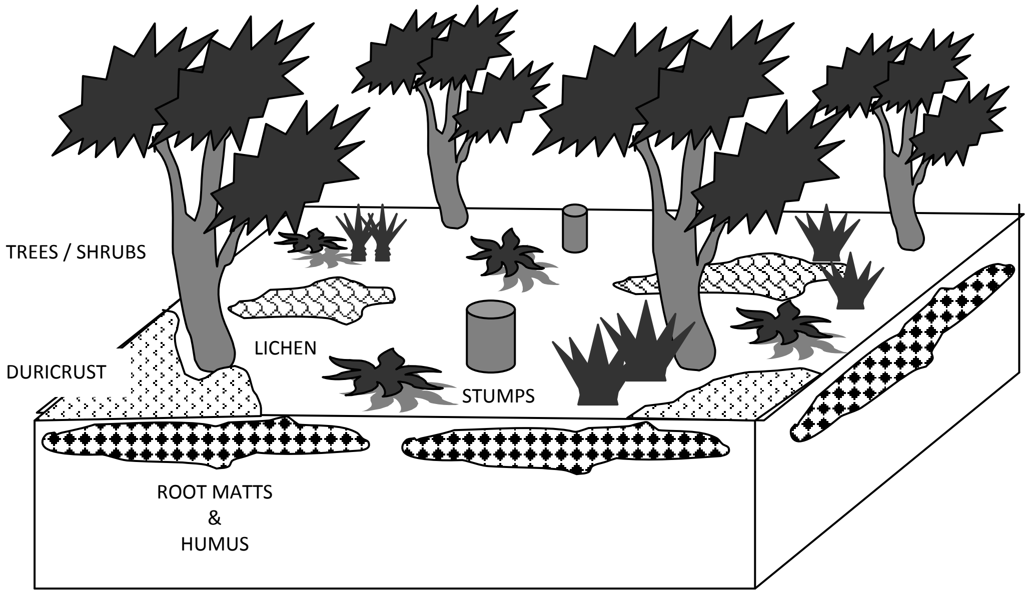
To discern such species basically requires careful study and resource material. This is because they are capable of becoming evenly dispersed through an area and consequently to the untrained eye they will appear to be part of the long-term fabric (in the south-west such species include Gladiolus and Freesia species). Amongst the most obvious to the untrained eye are bridal creeper, and veldt grass, as the former

c) Soil Surface Stability Attribute.

Look for the contrast between the soil surface stability components in the selected disturbed and undisturbed areas.

<u>The components that promote soil stability, and integrity</u>.
In the undisturbed area get a sense for the components that are contributing to binding the soil. Depending on the vegetation type there will be varying combinations of:

- Stems, and other plant bases such as rhizomes, bulbs, corms and tubers;
- Surface feeder roots and root mats;
- Humus – soil organic matter built up in the upper soil layer;
- Duricrust – a crust that can incorporate mineral oxides (alcrete, ferricrete, calcrete) and algae (blue-green bacteria);
- Cryptogams (mosses and liverworts);
- Lichens; and
- Litter and debris.



Try to overlook litter and weeds and build a sense of how well the other components of stability are dispersed, and interlocked in the target vegetation. In terms of getting a view of the soil profile small and shallow excavations, animal diggings, and other exposed parts of the surface layer will help form such a picture. So will man-made disturbance in nearby equivalent areas which can expose the soil profile.

<ins>Regarding litter</ins>.
Try to separate the litter layer from the other components because it is most subject to fluctuation due to intermittent factors such as fire and weather cycles. That is not to discount the fact that, in the absence of these factors, or in the presence of fauna, it may become humus and a significant component of the upper soil horizon.

<ins>The balance between weeds and native plants</ins>.
For the purposes of integrity weeds can be viewed as contributing to disturbance as they alter the soil fabric, soil conditions (such as the availability of water and nutrients), the balance of soil biota, and the carbon cycle (and so the fire cycle). Recognise the contribution made by weeds to soil structure as outlined above and make allowance for this. The cover of components that are stabilising the soil will be all the native plants, cryptogams (lichen, mosses and liverworts), and exclusive of native plant litter and debris, and exclusive of weeds and their litter.

<ins>Extent of surface disturbance due to native animals & other natural causes</ins>.
Get a feel for how vertebrate animal activity interacts with surface stability. Due to the absence of native medium body weight mammals from most of the mainland this is generally not “typical”. However, patches of more intense activity such as the rest areas of kangaroos, can illustrate how they dig. In some places they do break the surface to

get plant material. As the main stand-ins for medium body-weight native mammals rabbit activity might be considered to be at some sort of equilibrium in terms of surface stability if it affects a small proportion of the surface area (possibly <5%). Extremes of such activity will manifest as denuded vegetation and extensive disturbance to the soil surface.

Regarding naturally bare areas
In the absence of man-made disturbance, accelerated erosion, and weeds, and given a fair complement of native plants, it is likely that bare areas of surface are a normal part of the unit. There may also be a general pattern to occurrences which is repeated or interspersed in the unit, and which contrasts with any imposed disturbance.

In many situations rock becomes a significant part of surface stability. There are a range of ways that rocks may factor, such as a: primary outcrop; a significant part of the soil profile (packstone, mudstone & gravel); surface “gibber” plain (or colluvial strew or pavement); or as secondarily consolidated composite material such as conglomerate and calcrete or travertine.

d) Composition and Structure Attributes.

Composition
In terms of composition there are two things to accomplish:
i) In order to recognise and distinguish similar vegetation types first take note of the 1-3 most common species make up the bulk of cover, in the overstorey and then the understorey layers or equivalents. A basic working division of layers is given in table ***). With scrutiny it will become evident that a common, consistent, or “faithful” set of species mark out similar vegetation types. *This approach based on the dominants in each layer will give some idea of the character of each type and is likely to provide a good working account of the vegetation, but it cannot substitute for a full inventory of plant diversity*. (The pictorial chart in the “Bushland Plant Survey Recording Sheets” in Appendix***; will be helpful in this regard (Keighery 1994). This table allows for the 3 dominant species in each layer to be recorded, and for cover to be estimated; however it may be helpful to add estimates of the total number of species in each layer to this form).

◇ Note: It will be helpful to make a field book of specimens of at least the most common faithful species by layer in order to be able to reliably compare vegetation types from place to place.

Use this information along with the site selection section (section 4) to recognise and delineate vegetation types in the study locality.

ii) In order to establish and recognise what “typical” composition might look like select a site in relatively good condition, with low weed presence and little disturbance, and which is preferably located some distance into the vegetation (eg >50m).

Count and record the total number of species in each of the broad categories given on the orientation sheet. These will provide a guide to the number of species that may be expected in similar vegetation in a similarly good state.

Note that relevant information may be available from: i) bioregional survey (eg Gibson et al 1994 on the Swan Coastal Plain); and ii) locality-based survey work (a state government agency and local government library search may be required).

Also record the overall species number.

◇ IMPORTANT NOTE: *Although it is possible to conduct condition appraisal without assessing the full plant diversity at a site, it is highly desirable that this should be done at this stage*. The sheets provided in Keighery 1994 (see appendices), for recording all species by strata, are a useful standard for such work.

> The fundamental reasons that such assessment is required, and is likely to continue to be needed include:
> a) the extraordinary diversity of W.A.'s biota, and the extent and uniqueness of the continental ecosystem that has been their wellspring and refuge over deep time.
>
>> This means that variation from place to place is great and that the turnover in species with distance is high in many, if not most areas. Not recording the full signature of a site means that the information captured and stored in corporate files, databases, and GIS, upon which decisions about management may be made, will be grossly simplified. Consequently there is high risk of an inappropriate paradigm being promoted within the organisation and the wider society, about the nature of the vegetation and flora. This flows into a wide range of areas. Similarly reliance on a system of coarse level benchmarks against which to assess condition is also likely to promote and embed a paradigm that suggests to organisations and wider society that the biota is fully understood, and is quite simple, when this is far from the truth.
>
> b) that most work on the biota, including survey and taxonomic work is exploratory, and continues to find new organisms (especially taxa at the species or sub-species level) and new communities, and/or new occurrences of organisms and communities.
>
>> This means that, should condition assessment be taken as a default mode of operation, much exploratory information will simply not be captured, and even that survey work may be progressively usurped.

<u>Structure</u>

◇ Become familiar with the growth form layers shown in the following two tables *** and shown schematically in Keighery 1994 (see Appendix ***).

In terms of structure use the field sheet to record: i) the height range in each of the basic layers listed; and ii) the estimated total cover of the overstorey, and understorey and the range of cover of the litter and bare ground.

The requisite information may also be gathered from existing reference material as outlined above. It may appear in the Appendices with heights against species or it may appear as vegetation descriptions according to a scheme such as that of Muir (1977; see Table). Note that descriptions derived from this table can be used to make a basic outline of the layers and their height and cover by reference to the table.

There are of course, vegetation types that are “exceptions” in that they typically have low or sparse understorey; for example some Tuart woodland; some Wandoo woodland; *Acacia xiphophylla* shrubland on duplex soils; and rock or gibber plains.

Table : Growth Form Layers
(Adapted by PBP from Keighery 1994, McDonald et al. 1990 and Executive Steering Committee for Australian Vegetation Information 2003)

Tree: woody plant with a single trunk and canopy, the canopy is less than or equal to ⅔ of the height of the trunk, no lignotuber apparent

Mallee: woody plant with many woody stems, canopy well above the base, lignotuber usually apparent, commonly of the genus *Eucalyptus*

Shrub: woody plant with one or many woody stems, foliage all or part of the total height of the plant, includes grass trees (*Xanthorrhoea spp*.) and cycads (*Macrozamia spp*.)

Herb: non-woody plant with stems, generally under 0.5 m tall and not a grass, sedge or rush

Grass: non-woody plant that comes from the plant family Poaceae; all have inconspicuous individual flowers that are pollinated by wind; leaf sheath always split, ligule present, leaf usually flat, stem cross-section circular, evenly spaced internodes

Sedge: non-woody, tufted or spreading plant that comes from the plant family Cyperaceae; most have inconspicuous flowers that are pollinated by wind; leaf sheath never split, usually no ligule, leaf not always flat, extended internode below inflorescence

Rush: same as sedge but comes from the plant families Juncaceae, Restionaceae, Typhaceae or Xyridaceae; leaf sheath may be split in Restionaceae

Climbers: plants that climb or scramble over other plants for support

Scheme for Description of Vegetation Structure as adapted from Muir (1977) and via Aplin (1979) and Keighery (1994)				
	Canopy Cover			
Growth Form / Height Class	**100% to 70**	**% 70% to 30**	**% 30% to 10**	**% 10% to 2 %**
Trees over 30 m	Tall Closed Forest	Tall Open Forest	Tall Woodland	Tall Open Woodland
Trees 10-30 m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees under 10 m	Low ClosedForest	Low Open Forest	Low Woodland	Low Open Woodland
Mallee over 8 m (Tree Mallee)	Closed Tree Mallee	Tree Mallee	Open Tree Mallee	Very Open Tree Mallee
Mallee under 8 m (Shrub Mallee)	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Shrub
Shrubs over 2 m	Closed Tall Scrub	Tall Open Scrub	Tall Shrubland	Tall Open Shrubland
Shrubs 1-2 m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs under 1 m	Closed Low Heath	Open Low Heath	Low Shrubland	Very Open Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Sedges	Closed Sedgeland	Sedgeland	Open Sedgeland	Very Open Sedgeland

e) Regenerative Capacity or Resilience Attribute.

Look for the presence of seedlings or saplings of overstorey and midstorey species; record these in the table.

f) Plant Health Attribute.
Note the general health of the overstorey and understorey. Are there any obviously stressed plants or species - atypical leaf discolouration, leaf death, limb death, or whole plant death?
Rate the state of plant health by layer in the orientation sheet according to:
0 - healthy no signs of stress;
1 - some early signs of stress, a few individuals, likely one species;
2 - signs of stress in several individuals, one or more species;
3 - signs of stress in many individuals, several species;
4 - advanced decline and/or death of many individuals and several or most species.

3.2.5) EVALUATING MORE VEGETATION TYPES.

Simply repeat steps a-f for other vegetation types in the vicinity if so required.

3.2.6) FRAGMENTED OR RESTRICTED VEGETATION TYPES.
In the case of isolated or restricted vegetation types it may be necessary to: draw on the nearest equivalent vegetation type and/or the general state of adjacent un-related vegetation; rely on existing background material (where available); or travel further afield.

With time and experience this may prove to be less of an impediment because the spectrum of vegetation types and states that the assessor has been exposed to will help set the context for contemporary assessments. This is likely to require several years of involvement.

3.2.7) USING REFERENCE VALUES TO SUPPORT CONDITION ASSESSMENT.

Use the ranges found at reference areas to help make decisions about the condition of a target site in terms of the listed attributes. This will usually be within a 25mx25m quadrat for the purposes of condition.

(Alternatively, it may be possible to retrospectively adjust the scores. Especially if the target site is examined first it may be possible to record a systematic adjustment against 2 a) to e) above (that is +/- 1 scale), especially if later comparison with similar adjacent vegetation shows it is warranted).

4) SITE SELECTION

Site selection ensures that each occurrence of each type of vegetation in the study area is clearly recognised and delineated. This allows effective and representative sampling to be undertaken, whether for condition assessment or monitoring. Work should only proceed when sampling can be repeated with confidence within the same vegetation type.

4.1) AIDS TO SITE SELECTION

In the initial stages of site selection there are a number of aids that may be employed to assist the process of recognising and delineating fine-scale units within vegetation:

A. Vegetation maps
B. Regional vegetation classification schemes
C. Aerial photographs (and other maps and aids)
D. Ground truth by reconnaissance

A. <u>Vegetation maps</u>

Three forms of maps are currently used in Western Australia; state-wide mapping, land-systems and south-west vegetation complexes. When using vegetation maps it is essential to appreciate that scale has a great bearing on the application and limitations of the mapping process. Broad-scale mapping can be applied as a ‘first cut’. However, it needs to be supplemented by other methods in order to recognise the underlying and more uniform vegetation units by subdivision. There are two general levels of mapping:

i) Broad-scale mapping, featuring:

- low resolution, and so its level of application is also coarse, making it suited to major subdivisions within bioregions;
- categories that bound a mixture of small-scale vegetation units, that is they are a kind of compound vegetation type and not uniform (rather they tend to share a selection of typical common species); and
- vegetation descriptions that are often a gross simplification (such maps are a poor representation of the intensity of plant species turnover from place to place).

ii) Fine-scale vegetation mapping, which have:

- high resolution;
- applicability at the local scale;
- well delineated vegetation units that are relatively uniform in composition;

B. <u>Regional vegetation classification schemes</u>

Regional vegetation classification schemes are a means of better understanding the relationships between the various forms of vegetation in an area and of recognising subdivisions based on plant species diversity. They have application as a guide to what species can be expected in closely related vegetation. This may be helpful in defining vegetation units and as an aid to the recognition of benchmarks suited to the condition assessment part of this process.

There are a number of different types of classification scheme which have various strengths and weaknesses. Some schemes are based on plant species composition and recognition of similarities and differences within vegetation by comparing the proportions of shared and unique species. Others offer partial local-scale resolution, but only in the localities where plots are based.

These types of classification scheme tend to give a better indication of the range of variation within and between vegetation types but do not yet reflect the full extent of such variation because the density of sites on the ground can always be improved. Further, they are generally not supported by complementary maps.

C. <u>Aerial images and other maps and aids</u>

The use of aerial photographs helps fill in detail of vegetation units at the fine scale. There are a number of basic steps in their application:

- Obtain the best resolution aerial imagery available for the study area.
- Use the image to draw boundaries around each part of the vegetation that appears to have consistent patterning of dominant plants (see example).
- Attempt to subdivide the area as much as possible.
- The use of “stereo pairs” of images to help recognise features of the landscape likely to correspond to vegetation boundaries (slopes, flats, soils, etc).
- The use of topographic maps, at the same scale as the images to help recognize features of the landscape.
- The use of soil and geology maps because their boundaries may also correspond with vegetation boundaries, (may have limitations if their resolution is coarse).

Some vegetation units will prove difficult to subdivide, especially areas that are highly variable at a very small scale. (These are usually referred to as a mosaic pattern. Mosaics can be found in areas with fine-scale mottling of soils and or undulations, or where there are big changes in plant species composition in very small distances; such as some heaths). However, practice will improve the finesse of boundary setting. In many cases there will be reason to decide in advance where sites will be placed using aerial photographs, and other aids. These can then be refined during reconnaissance.

The aim of this type of planning is to commence with a representative coverage of a vegetation unit. (Some sources talk about random placement of plots. However, in practice this is rarely the case and historically most sites have been selected based on critical interpretation of the pattern and composition of the vegetation. There appears to be quite some confusion between bio-geographic work, the range in potential monitoring schemes, and *truly randomised trials that have a quite specific nature, purpose, location and structure*.) This ensures the overall geographic range of a vegetation unit is covered. It also ensures that the variation within a single occurrence of a vegetation unit is covered. If the unit is a mosaic it will be necessary to ensure an even spread of plots on the ground. A basic means of achieving this is to overlay a grid on the photo of the occurrence.

D. <u>Ground-truth by reconnaissance</u>

Ground-truth work involves interpretation of the common or dominant plants in tandem with landscape features. In the field it is possible to rely on the conjunction of vegetation composition and structure, and its relationship with the topography, soils, and geology. When undertaking ground-truthing a representative choice of vegetation unit should be made and a number of factors considered.

It is best to begin in an area where units are fairly clear, such as where the landscape progresses from low to high relief (A classic profile that moves from low to high in the landscape is an example of a gradient and is also specifically referred to as a catena), and the zones along the profile are likely to correspond to small-scale vegetation types. The dominant and common plant species should be faithful to a recognizable vegetation unit. Consideration should also be given to whether the vegetation unit occurs on a particular part of the landscape (such as a river bank, floodplain, lower slope, mid-slope, upper-slope, crest, or ridge) and whether it occurs on a particular soil.

There is likely to be a reasonable conjunction of these factors. If they appear repeatable at similar places in the landscape over distance it is likely that the same or very similar vegetation is being sampled. The boundaries to vegetation units can be variable and may be either clear, quite sharp (such as between rock outcrop and sand) or more gradual and contain a mix of plant species and other features from both sides (literally an ‘inter-zone’or ‘ecotone’; such zones are often narrow).

4.2) POSITIONING PLOTS IN FINE-SCALE VEGETATION UNITS

Once vegetation units are outlined plots can be positioned within them. At this stage it is necessary to consider whether the purpose is to do widespread vegetation assessment or monitoring, or a combination of the two. It is prudent to ask two questions:

A) Is coverage of the whole geographic range of the vegetation unit required?
B) How can representative coverage within any single occurrence of a unit be achieved?

Coverage of geographic range is most relevant to widespread vegetation (condition) assessment. At its most basic this means putting plots at the northern, eastern, southern, western extents and centre of the range of a vegetation unit. If the purpose of monitoring is a specific locality or unit, the geographic range of a unit may not matter. However, in this case, it may be more important to pick sites that are very similar replicates, rather than to reflect the range of variation within a unit.

In order to get representative coverage within a unit it is important to have at least one plot per small-scale vegetation unit, but attempt to get replicates. A more representative picture of the unit can be built as plot coverage increases. Hence, two plots constitute basic replication, and three plots constitute better coverage of variation for basic statistical purposes.

A greater number of plots will reflect the range of variation within a unit. With only one plot a basic approach is to select an 'average' or 'median' plot . With two plots it is possible to have a plot in the polar extremes (such as sparse and dense areas). With three plots it is possible to cover the extremes, and the middle. This approach can be used to adjust preliminary plot location that may have been selected using aerial photographs and other aids.

It is important to make allowance for small patches of anomalous vegetation (for example rock outcrops) that occur within an otherwise uniform unit. Such areas may be too small to meaningfully separate out on their own. However, it is advisable to have a strategy to deal with them. If they are very restricted in extent it may be best to avoid them when positioning plots. This prevents an artificial bias in the data. If they are common (say ≥10% of the unit) try to install a representative proportion of plots in the patches (e.g. 10% equates to 1 in 10 plots).

A management intervention in an area can also create patches. For example if only part of a long-standing monitoring plot is burnt the data from within the plot will need to be split into burnt and unburnt patches.

Similarly, a mosaic is a heterogeneous area comprised entirely of many small patches. A small occurrence of mosaic will require at least 2 and preferably 3 sites within it in order to reflect the range of variation. A larger area of mosaic may warrant more sites and a strategy to ensure representative coverage, such as a grid overlaid on the aerial image.

It is important to note that a bias or limitation of this approach occurs when boundaries are marked on vegetation units. First, because boundaries are often narrow areas of transition with a mix of plant species and they can also have unique plant species. Second, the plots involved in condition assessment are unlikely to be placed on the boundary as that would be atypical of the majority of the unit. Third, the narrowness of transition zones do not make them amenable to common plot. Plot size and shape often needs to be adapted to fit into narrow transition zones.

4.3) EDGE EFFECTS

Edge effects may require consideration. In some cases it may be desirable to reduce them, in other cases edge effects may be part of the intent of the assessment, especially in fragmented areas. If it is desirable to reduce edge effects the sites may have to be located some distance from any external vegetation boundary, for example 50 to 100m.

5) CONDITION

To conduct an assessment in the field it is necessary to read this preamble with 5.1) and 5.2), and then add: for a quick assessment 5.5.2); or for a basic assessment 5.6.1); or to add more attributes 5.6.2) & 5.6.3).

Considerations that will help optimise the assessment.

Condition assessment can be viewed as a qualitative complement or surrogate for quantitative ecological assessment.

Consequently the quality will improve if:
i) the quality of observation improves (ie experienced and/or well trained assessors are deployed, if there is more effort expended &/or more time spent at a site, and if the site is visited more than once (ideally coverage will take in season, year, and longer intervals));
ii) the number of attributes, spread evenly across a wide range of factors, is increased;
iii) the means of assessing the attributes are clear;
iv) similarly to ii) a good range of background information is collated to help inform the assessment on a range of factors;

5.1) SITE LAYOUT

The core of condition assessment within this manual is a 25mx25m area.

For basic condition assessment it is not essential that this is pegged or marked; (although for future reference or any other use it is likely to be a requirement).

However, care should be taken to:
i) Record the coordinates by way of a calibrated GPS at the centre point (and ideally the north-west corner) and to clearly describe the location and directions to the site;
II) take photographs outside the north-west corner (from about 3m to the north-west and 3m from the sides about 5m to the south and east of the northwest corner; variable plant density will mean that a workable compromise may have to be found);
iii) Closely delineate the 25mx25m quadrat in a visual sense (the use of a compass, known pacing distance, and flagging tape will help in this regard);
iv) ensure the quadrat runs N-S & E-W where possible;
v) nest any pre-existing quadrats of merit in the north-west corner;
vi) where possible make allowance for the addition of a full 75mx75m remote-sensing array that utilizes this quadrat at its centre (especially if the site is in some way unusual or important; see part 7). Where possible this larger array should fit a single vegetation type;
vii) consider the merits of walking (or even mapping any sub-types or zones or key dominants in) the whole 75mx75m area in order to get a better appreciation of the attributes of the site and its immediate context (In terms of scale allowance is possible for the site (the 25mx25m quadrat, the 75mx75m array, the adjacent area), and by virtue of adding landscape attributes the immediate part of the landscape. Proper capture of the landscape or catchment scale will require many sites through the area and/or remote sensing work.); and
viii) consider the merits of adding a full plant diversity approach and other forms of assessment in order to address issues at the site.

See 6) or 7) for how this relates to a plant diversity quadrat or a remote sensing array respectively. Where this has been overlaid on a quadrat of another size one condition quadrat should suffice for comparison. However, if it is overlaid on a 50mx50m or larger quadrat *and* there is variation in condition the installation of another condition quadrat may be justified in order to reflect the variation in condition. Above 50mx50m it is likely to be mandatory.

5.2) RECORDING DATA AND SCORING ATTRIBUTES

General format

Both the condition scales and the recording sheets have the same layout. There are 5 central scores available and which will mainly be used (from "VERY DEGRADED" to "EXCELLENT"). At either side of these are "A" (ALIENATED) and "P" (PRISTINE). In general it is unlikely that "A" will apply because it refers to the built environment or land that is under agriculture or horticulture, which lacks any native plants and most other native organisms. In general it is likely that "P" will not commonly be used because there are very few places that have not been subject to feral animal grazing (rabbits, camels, goats, etc) or that have remained unaffected by exacerbated wind-borne dust deposition, or emissions. This might be used if an attribute seems to be in *truly outstanding* condition.

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄							

HINT: scoring should first focus on the listed sub-attributes for each scale; try not to rely on column labels "very degraded" to "excellent" alone as these are essentially secondary.

In some cases it may prove too hard to rate the attribute due to uncertainty or a lack of experience or evidence, in which case there is provision to tick the "NA" (not applicable) box and move to the next attribute. It is intended that any attribute with an "NA" against it will not be included in the overall summation. (If desired several options might be used. For instance: N/A default - (X); not confident to assess attribute (N); inappropriate season (S); insufficient time for attribute (T); insufficient evidence (E).)

(Note: some attributes may warrant a default score on the scale as a tick box. This may vary, though at present "good" may be the closest to a neutral score that is available. Note: *in general 5 category values suffice to make sensible ecological distinctions & provide a balance of signal to noise in data* (Belbin 2004)).

General pointers about attributes

Attributes are innately interlinked in an ecological sense; however, they can be viewed as independent for the purposes of rating condition.

Under each attribute there is often more than one facet which is outlined. ***Each facet is capable of being used independently or together; which means they can be regarded as an "and/or" choice***. The more important part of the attributes generally comes first, and other facets follow. For this reason percent cover or extent values are last. Please note that the percent cover or extent values shown under some attributes are a guide only, and not absolute; they support the pivotal descriptive part of the attributes.

Adopt a steady approach.

It is advisable to try and gather as many facets under an attribute as possible in order to build a more inclusive picture, and to encourage an element of objectivity. In this regard it may help to:
i) have a blank worksheet available to make notes and on which to mark facets under the appropriate column for any attribute in order to make an overall decision;
ii) take the overall rating for the attribute to be the column/category that gathers the most facets. It is unavoidable that there will not be perfect agreement between facets as they are differential;

iii) if a rating falls between two categories, provisionally mark it on the border, and then revisit it at the end of the process. This is in order to ensure that the final call on its category reflects the state of the other attributes.
iv) in many cases it may help to mark the direction to the next closest rating on a given attribute.

Consequently the most coherent picture of the state of the vegetation and the factors that contribute to it, and to the trend in change of state, is best composed by assessing as many facets and as many attributes as possible. There is no guarantee that all or many facets under every attribute will be evident at one time.

Similarly prolonging the time spent observing attributes combined with more than one visit to the site during the year is likely to result in a better rating.

The field sheets.

On the first page is a figure that shows components of the 25mx25m quadrat, which is an aid to visual estimation of percent cover.

On the second page is a figure that shows how to take account of scale using the expanded site layout as a means of reference. This can be done if the 25mx25m condition quadrat is taken to be at the centre of a block of 9 such quadrats (or the “array” as considered in part 7). Using this arrangement it is possible to score any attribute with: 1) a ‘1’ if it was observed in the quadrat (alternatively ‘B2’ as this is the label for the central condition quadrat in the array); 2) a ‘2’ if it was observed in the other quadrats (alternatively use the label for each quadrat from the array; see below); and 3) a ‘3’ if it was observed in the locality adjacent to the array. (See presentation for more on scale.)

On the second page is also provision to account for the time taken. Record the amount of time that the whole exercise took, and also estimate and record the relative time per attribute. Note if any attribute took more time than most of the rest. The main reason for this is that it may help make allowance for time constraints. If time is very short it is preferable to use the Keighery scale. The season and its effects on the assessment can also be noted.

Even a basic assessment of a reduced set of about 15 to 20 attributes is likely to take about three hours per site (to array), and a good half a day is likely to be better.

That is because this work is grounded in observation. It is observation dependent, and the more observations that are made for each attribute, and the more time that is devoted to the task, the better the picture of the state or trend will be. It pays to walk around the site for most of the allotted time making notes, and to leave the actual scoring to the very end. Consequently this assessment can be added to supplement other activities; especially those focused on plants, and again should be assessed last, and accorded sufficient time.

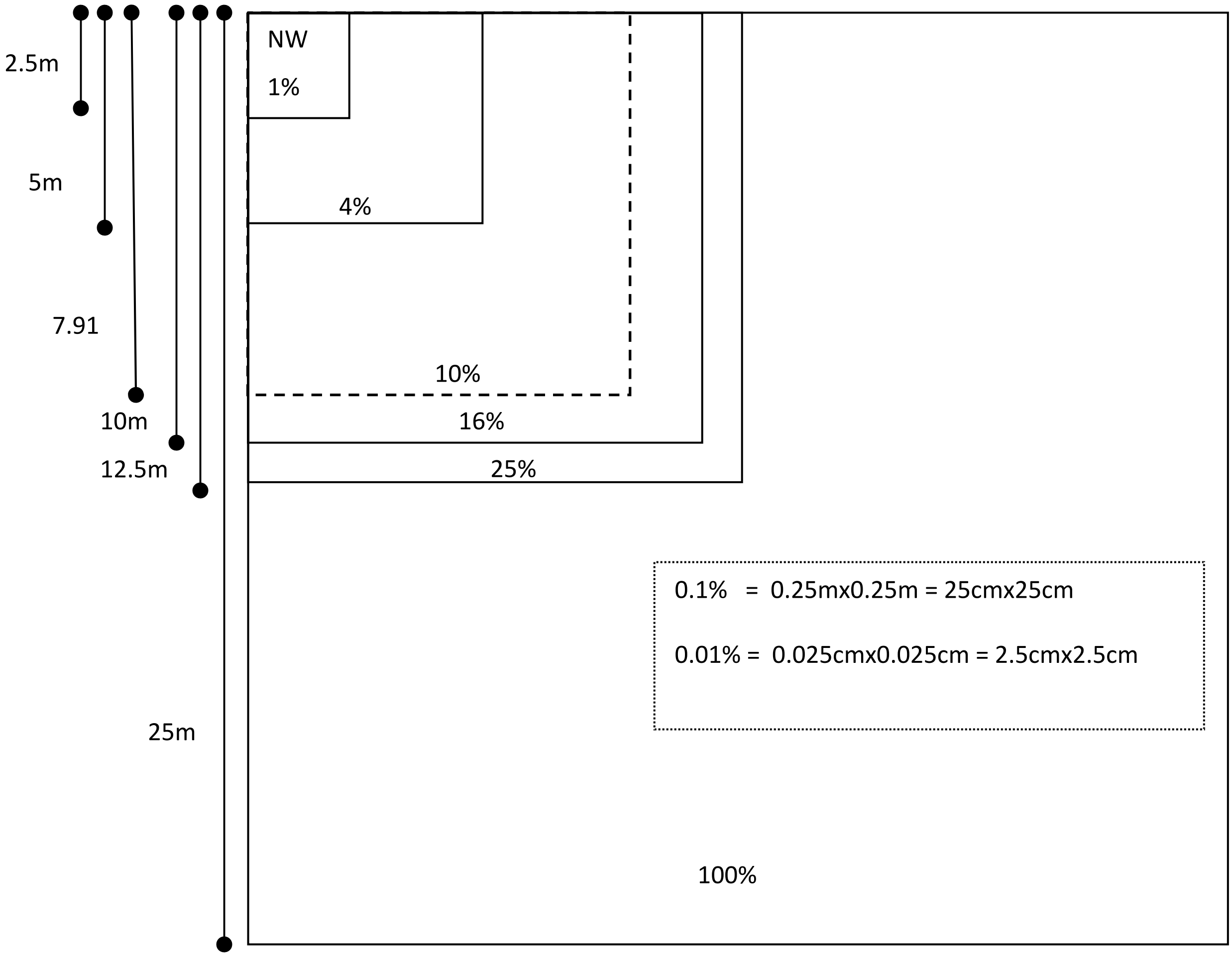
If return visits are made this will become a monitoring exercise and for the sake of comparison it will be important to return at the same time/s of year.

Thereafter follow site attributes; the 3rd page has the Keighery scale, and a reduced set of attributes, and the 4th page has more attributes that might be used.

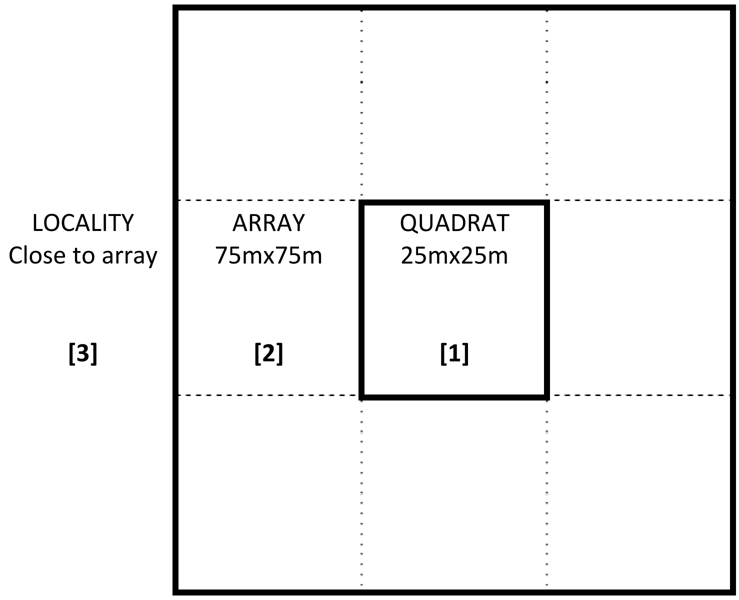
On the 5th page are common landscape scale attributes which address fragmentation.

On the 6th page is the support sheet to help work out the fire attribute in more detail.

FIGURE : Percent cover values of parts of the 25mx25m quadrat to assist estimation.



<table>
<tr><td colspan="2">How to use the same data sheet to accommodate attributes at three scales relevant to the immediate context (eg an adjacent potential threat); namely use 1 for the quadrat, 2 for the array outside the quadrat, and 3 for the area adjacent to the array. (Note if using the full array the scoring is specific to each quadrat and the quadrat label is recorded; see array section.)</td></tr>
<tr><td></td><td>LAYOUT</td></tr>
<tr><td>TARGET AREA >

Mark each attribute with [#] ></td><td></td></tr>
</table>

PRELUDE:
DATA RECORDING SHEET

TIME TAKEN ON OVERALL ASSESSMENT _______________________________

DID ANY TASKS TAKE LONGER THAN THE OTHERS? ______ESTIMATE FOR THE MAIN 5.
ATTRIBUTE ___________ TIME _____________ ATTRIBUTE ___________ TIME _____________
ATTRIBUTE ___________ TIME _____________ ATTRIBUTE ___________ TIME _____________
ATTRIBUTE ___________ TIME _____________ ATTRIBUTE ___________ TIME _____________
ATTRIBUTE ___________ TIME _____________ ATTRIBUTE ___________ TIME _____________
ATTRIBUTE ___________ TIME _____________ ATTRIBUTE ___________ TIME _____________

TIME OF YEAR & LIKELY EFFECT ON SCORES: ____

SITE LOCATED IN A REMNANT YES ___ NO ___ SIZE OF REMNANT ______m x ______ m

ALTERNATIVE SINGLE CONDITION SCORE

SHORT SCALE									

REDUCED ATTRIBUTE SET [NA - not applicable if not assessable; Some attributes may require a default - to be shown as a tick box.]

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄							
VEGETATION STRUCTURE	A	◄							
RECRUITMENT	R	◄							
HEALTH - GENERAL	R	◄							
DEATH OF KEY SPECIES	R	◄							
SURFACE STABILITY	M	◄							
LITTER	M	◄							
BIOTURBATION	M	◄							
WEEDS LINKED TO DISTURBANCE	W	►							
WEEDS - NON-DISTURBANCE	W	►							
EROSION / DEPOSTION	D	►							
INFRASTRUCTURE CHARACTERISTICS	D	►							
EXTENT OF CLEARING	D	►							
RESOURCE EXTRACTION	D	►							
OTHER SURFACE DISTURBANCE	D	►							
WATERLOGGING OR DROUGHT	D	►							
SALINITY - SECONDARY	D	►							
HARVESTING OF BIOMASS	D	►							
FERAL ANIMALS PRESENT	D	►							
TOTAL GRAZING	M /D	◄							
FIRE FREQUENCY RISING	M	◄							
FIRE FREQUENCY DECLINING	M	◄							
RESILIENCE	_	_							
TOTAL (-3C)									

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*									
GROUP LIKE QUADS BY STATE									

COMPLEMENTARY ATTRIBUTES

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
Input to promote regeneration	R								
Health - Disease in main species	R								
Health - Insect damage	R								
Health - Plant parasites	R								
Native fungi.	M								
Nutrient cycling	M								
Enrichment planting / sowing	W								
Corridors - as invasion route	D								
Waterlogging Or Drought - history	D								
Salinity secondary history	D								
Salinity second-ary remedial actn	D								
Wetland eutrophication	D								
Pollutants -input nutrients & other	D								
Rubbish dumping	D								
Sivicultural mngmnt forests	D								
Acidity buildup	D								
Native Vertebr. indicators	M								
Indicators -(Emus & other vectors?)	M								
Native Invertebr. indicators	M								
Indicators - ants as vectors	M								
Indicators - Orchids	M								
TOTAL									

LANDSCAPE ATTRIBUTES

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
REMNANT (PATCH)									
SIZE									
SHAPE									
DISTANCE TO BIG CORE AREA									
MATRIX									
CONNECTIVITY									
NEIGHBOURHOOD LAND USE - DEGRADATION RISK									
NEIGHBOURHOOD LAND USE - % STILL VEGETATED									
TOTAL									

TABLES TO HELP FILL OUT THE FIRE ATTRIBUTE

FIRE FREQUENCY RISING & INTERVAL CONTRACTING		**A**	**VERY DEGRADED**	**DEGRADED**	**GOOD**	**VERY GOOD**	**EXCELLENT**	**P**	**NA**
Fire scars on woody dominants									
Small-scale uniformity and openness of vegetation.									
Presence of epicormic or basal sprouts on trees/woody plants									
Biomass stored in vegetation. Plant litter.									
Presence of perennial seeder species. Presence of senescence.									
Presence of fire-ephemeral and ephemeral species.									
TOTAL									

FIRE FREQUENCY DECLINING & INTERVAL EXPANDING		**A**	**VERY DEGRADED**	**DEGRADED**	**GOOD**	**VERY GOOD**	**EXCELLENT**	**P**	**NA**
Fire scars on woody dominants									
Small-scale uniformity and openness of vegetation.									
Presence of epicormic or basal sprouts on trees/woody plants									
Biomass stored in vegetation. Plant litter.									
Presence of perennial seeder species. Presence of senescence.									
Presence of fire-ephemeral and ephemeral species.									
TOTAL									

5.3) SUMMATION OF THE SCORES

For most purposes the scoring sheets provide a clear indication of which attributes are subject to an adverse trend.

However, it is also necessary to have a single score for gross comparative purposes with schemes such as VAST. A provisional way of working out a single score is shown below.

The basic division of attributes is:
i) non-landscape or site attributes.
In turn this is split into:

a) plant species composition (because this encapsulates much ecological information); and
b) the other non-landscape attributes (which can be viewed as processes and threats); and

ii) landscape attributes.

The Implied basic weighting in the summation table is:

		RATIO
i) a)	SPECIES COMPOSITION	1.0 :
i) b)	OTHER NON-LANDSCAPE PROCESSES ↙◢	0.5 :
	OTHER NON-LANDSCAPE ◣↘ THREATS	0.5 :
ii)	LANDSCAPE	1.0 :

The left hand side of the following table shows a mock recording sheet with data and the calculation column shows the workings. THIS JUST REFLECTS THE NUMBER OF ATTRIBUTES AND SO WILL BE THE SAME FOR EVERY CASE. IT NEEDS WORK. Where there are multiple attributes a simple midpoint is calculated for the total.

Possible means of deriving an overall score.
In the act of combining compound ranks if the outcome is a score that falls between two categories the default may be taken to be to the left or threat side because this errs on the side of caution in terms of trend and the requirement for management intervention.

	RANK >	VD	D	G	VG	E	CALCULATIONS	VD	D	G	VG	E
ATTRIBUTE GROUPS												
SPECIES COMPOSITION	TOTAL			1			TRANSFERRED >			1		
OTHER NON-LANDSCAPE												
	A	1					CALCULATION :					
	B			1								
	C				1		MID-POINT					
	D					1	(6 + 6 + 5 + 3 + 4) / 2 = 12					
	E		1									
	F					1	FALLS :					
	G		1				Exactly between D & G					
	H			1								
	I	1					DEFAULT TO THREAT (LEFT) SIDE? :					
	J					1	So score as 'D'					
	K		1									
	L			1								
	M	1										
	N				1							
	O	1										
	P		1									
	Q			1								
	R					1						
	S	1										
	T				1							
	U		1									
	V			1								
	W	1										
	X		1									
	TOTAL	6	6	5	3	4	TRANSFERRED TO 'D' >		1			
LANDSCAPE	A			1			AS ABOVE					
	B	1					(1 + 1 + 1) / 2 = 1.5					
	C				1		So score as 'G'					
	TOTAL	1		1	1		TRANSFERRED TO 'G' >			1		
OVERALL							AS IMMEDIATELY ABOVE			1		

5.4) PRESENTATION OF THE SCORES

In terms of management it is likely that an overall rating of “GOOD” is a cause for concern as below that several threats are accelerating (that is because many attributes are logarithmic). Transition from ‘good’ to ‘degraded’ is best viewed as an indication that management is required, because there is an element of accelerated change or threat implied in many of the attributes below this rating.

Nonetheless this does not imply that anything down-gradient from “GOOD” necessarily reduces the value of the vegetation or habitat to zero. Even a “DEGRADED” to “VERY DEGRADED” site may have significant values that require time and resources to redeem them.

In order to present the scores graphically they are simply ascribed a single value per attribute. Then the major divisions shown in the interim attribute list or conceptual figure are used create major groupings in order to graph general trends.

The issue of scale may be vexed for hand mapping of vegetation condition. It has been pointed out that ranges or broader units may be required as most vegetated areas are a mosaic of conditions and it can be impractical to show all condition scores separately (see Trudgen 1991, & Kaeshagen 1994).

5.5) ASSESSMENT WITH CONDENSED SCALES OF FEW ATTRIBUTES

5.5.1) CONDITION SCALES - THE NATIONAL “VAST” SCHEME

The VAST (Vegetation Assets, States and Transitions) system is a very broad means of scoring the condition of vegetation, both native and non-native. It assesses the components: vegetation community structure, composition and regenerative capacity, with regard to disturbance due to land use. This information can be used to identify and prioritise which vegetation types and areas should be targeted to provide maximum benefit to ecosystem functions and services eg. biodiversity conservation and optimising sustainable production for food and fibre. The VAST system can also account for changes in land use and can help land managers identify areas for remediation or conservation (Thackway and Lesslie 2006). The categories can be readily mapped.

The VAST framework:
I) orders native vegetation by degree of anthropogenic modification as a series of states, from a reference base-line condition through to total removal;

It classifies vegetation into native and non-native cover. These in turn are divided into residual, modified, & transformed, and replaced or removed respectively.

II) is not linked to any particular method of vegetation survey, and is designed to accommodate a range of survey data from which inferences (information) about vegetation composition, structure and regenerative capacity can be derived;
III) is not confined to any particular scale or resolution of data.

The categories from VAST are reproduced in the following table, where they are also aligned with the Keighery scale from Western Australia, which is outlined next.
[Note the last category on the Keighery scale has been provisionally amended and this needs to be resolved.]

Table 1: VAST (Vegetation Assets, States & Transitions (Thackway & Leslie 2006)), with columns-as-states & shifts between them transitions, versus an amended WA scale (Keighery 1994).

> Increasing vegetation modification from left to right >								
		Other Cover	***Native Vegetation Cover*** Dominant structuring plant species indigenous to the locality and spontaneous in occurrence – i.e. a community described using definitive vegetation types relative to estimated pre1750 types#			***Non-native Vegetation Cover*** Dominant structuring plant species indigenous to the locality but cultivated; alien to the locality and cultivated; or alien to the locality and spontaneous*		
Vegetation Cover Classes		State 0: NATURALLYBARE Areas where native vegetation does not naturally persist, and recently naturally disturbed areas where native vegetation has been entirely removed (ie open to primary succession).	State I: RESIDUAL native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practice	State II: MODIFIED native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice	State III: TRANSFORMED native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice	State IV: REPLACED - *ADVENTIVE* native vegetation replacement – species alien to the locality and spontaneous in occurrence	State V: REPLACED - *MANAGED* native vegetation replacement with cultivated vegetation	State VI: REMOVED vegetation removed – alienation to non-vegetated land cover
Diagnostic criteria	Current regenerative capacity	Natural regenerative capacity unmodified - ephemerals and lower plants	Natural regenerative capacity unmodified	Natural regeneration capacity persists under past and/or current land management practices	Natural regenerative capacity limited / at risk under past &/or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice	Regeneration of native vegetation community has been suppressed by ongoing disturbances of the natural regenerative capacity/in-situ resilience at least significantly depleted. May still be considerable potential for restoration via assisted natural regeneration approaches.	Regeneration potential of native vegetation likely to be highly depleted by intensive land management. Very limited potential for restoration using assisted natural regeneration approaches.	Nil or minimal regeneration potential. Restoration potential dependent on reconstruction approaches.
	Vegetation Structure	Nil or minimal	Structural integrity of native vegetation community is very high	Structure is predominantly altered but intact e.g. a layer /strata and/or growth forms and/or age classes removed	Dominant structuring species of native vegetation community significantly altered e.g. a layer / strata frequently & repeatedly removed	Dominant structuring species of native vegetation community removed or predominantly cleared or extremely degraded	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
	Vegetation Composition	Nil or minimal	Compositional integrity of native vegetation community is very high	Composition of native vegetation community is altered but intact	Dominant structuring species present - species dominance significantly altered	Dominant structuring species of native vegetation community removed	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Examples		Bare mud; rock; river and beach sand, salt and freshwater lakes, rock slides and lava flows.	Old growth forests; Native grasslands that have not been grazed; Wildfire in native forests and woodlands of a natural frequency and/or intensity;	Native vegetation types managed using sustainable grazing systems; Selective timber harvesting practices; Severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity	Intensive native forestry practices; Heavily grazed native grasslands and grassy woodlands; Obvious thinning of trees for pasture production; Weedy native remnant patches; Degraded roadside reserves; Degraded coastal dune systems; Heavily grazed riparian vegetation	Severe invasions of introduced weeds; Invasive native woody species found outside their normal range; Isolated native trees /shrubs /grass species in the above examples	Forest plantations; Horticulture; Tree cropping; Orchards; Reclaimed mine sites; Environmental and amenity plantings; Improved pastures. (includes heavy thinning of trees for pasture); Cropping; Isolated native trees/ shrubs/ grass species in the above examples	Water impoundments; Urban and industrial landscapes; quarries and mines; Transport infrastructure; salt scalded areas
Keighery equivalent	(Amended scale)	**NATURALLY BARE [*0 – added*]**	**PRISITINE [1]** **EXCELLENT [2]**	**VERY GOOD [3]** **GOOD [4]**	**DEGRADED I [5]** ***DEGRADED II* [*6 – added*]**	**COMPLETELY DEGRADED [*7 – raised*] (=REPLACED - ADVENTITIVE)**	**REPLACED – MANAGED [*8 – added*]**	**REMOVED [*9 - added*]**

Modified Keighery Condition Scale (Keighery 1994) compared to the VAST framework for modification (Thackway & Leslie 2006).

Keighery Condition Scale (Keighery 1994)	**VAST** (Thackway & Lesslie 2006)	
(0)	**State 0: NATURALLY BARE**	Areas with naturally little cover and recently, naturally, disturbed areas where native vegetation has been entirely removed (ie open to "local primary succession").
Pristine [Pristine] (1) Pristine or nearly so, no obvious signs of disturbance.	**State I: RESIDUAL**	Native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practices.
Excellent [Excellent] (2) Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species.	**State I: RESIDUAL**	
Very good [Very good] (3) Vegetation structure altered; obvious signs of disturbance For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; & grazing.	**State II: MODIFIED**	Native vegetation community structure, composition, and regenerative capacity intact – perturbed by land use/land management practices.
Good [Good] (4) Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; & grazing.	**State II: MODIFIED**	
Degraded I [Poor] (5) Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; &grazing.	**State III: TRANSFORMED**	Native vegetation community structure, composition, and regenerative capacity significantly altered by land use/land management practice.
Degraded II (*6-added)* Very few values remaining.	**State III: TRANSFORMED**	
Completely Degraded (*7 – raised)* The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.	**State IV: REPLACED - *ADVENTIVE***	Spontaneous occurrence of alien species.
(8)	**State V: REPLACED – *MANAGED***	Replacement with cultivated vegetation.
(9)	**State VI: REMOVED**	Alienation to non-vegetated cover.

5.5.2) CONDITION SCALES - THE W.A. KEIGHERY SCALE

Major themes in the Western Australian vegetation scales are the assessment of disturbance and a sense of the ability of the bushland to self-maintain. It can be seen that there are a range of attributes that are actually mentioned, though the basic structure, composition and resilience elements, in relation to disturbance are clear. Initially these scales were used on unbounded assessments (relevees) but they have since been applied to legions of 10mx10m quadrats in the southwest (Trudgen 1991; Keighery 1994; Department of Environmental Protection 2000).

The relative alignment of the better known versions of such scales with the ubiquitous Keighery scale is given in the table.

Given that there is a substantial amount of condition rating based on bioregional survey and environmental impact work that has used, and may continue to use, the latter scale, it was imperative that it align to some degree with the current scales. This means that comparison is possible, and graphic and tabular representations are also feasible, although this will have to be qualified. Both scales share key attributes and many minor attributes, though they are not exact translations.

Only a minor adjustment was required to make this existing scale align with the general arrangement adopted here and this is shown in the subsequent tables.

With this minor adjustment the two scales are amenable to colour coding on maps (including GIS) as shown.

5.5.3) CONDITION SCALES - AN ALTERNATE SHORT SCALE

A short scale is provided that reflects the essence of four key attributes from the expanded scales and the intent of the Keighery scales.

It may have application in situations where there are limitations such as time constraints or where the assessor has limited experience of such assessment.

Provision is made to rate the state of vegetation using the short scale, though the Keighery scale may also be used.

It is preferable that the short scale is used given that it is inherently consistent with approaches using more attributes.

◊ The short scale is best appraised in two steps: i) a semi-sequential order taking into account structure, then plant species composition, then disturbance (particularly extent and loss of soil), then evidence of recruitment; ii) balancing this with a sense of the category that, on balance, collects most of the sub-attributes.

This approach recognises there will always be a degree of tension between attributes. This is because they are not necessarily closely correlated, and so neat alignment is not a certainty.

◊ It is preferable that reconnaissance and orientation precede such rating.

First-pass comparison of key vegetation condition scales for natural area assessments which have been applied in WA. Two parts are not well aligned: i) the last section in Keighery holds the last elements of deteriorating state & complete alienation; & ii) Connell is at least a half category too high.

Keighery Condition Scale (Keighery 1994) [& ` **Auction for Landscape Recovery]**	**Kaesehagen Condition Scale** (Kaesehagen 1994)	**Land For Wildlife** [& **Managing Your Bushland** (Hussey & Wallace 1993)]	**Trudgen (1991) (**basis of Keighery 1994 & of Connell 1995)	**Connell** (1995)	
Pristine [Pristine] (1) Pristine or nearly so, no obvious signs of disturbance.			**Excellent (E) (1)** Pristine or nearly so, no obvious signs of damage caused by the activities of European man.		1
Excellent [Excellent] (2) Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species.			**Very Good (VG) (2)** Some relatively slight signs of damage caused by the activities of European man. For example, some signs of damage to tree trunks caused by repeated fires and the presence of some relatively non-aggressive weeds such as *Ursinia* or *Briza* species, or occasional vehicle tracks.	**Very Good (vg) (2)** Evidence of localised low level damage within healthy bush. Seedling recruitment & generally healthy population size (age/stage) structure apparent. Weed & grazing damage is confined (<20% of area). Possible modification to structure due to altered fire regimes. Possible signs of logging or fire wood collection. High likelihood that structure & richness can be maintained.	2
	Very good to excellent (2.5) 80% to 100% native flora composition Vegetation structure intact or nearly so Cover/abundance of weeds <5% No or minimal signs of disturbance	**Excellent (Undisturbed remnant) (2.5)** intact community, all expected plant layers present and healthy few weeds or localised only almost no disturbance or disturbance confined to a small area little or no history of grazing			
Very good [Very good] (3) Vegetation structure altered; obvious signs of disturbance For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; & grazing.			**Good (G) (3)** More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones.	**Good (g) (3)** Some localised high level damage within little damaged bush. Recruitment localised & populations of some species may be senescent. Weed &grazing damage apparent in 20-50% of the area. Possible modification to structure due to changes to in fire regimes. Localised gall & parasitic plant damage; logging or firewood collection. Moderate chance of maintaining structure & richness.	3
	Fair to good (3.5) 50% to 80% native flora composition Vegetation structure modified or nearly so Cover/abundance of weeds 5% to 20%, any number of individuals Minor signs of disturbance	**Good (Moderately disturbed rem.) (3.5)** all expected plant layers present, but sparse & may show signs of stress weeds may be extensive, up to 50% of total area change in soil structure evident, but not widespread moderate grazing pressure			
Good [Good] (4) Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; & grazing.			**Poor (P) (4)** Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man such as grazing or partial clearing (chaining) or very frequent fires. Weeds as above, probably plus some more aggressive ones such as *Ehrharta* species.	**Poor (p) (4)** Widespread high level damage. Recruitment disrupted & most woody species are senescent. May be weed & grazing damage to >50% of area. Evidence of modification to structure due to changes in fire regimes. Locally some strata are absent. Evidence of gall & mistletoe damage; logging or firewood collection. Low likelihood that structure & richness can be maintained or re-established.	4
	Poor (4.5) 20% to 50% native flora composition Vegetation structure completely modified or nearly so Cover/abundance of weeds 20% to 60%, any number of individuals Disturbance incidence high	**Moderate (Partly degraded rem.) (4.5)** plant community simplified, often with shrub & ground layer sparse or absent change in soil structure &/or water balance evident may be signs of erosion, salinity or waterlogging heavy, prolonged, grazing pressure			
Degraded [Poor] (5) Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; &grazing.			**Very Poor (VP) (5)** Severely impacted by grazing, fire, clearing, or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species including aggressive species.	**Very Poor (vp) (5)** Widespread high level damage. Recruitment disrupted * most species senescent. Evident weed & grazing damage throughout the area. Evident modification to structure due to altered fire regimes. Widespread loss of strata. Evident gall & mistletoe damage. Evident logging or firewood collection. Little to no likelihood that structure & richness can be re-established.	5
	Very Poor (5.5) 0% to 20% Native flora composition Vegetation structure disappeared Cover/abundance of weeds 60% to 100%, any number of individuals Disturbance incidence very high	**Fair (Degraded remnant) (5.5)** plant community severely altered, few remaining original species, may show severe stress, may be dead or dying; replaced by weeds, or swamp- or salt tolerant plants very heavy grazing or salinity or waterlogging			
Completely Degraded (6) The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.			**Completely Degraded (D) (6)** Areas that are completely or almost completely without native species in the structure of their vegetation, i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.		6

Table : Second-pass alignment to reconcile several condition scales that have been applied in W.A..

Keighery Condition Scale (Keighery 1994) [& ` **Auction for Landscape Recovery' scale]**	**Kaesehagen Condition Scale** (Kaesehagen 1994)	**Land For Wildlife** [& **Managing Your Bushland** (Hussey & Wallace 1993)]	**Connell** (1995)	**Trudgen (1991) (**basis of Keighery 1994 & of Connell 1995)
Pristine [Pristine] (1) Pristine or nearly so, no obvious signs of disturbance.				**Excellent (E) (1)** Pristine or nearly so, no obvious signs of damage caused by the activities of European man.
Excellent [Excellent] (2) Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species.	**Very good to excellent (2.5)** 80% to 100% native flora composition Vegetation structure intact or nearly so Cover/abundance of weeds <5% No or minimal signs of disturbance	**Excellent (Undisturbed remnant) (2.5)** intact community, all expected plant layers present and healthy few weeds or localised only almost no disturbance or disturbance confined to a small area little or no history of grazing	**Very Good (vg) (2/2.5)** Evidence of localised low level damage within healthy bush. Seedling recruitment & generally healthy population size (age/stage) structure apparent. Weed & grazing damage is confined (<20% of area). Possible modification to structure due to altered fire regimes. Possible signs of logging or fire wood collection. High likelihood that structure & richness can be maintained.	**Very Good (VG) (2)** Some relatively slight signs of damage caused by the activities of European man. For example, some signs of damage to tree trunks caused by repeated fires and the presence of some relatively non-aggressive weeds such as *Ursinia* or *Briza* species, or occasional vehicle tracks.
Very good [Very good] (3) Vegetation structure altered; obvious signs of disturbance For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; & grazing.	**Fair to good (3.5)** 50% to 80% native flora composition Vegetation structure modified or nearly so Cover/abundance of weeds 5% to 20%, any number of individuals Minor signs of disturbance	**Good (Moderately disturbed rem.) (3.5)** all expected plant layers present, but sparse & may show signs of stress weeds may be extensive, up to 50% of total area change in soil structure evident, but not widespread moderate grazing pressure	**Good (g) (3/3.5)** Some localised high level damage within little damaged bush. Recruitment localised & populations of some species may be senescent. Weed &grazing damage apparent in 20-50% of the area. Possible modification to structure due to changes to in fire regimes. Localised gall & parasitic plant damage; logging or firewood collection. Moderate chance of maintaining structure & richness.	**Good (G) (3)** More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as caused by low levels of grazing or by selective logging. Weeds as above, possibly plus some more aggressive ones.
Good [Good] (4) Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; & grazing.	**Poor (4.5)** 20% to 50% native flora composition Vegetation structure completely modified or nearly so Cover/abundance of weeds 20% to 60%, any number of individuals Disturbance incidence high	**Moderate (Partly degraded rem.) (4.5)** plant community simplified, often with shrub & ground layer sparse or absent change in soil structure &/or water balance evident may be signs of erosion, salinity or waterlogging heavy, prolonged, grazing pressure	**Poor (p) (4/4.5)** Widespread high level damage. Recruitment disrupted & most woody species are senescent. May be weed & grazing damage to >50% of area. Evidence of modification to structure due to changes in fire regimes. Locally some strata are absent. Evidence of gall & mistletoe damage; logging or firewood collection. Low likelihood that structure & richness can be maintained or re-established.	**Poor (P) (4)** Still retains basic vegetation structure or ability to regenerate to it after very obvious impacts of activities of European man such as grazing or partial clearing (chaining) or very frequent fires. Weeds as above, probably plus some more aggressive ones such as *Ehrharta* species.
Degraded I [Poor] (5) Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; &grazing.	**Very Poor (5.5)** 0% to 20% Native flora composition Vegetation structure disappeared Cover/abundance of weeds 60% to 100%, any number of individuals Disturbance incidence very high	**Fair (Degraded remnant) (5.5)** plant community severely altered, few remaining original species, may show severe stress, may be dead or dying; replaced by weeds, or swamp- or salt tolerant plants very heavy grazing or salinity or waterlogging	**Very Poor (vp) (5/5.5)** Widespread high level damage. Recruitment disrupted * most species senescent. Evident weed & grazing damage throughout the area. Evident modification to structure due to altered fire regimes. Widespread loss of strata. Evident gall & mistletoe damage. Evident logging or firewood collection. Little to no likelihood that structure & richness can be re-established.	**Very Poor (VP) (5)** Severely impacted by grazing, fire, clearing, or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species including aggressive species.
Degraded II (*6- added*) Very few values remaining. # ("These areas …" below belongs here)				(*<equivalent to worst in this category*)
Completely Degraded (*7- raised*) The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. #These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.				**Completely Degraded (D) (6)** Areas that are completely or almost completely without native species in the structure of their vegetation, i.e. areas that are cleared or 'parkland cleared' with their flora comprising weed or crop species with isolated native trees or shrubs.

How the Keighery scale aligns with the current scales (this is an aid to consistent format for comparison & storage).

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Keighery Condition Scale (Keighery 1994)	**Completely Degraded** *[completely # is better here & such a split improves alignment]*	**Degraded II** The structure of the vegetation is no longer intact and the area is *[completely #]* or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.	**Degraded I** Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; &grazing.	**Good** Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; & grazing.	**Very good** Vegetation structure altered; obvious signs of disturbance For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; & grazing.	**Excellent** Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species	**Pristine** Pristine or nearly so, no obvious signs of disturbance.

Short scale for quick assessment (this is recommended for consistency with this document).

Order of priority (Semi-sequential & independent)	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Structure of vegetation	Complete absence of native plant species and either loss of the soil or long-standing barriers to recruitment from seed.	Widespread loss of layers.	One or more layers missing or frequently & repeatedly removed.	All layers present, but some may be sparse or discontinuous.	All layers present, with minor modification.	All layers present.	Complete absence of any measure of influence from post-settlement activities.
Plant composition.		Many species missing.	Several species diminished/missing.	One or more species diminished	At least one species diminished.	Full range of native species present.	
Disturbance &/or weeds (Converse is soil seed bank integrity)		High level <> Extensive area (consolidated) <> Repeated/ongoing (frequent)	Mod/high level <> Growing area (melding) <> Intermittent (sporadic)	Moderate level <> Limited area (scattered) <> Single incidence (infrequent)	Mod/low level <> Minor area (isolated) <> Single incidence (infrequent)	Low level	
Recruitment		No seedlings <> No saplings	Scarce or no seedlings <> Scarce or no saplings	A few species have isolated seedlings <> A few species have isolated saplings	Several species have few seedlings <> Several species have a few saplings	Several species have several seedlings <> Several species have several saplings	

5.5.4) CONDITION SCALES - COLOUR CODE FOR DISPLAY

The set of five categories is readily graded into a grey-scale or colour spectrum for the purposes of display. It may require the categories alienated and pristine to be defined in a complementary and contrasting way to provide full context.

Standard colour code for the 5 central categories for GIS (greyscale - colour blind friendly).

		VERY DEGRADED **0%**	**DEGRADED** **25%**	**GOOD** **50%**	**VERY GOOD** **75%**	**EXCELLENT** **100%**	

Standard colour code for the 5 central categories for GIS (colour - colour blind friendly).

		VERY DEGRADED	**DEGRADED**	**GOOD**	**VERY GOOD**	**EXCELLENT**	

5.6) ASSESSMENT WITH MORE ATTRIBUTES

An alternate approach to a composite scale is the use of multiple separate attributes. This provides more latitude to assess attributes independently and then combine them.

For presentation purposes the following works with four major trend groups of attributes or factors, namely:
i) composition (essentially plant diversity; though it may be extended to full other aspects of biodiversity (structure as applied to vegetation is somewhere between composition and architecture because life-forms tend to reflect their genetics);
ii) architecture (the physical expression of plants - roughly habitat);
iii) regenerative capacity (used for plant regeneration by seed as this is the most evident means of reproduction); and
iv) maintenance (the interactions of the biota or processes that tend to support the community in-situ).

These groups diminish from right to left on the scales. Two reappear at landscape scale.

These are opposed by:
v) disturbance (as imposed by anthropogenic activity); and
vi) weeds (which could be lumped with disturbance, especially ‘aggressive’ weeds).

These groups diminish from right to left on the scales.

TABLE : Major trend groups that can be used to gather attributes (as in the next list).

TREND (~WEIGHTING)	KEY CONCEPT	
↙◢	**UNRECOGNISED PROCESSES**	Open category: in case a new ecological dimension is uncovered and verified
↙◢ (25/2)TOGETHER?#	**COMPOSITION** /Plant Diversity /(Full complement of organisms) [Applies equally to seed soil reserve] **> STRUCTURE ***	Includes: CONSERVATION SIGNIFICANCE (source - ALR)
↙◢	**ARCHITECTURE** /Habitat /Niche (in time & in space)	Resources: i) food; ii) refuge; iii) other. Uniform or varied (a patchwork is achievable in larger remnants): i) in time (chronologically) [*often stages in the fire cycle*]; ii) in space (vertically & horizontally – which creates tertiary structure) [often *different vegetation types* (topography & soils)]; iii) together i) & ii) provide quaternary structure (and may see the fire cycle tend to overlay directly on the vegetation type in the long-term).
↙◢ (25/2)TOGETHER?#	**REGENERATIVE CAPACITY** /Resilience/Persistence (Sustainability) [Applies equally to seed soil reserve]	

↙◢ 25	**MAINTENANCE** /Services/Interactions/Vectors-dispersal/Housekeeping by all biota/The web – full complement of organisms	Includes: Bioturbation Landscape Function Measures
◣↘ 25	**WEEDS** /Exotic species	
◣↘ 25	**DISTURBANCE** /Impacts/Health	
LANDSCAPE CONTEXT	MAINTENANCE A/A	Processes – i) outbreeding; & ii) immigration; - i) isolation; ii) inbreeding; iii) emigration; iv) extinction.
LANDSCAPE CONTEXT	ARCHITECTURE /patchwork/niche (in time & in space)	

A broader set of attributes is provided in the following table. It approximates the range of attributes typically used in other states (Oliver et al 2007) or that have been applied in W.A.. Although it is derived from such lists it is not a direct reflection of them for several reasons. First, because some attributes were amalgamated in order to create a small set of attributes. (For instance rather than have tracks, roads, firebreaks, railways, etc, separate they have all been lumped into disturbance corridors). Second, there are a couple of attributes which do not appear in these schemes and which were devised in order to address recurring themes in the literature. (These include the fire and the surface stability attributes. They are included because they are important and because they are the sorts of things that an experienced assessor tends to subconsciously address. They are worth trialling with a view to refinement.)

Attributes may be able to be better rationalised
Attributes may be able to be supplemented
Attributes may be able to be added.

The key to the following table outlines:
i) how the attributes are arranged according to the trend group;
ii) whether the attributes hold a sense of fragmentation or landscape effects;
iii) whether the attribute might express some sense of patchiness in the environment;
iv) whether they align with the broad sense of composition, structure, resilience or disturbance that is embedded in VAST, Keighery, and other schemes;
v) the attributes deployed by a South Australian scheme (note all such schemes include landscape attributes);
vi) the key broad threats to Threatened and Priority ecological communities; and
vii) the key broad threats identified in DEC regional plants.

KEY TO TABLE:
TREND GROUP: C - Composition; A - Architecture (Subgroup I - Structure of vegetation; Subgroup II - Vegetation as "Habitat") R - Regenerative capacity; M - Maintenance; W - Weeds; D - Disturbance. (Subgroup: surface disturbance; hydrology.)

FRAGMENTATION and landscape impacts affect these attributes and also those shown under & REG. PL. THREATS. [**X**] **- is an attribute linked to fragmentation & which could be referred to landscape**; [#] applies to loss of remnants & a large amount of land use impacts.
PATCH: attribute strongly expresses or interacts with patch
VAST: Attrbutes colour coded according to basic subgroups in VAST. COMPOSITION / STRUCTURE / +/-STRUCTURE / RESILIENCE / +/-RESILIENCE / DISTURBANCE
SMLR ♦ - (SOUTHERN MT LOFTY RANGES) the attributes used by South Australian group (*This does not include the landscape; or "bushland degradation risk*").
TEC/PEC THREATS: The main threats to about 500 threatened and priority ecological communities in 2008 were in order: (>50%) [1] hydrological change; [2] grazing and compaction; [3] weeds; [4] recreational impacts; (<50->30%) [5] clearing; [6] disease; (<30%) [7] rubbish dumping; [8] fragmentation; [9] mining; [10] infrastructure; [11] climate change; [12] miscellaneous {erosion etc}.
Dec regional plan threats: Main threats from all 2008 regional plans. ((**Fragmentation is incorporated refer to landscape attributes**; it applies to loss of remnants & a large amount of land use impacts) [a) hydrology other + climate change; b) lack of recruitment; c) negative impacts of native fauna; d) other - people pressure]

INTERIM SITE ATTRIBUTE TABLE

TREND GROUP	FRAGMENT/N	PATCH ATTR.	VAST	SMLR	TEC/PEC THRT.	REG. PL. THRT.	REDUCED ATTRIBUTE SET (AN INTERIM BASIC SET OF ATTRIBUTES: I) FIRM - DARK GREEN; II) LIKELY - LIGHT GREEN.)	COMPLEMENTARY ATTRIBUTE SET [MAY ADD SUPPLEMENTARY ATTRIBUTES] KEY: (RS?) - better estimated for remote sensing purposes Black shading - limited scope as an attribute (Possible with work or in part with qualifacation)
C				♦			Native plant species composition	
A1				♦			Structure of vegetation	
A2				♦				Tree habitat
A3								(RS?) Interconnecting upper & mid strata for continuous foraging
A4		P						(RS?) Thickets or refuge areas.
A5		P						(RS?) Open areas. Presence of areas of young re-growth.
A6		P						(RS?) Ecotones and a mosaic of patches.
R1				♦		#b	Recruitment	
R2								Input required to promote regeneration
R3							Health of plants- general	
R4							Death of plants - key species	
R5	X			♦	6	#		Health of plants - Disease in predominant species
R6	X			♦				Health of plants - Insect damage
R7	X			♦				Health of plants - Plant parasites chiefly mistletoe
M1							Surface stability	
M2		P					Litter	
M3							Bioturbation (by which means?)	
M4		P						Native fungi.
M5								Nutrient cycling
W1	X							Enrichment planting / sowing
W2	X			♦	3	#	Weeds	
D1	X				12	#	Erosion/deposition due to disturbance	
D2	X				10		Infrastructure disturbance corridors - characteristics	
D3	X							Infrastructure disturbance corridors - invasion route
D4	X				5	#	Extent of clearing	
D5	X				9	#	Resource extraction	

D6					2, 4	#d	Other surface disturbance (stock, ferals, machines, recreation)	
D7	(X)				1, 11	#a	Waterlogging Or Drought	
D8	(X)				1			Waterlogging Or Drought - history if known
D9	X				1	#	Salinity - secondary	
D10	(X)				1			Salinity - secondary; history if known
D11	X				1			Salinity - secondary; remediation (site/catchment)
D12					1			Wetland eutrophication
D13						#		Pollutants -input of nutrients & other chemicals
D14					7			Rubbish dumping
D15	X	P						Sivicultural management
D16						#	Harvesting of biomass	
D17								(Nutrient export)
D18								Acidity buildup
D19								(Acid sulphate soils)
D20				♦		#	Feral animals present - vertebrates	
D21								(Feral animals present - i nvertebrates)
D22	X			♦	2		Total grazing	
D23						#		(Grazing by stock &/or feral animals)
M6				♦		#c		Native fauna present - vertebrates (specific indicators)
M7								Indicators -(Emus & other vectors)
M8		P						Native fauna likely habitat - vertebrates
M9								Native fauna present - invertebrate (specific indicators)
M10		P						Native fauna likely habitat - invertebrates
M11								Indicators - ants as vectors
M12								Indicators - Orchids
M13	X	P				#	Fire frequency rising & interval contracting	
M14	X	P				#	Fire frequency declining & interval expanding	
DR MW								Resilience

5.6.1) CONDITION SCALES - A BASIC VERSION

A reduced attribute set is shown in the above table in green highlighting. In order the highlighted attributes align with VAST, the Southern Mt Lofty Ranges, the TEC/PEC threats and the Regional Plan threats of DEC W.A. (although there is no perfect general agreement).

It is these attributes that may be used to form a first version of a field set. The text to accompany them is in the broader attribute list and a guide may be extracted from that source. The text includes background to the attribute, and in some cases attributes have pointers on what to look for.

The default if field time at the site is constrained would be the short scale above, which is recommended for consistency with this document (or alternatively the Keighery scale).

To add landscape attributes see 5.6.3).

5.6.2) CONDITION SCALES - A TYPICAL LIST OF ATTRIBUTES

A broader attribute set can be selected from the whole table above, and there is potential to add more if this becomes warranted. (Though note that some attributes are partly amalgamated - 5.6 paragraph 6.) Some are no more than markers to ecological features that might be conceptualised and incorporated. It also became clear with some attributes that they were not readily assessed by means of a single quadrat, and were better assessed via remote sensing and the 9 sites in the array. The text to accompany the attributes follows (5.6.2.3). The text includes background to the attribute, and in some cases attributes have pointers on what to look for.

In practice it is anticipated that the text will initially be read in conjunction with the attributes, then eventually the attribute scales should serve as sufficient reminder in the field.

The consistent alignment of attributes means that it is feasible to select more of the attributes or to develop more if there is justification from ecological principle or a specific requirement.

5.6.2.1) NOTES ON SOME UNDERLYING CONCEPTUAL MATTERS

Several of the attributes require an in-experienced assessor to come to terms with concepts that emulate ecological processes and/or plant diversity. They include the plant species composition, soil stability, fire frequency, and resilience.

Plant species composition requires an assessor to at least become familiar with the more common, faithful, species in the vegetation types in question. Becoming familiar with the major weeds in the region will assist this process as their absence can suggest there has been limited soil disturbance or invasion.

At the same time the assessor should be attempting to get a sense of the pattern of soil surface stability or integrity. This may include whether there are characteristically bare areas throughout the vegetation type in a self-sustaining state. (*Note that there is little value in attempting to rate the condition on such features because in this case they simply reflect the identity of the vegetation*.) *How plants and plant matter and bare areas are dispersed across the surface gives a sense of the heterogeneity or patchiness in space*.

This sense of heterogeneity or patchiness in space is complemented by a sense of heterogeneity or patchiness in time. Various natural disturbances can create such patchiness, including inherent flooding, drought, sedimentation or erosion, and fire. Each of these factors can cause flexible elements of the spatial pattern to move with time. Fire is the major conceptual pivot for the interplay of *heterogeneity or patchiness in time because it is predominant and overlays and interacts with enduring aspects of heterogeneity or patchiness in space that reflect identity*.

Resilience is an attribute that needs to be handled with care because it can easily be assessed in a very subjective way (namely using opinion rather than deduction, such as is implied in Connell 1995). For this reason an adaptation of a decision tree approach to this attribute has been retained for future reference.

One concept that has no obvious place for inclusion at present is a lag for indicators that are slow to change. For instance the lack of pollinators in an area may mean that some species may represent the “living dead” in an area and with time they may inevitably become locally extinct. The use of select indicators may be one way to address this.

5.6.2.2) NOTES ON RESOURCE DOCUMENTS

Several attributes could be underpinned by the provision of resource documents at a regional/sub-regional level. This could be implemented incrementally.

Such resources are mentioned under the attributes. The most fundamental include a guide to the common regional weeds; a resource which is largely in place for the metropolitan area. Some other attributes may already be well supported. For instance the common dieback susceptible species in several regions are publicly available.

The selection of what to include in such guides requires a degree of discretion. For instance (to use a supplementary attribute) in order to establish that the soil invertebrate fauna is likely to be intact it may be sufficient to recognise a spread of broad groups such as phyla, or orders, or families, and that more than one species is present in at least one group (ie sufficient to preclude an invasive dominant). For fundamental groups such as termites and ants a guide to the common regional genera may be more appropriate. Some key genera reveal much about the ecology, for example grazing pressure excludes harvester termites, whereas fire diminishes wood eating termites (Abensperg-Traun & Milewski 1995; Abensperg-Traun & Smith 1999).

Such support documentation would ideally be backed up with training. For example such training for invertebrates relies on learning to discriminate taxa, has been shown to be reliable, and does not require extensive hours (Oliver & Beattie 1992).

It may also be helpful to have regional links to registers of things such as highly fire sensitive areas, Threatened Ecological Communities, etc.

5.6.2.3) BACKGROUND & GUIDANCE FOR SITE ATTRIBUTES

The following attributes conform to the broad groupings and order presented in the tables at the start of section 5.6.

Features of the scales.

◇ This symbol accompanies comments about using the scales to make a rating. Such comments provide guidance on the approach that will help support rating the attribute.

<> This symbol appears inside the condition scales and means “&/or”. It means that the facets may be taken as semi-independent.

Do not expect that facets separated by &/or necessarily correlate or are exactly equivalent in each category; they may provide separate cues.

In general it helps to examine as many sub-attributes or facets as possible and take the category which collects the majority of these or alternately the mid-point of the collective whole as the rating.

Some attributes are suited to ranking at different scales, such as the site, array, the surrounds and the catchment. or landscape scales.

C) TREND GROUP - NATIVE PLANT SPECIES COMPOSITION

This single attribute summarises a lot of information, and so is both fundamental and of high importance in terms of assessing the state of vegetation condition. This is not simply because it provides an indication of the state of the plant species diversity. Rather it is because the presence and persistence of a native plant species or a group of such species reflects the persistence or recent presence of most of the conditions that suit such species. Essentially the plant species, by their presence, summarize a lot of ecological information. Their presence reflects many parameters such as soil type and processes (including mineralization, nutrient cycling, & soil micro-flora and fauna), microclimate (regimes of moisture, temperature, wind and sunlight), plant interactions (competition, parasitism, etc), and fauna/plant interactions (grazing, parasitism, pollination, seed dispersal, etc). Strong correlations can be readily demonstrated between communities and factors such as soil electrical conductivity, pH, levels of carbon, levels of nitrogen, levels of phosphorus, soil particles, and various climatic variables (Gibson et al 2004; Lyons et al 2004).

Native species composition is best supplemented by other attributes in order to get a sense of trend. This is particularly so if there is a lag between the start of any disturbances or adverse process/es and their effects. For instance plants may linger in an isolated remnant for the duration of their lifespan, but lack pollinators, or sufficient numbers to produce viable seed. This is where other attributes, such as those about fragmentation and remnant size, the presence of fauna which distribute seeds, or critically, about the presence of seedlings and other indicators of regeneration, assume importance.

Note that the inventory of higher plants and vertebrates is often taken as a surrogate for biodiversity, but this is based on ease of assessment, rather than any empirical relationship between the former and other groups such as invertebrates and lower plants (Oliver and Beattie 1992).

Relationship to plant diversity/floristic survey

The assessment of this attribute (if not the whole condition assessment process) is best undertaken in conjunction with full plant diversity or floristic survey, where the presence and identity of every species is determined. (In this regard the sheets provided in Keighery 1994 (see appendices), for recording species by strata, are a useful standard for such work. They can be used alongside other orientation material to inform the following appraisal of the composition and structure attributes.)

Timing of assessment of plant diversity

It is possible to conduct this work at “off-peak times of year” for the native flora; however, it is likely that total number of native species and weeds will be underestimated. At “off-peak times of year” more effort will be required to locate signs of seasonal species, and even this is unlikely to compensate for the effect of off-peak timing.

Ideally the timing will be during the main period of plant emergence and reproduction as outlined above, and more than once in that period. In addition, an even better assessment of this attribute will emerge with additional sampling at complementary times of year because some species flower and reproduce at “off-peak” times.

The seasonal effect of flowering is pronounced, for example within the jarrah forest 75% of species flower in spring (Burrows and Friend 1998).

Note that such timing does not necessarily conform to the timing that will best suit the assessment of other attributes. For example grazing may be best assessed at the end of the dry period, at which time the effects have become most acute.

<u>Assessment of the attribute</u>

◇ Compare the vegetation at the site with the same or similar vegetation by means of:

- Background information (as outlined above). (But note, with regard to timing above, that if the fieldwork for background information was conducted at a “peak” time of year and the condition assessment is not, the absence of seasonal germinants and emergents in the latter case, will make it appear that there are fewer plant species than there should be, and some allowance will have to be made for this effect. Note that some communities are entirely comprised of ephemeral species and this effect is predominant - dependent on the time of year the community is either present or absent);
- Reconnaissance and orientation at the site and in the local area (as outlined above); and/or
- On the basis of extensive experience of plant diversity survey *in the region or similar regions* (typically this will mean at least 5 and preferably 10 years working in this field).

◇ Consider whether:

- Primarily:

  i) *the species complement in broad layer categories is towards the disturbed (atypical or diminished) or undisturbed (typical) end of the spectrum in terms of number and spread of species*.

    - If using material gathered from orientation and/or background compare these to species numbers at the site on the basis of the categories given in the orientation sheet.

  Locality specific vegetation reports are likely to provide full species lists for vegetation types and structural descriptions of types; as are the appendices in regional vegetation reports. .

  ii) *if any of the typical dominant or other most common faithful species in the vegetation type are missing; as this will provide a very strong cue* *regarding whether the composition is moving towards the disturbed end of the spectrum*.

Some of these common species may have become apparent from reconnaissance as they are repeatedly found in the same vegetation type. Dominants will be the most obvious species such as the main trees (eg on the Swan Coastal Plain jarrah, and marri or banksias species) and the most common understorey species (eg *Hibbertia hypericoides* and *Acacia pulchella*); note that these examples are also some of the most widespread common species, and hence are likely to be amongst the last to decline in response to disturbance. Consequently the next tier of less common species may prove better early indicators of trend in species composition.

Many common faithful species are outlined in background material such as regional survey work. Such an account of a banksia woodland is shown in the Figure *** (Gibson et al 1994); their typical species probably correspond to the main dominants in all layers and the common species to the common or faithful species.

Such an account for part of the northern jarrah forest is shown in Figure *** in a different format (Havel 1975). It shows typical and common species for several vegetation types. It can be seen, that from a pool of 71 typical species, Jarrah (*Eucalyptus marginata*) and marri (*E. calophylla*) are the only species that are likely to be present in most of these types.

Note that these summary lists from regional survey are only subsets of all the species in the vegetation (derived from particular analysis) and the full lists of species are in supporting parts of the reports. In the case of Gibson et al (1994), an indication of the number of native species, of weed frequency and of Keighery scale vegetation condition, per type, is also provided.

◇ *Select a condition rating from the scale on the basis of i) above with consideration of ii) above*.
Note that the scales from the national VAST scale are also included for comparison (Thackway & Leslie 2006).
◇ Record if fire happened recently and indicate whether this has rendered composition un-interpretable; if this is the case record n/a against the attribute.

◇ In case of uncertainty or limited reference points on the given vegetation type, use a brief appraisal of soil disturbance, weed presence, grazing, and harvesting, as secondary guides.
Consider:

i) whether the topsoil is undisturbed or disturbed.
It is less likely that the composition is intact in areas that are heavily and/or repeatedly disturbed by agriculture, resource extraction, construction, infrastructure, and repeated, episodic clearing. (However,

a single round of disturbance that leaves most of the soil in place and intact, and does not introduce weeds, is less likely to have such impacts. Very superficial grading or even clearing can also serve to stimulate regeneration of many species from seed, provided the soil seed bank is intact, and some species may even re-sprout. Similarly, in larger areas, with little other disturbance and the absence of weeds, more than one round of such clearing may not be too detrimental if the interval between disturbances is sufficient for most species to mature, and set sufficient seed to replenish the seed bank; much like fire below);

ii) the extent of weed invasion.

A growing predominance of weeds can also mean a proportionate decline or loss of understorey. In particular annual and other short-lived species or those which emerge from underground organs tend to be affected (weeds that strongly exclude natives in the south-west include veldt grass, Guildford grass, and Watsonia);

iii) the extent grazing which can steadily diminish plant populations. For example evidence of rabbit grazing is likely to mean species such as orchids are being affected, and heavy grazing is likely to show considerable decline in a range of species. Look for signs of leaves and shoots being nipped off (see below);

iv) whether there is evidence of harvesting (such as logging, firewood, or wildflower picking). This may have altered the composition and will affect and inform the rating; though it is more likely harvesting will first affect structure.

◇Use good as a default if no other reference points are locatable *and* no other reference points are locatable, and in the absence of disturbance and weeds and other adverse factors such as heavy grazing.

Note that ALIENATED means that there are no native species and PRISTINE means that there is a full complement of native species and *no* influence of post-settlement activity.

Native plant species composition (Note: 1) record if fire happened recently & composition is un-interpretable; use n/a.)	Few remaining native species <> Typical dominants & faithful species scarce. <> >0-20% native plant composition.	Less than half of the original complement of native species present <> <> >20-40% native plant composition.	Around half the original complement of native species present <> Some typical dominants or faithful species declining or scarce. <> >40-60% native plant composition	More than half of the original complement of native species present <> <> >60-80% native plant composition	Native species at full complement, minor evidence of impacts) <> Typical dominants & faithful species common. <> >80-100% native plant composition
Native plant species composition form VAST	<> Dominant structuring species present. Many other species missing.	<> Dominant structuring species present. Several species diminished/missing.	<> Dominant structuring species present. One or more species diminished.	<> Dominant structuring species present. At least one species diminished.	<> Dominant structuring species present. Full range of native species present.

Additional cues (Either: compared to a reference area or state, or due to disturbance at site).	Soil disturbance consolidated & extensive. Topsoil widely removed &/or repeatedly disturbed and it is likely the soil seed reserve is also depleted. <> Weed dominance, replacing natives. <> Heavy grazing, of most species. <> Heavy harvesting. <> Any of above <90-60%	Soil disturbance melding & growing <> Balance tipping to weeds. <> <> <> Any of above <60-30%	Soil disturbance Scattered & limited, not repeated. <> Weed presence building, under equity. <> Moderate grazing, of several species. <> Moderate harvesting. <> Any of above <30-15%	(Soil disturbance little) <> Weed presence low. <> <> <> Any of above <15%	(Soil disturbance little or none) Topsoil intact and may contain a soil seed reserve. <> Weeds scarce. <> Limited grazing. <> No harvesting. <> Any of above none

A) <u>TREND GROUP - ARCHITECTURE: SUBGROUP I (- COMPOSITION)</u>

A1) STRUCTURE OF VEGETATION

Structure is essentially a reflection of species composition. The combination of the life forms that are resident at a site in conjunction with the influence of climate and microhabitat determine a community's appearance (episodic or cyclic disturbance excepted).

Layers in vegetation usually equate to, and are most easily recognized by, their signature growth forms (a basic description of these is given in the vegetation description table in the orientation section). In some cases the layers may also be a product of the age classes within growth forms (Thackway & Leslie 2006). A ready example of the latter is cut-over forest where old stumps, coppicing re-sprouts, and cohorts of immature trees and saplings, indicate a successive series of impacts that have altered the structure.

Structure is not constant. Even given stable composition it is likely to vary with time. For instance in the short to medium term "natural" cyclic or random factors can alter the appearance of the vegetation. Such factors include: clear-felling by willy-willys; stripping by cyclones; fire (especially severe fire; or in savannah where the balance of grass and shrubs or trees can oscillate); erosion (eg sand dunes; which move and consequently so do the inter-dune depressions or pans); flooding; and senescence and death (allowing new growth). Over the very long-term structure at a location can change completely (Churchill 1961; Bowler 1982; Buckley 1982a).

◇ Consider if any of the preceding factors may have affected the vegetation in a way that only reflects a transitory change in structure.
For instance it will not be very useful to assess the condition of the vegetation in the first few months to a year after the direct effects of a cyclone or to assess the condition of layers, other than overstorey, in the first two to three years after fire. This is because underlying trends will be obscured. *In such*

cases either clearly annotate and qualify the score given or apply an n/a (not applicable) rating.
Specifically:

◇ Record if the state is due to “natural” cyclic or random events, as such things may not constitute a medium term change of state or modification of trend. This may help clarify current and future interpretation of deeper longer-term trends and assist with future reference and assessment.

◇ Record if fire happened recently and indicate whether this has rendered structure un-interpretable; if this is the case record n/a against the attribute.

◇ Compare the vegetation at the site with the same or similar vegetation by means of:

- Background information (as outlined above). (But note, with regard to timing above, that if the fieldwork for background information was conducted at a “peak” time of year and the condition assessment is not, the absence of seasonal germinants and emergents in the latter case, will make it appear that there are fewer or sparser layers than there should be, and some allowance will have to be made for this effect. Note that some communities are entirely comprised of ephemeral species and this effect is predominant - dependent on the time of year there is either structure or no structure);
- Reconnaissance and orientation at the site and in the local area (as outlined above); and/or
- On the basis of extensive experience of plant diversity survey *in the region or similar regions* (typically this will mean at least 5 and preferably 10 years working in this field).

◇ <u>At the milder end of the scale consider whether any layers are depleted</u> (that is missing an element or modified or diminished or sparse (Thackway & Leslie 2006)).

Very early changes in the layers may be subtle and hard to discern. It may prove difficult to discriminate some of this from natural patchiness or small-scale pocketing in the vegetation.
In cases of such doubt default to very good, particularly if there is no obvious disturbance or other adverse factors (see note on the scale).

In terms of composition this may also mean that there is progressive loss of component species. Generally the more localised and restricted species are the first to decline and the more widespread and common and/or dominant and key structural species are the last to decline or stand a chance of re-introduction from the surrounds (this is particularly true of rural and semi-rural clearing and is reflected in the common treatment of the dominant structural plants as the last persistent vestiges of the community in both state and national scales (see Keighery 1994 & Thackway & Leslie 2006 (VAST)). Use cross reference to the species composition attribute to support the interpretation of structure (the use of a fieldsheet with the 3 dominants per layer will be useful in this regard (Keighery 1994 - Appendix ***)).

To rate as “EXCELLENT” all expected layers will be present and there will be little or no signs of impacts. *Note that the vegetation and ecosystem processes are unlikely to be in a pre-settlement state because change linked to settlement has been too pervasive*. *It is a total lack of disturbance that sets “PRISTINE” apart from “EXCELLENT”. For this reason it is likely that there will be little call to use “PRISTINE”*.

To rate as “VERY GOOD” all expected layers will be present and there may be early signs of impacts, and minor modification to at least one still consistent layer. The dominant structuring species will remain unaffected.

To rate as “GOOD” all expected layers will be present and there may be clear signs of impacts, and at least a layer may be sparse, or discontinuous with irregular loss of an element (that is in pockets a layer may be broken up or a growth form may be missing,). It is unlikely that the dominant structuring species is/are affected.

◇ At the stronger end of the scale consider whether any layers are missing.

To rate as “DEGRADED” one or more layers will be frequently, and repeatedly removed. The dominant structuring species *may* be affected to some degree.

To rate as “VERY DEGRADED” there will be widespread, consistent, loss of several layers; this means loss of several layers in a multi-layer unit or the main layer in a single layer unit. At this stage decline or loss of the main dominant structuring species is likely to be evident (including absence of recruitment).

“ALIENATED” applies to areas where all the layers and species are missing.

◇ Select a condition rating from the scale on the basis of the above considerations.

Structure of vegetation *(VAST shown in italics)* (Note: 1) layers may also be taken as growth-forms & age classes of species; 2) if change is subtle & it is unclear if natural patchiness or impacts are the cause default to “very good”; 3) record the cause if the state is due to “natural” cyclic & random events; 4) record if fire happened recently & structure is un-interpretable; use n/a.	Structure greatly altered. Widespread loss of layers. (loss of: i) several layers in a multilayer unit or ii) near loss of the main layer in a one layer unit.) <> *Several layers frequently & repeatedly removed.* <> Dominant structuring species likely to be affected.	Structure partially altered. One or more layers missing. (Community may lack shrub & ground cover species) <> *At least one layer frequently & repeatedly removed.* <> Dominant structuring species may be affected.	Structure basically intact, impacts evident. All layers present, but may be sparse. <> *At least one layer thin or discontinuous.* <> Dominant structuring species unlikely to be affected.	Structure intact, early signs of impacts. All layers present, with minor modification. <> *At least one layer somewhat diminished.* <> Dominant structuring species unaffected.	Structure intact, verging on pristine. All layers present.
Extent of disturbance at site.	Disturbance high.		Disturbance moderate.		Disturbance minimal.

A) TREND GROUP ARCHITECTURE: SUBGROUP II (- VEGETATION AS “HABITAT”)

Habitat is a difficult attribute to include in condition assessment. This is for three reasons.

First, because it is strongly linked to the identity of the vegetation type, which in turn influences the sorts of opportunities afforded to the biota. Consequently it is possible to fall into the trap of over-emphasizing identity when the intent was to focus on condition. For example within the eastern state’s schemes there is a strong focus on woodlands and old trees, tree hollows and logs; which in turn implies a bias towards the vertebrates that use these features at some stage. There is of course far more to a sense of habitat and the processes that sustain the system and its biodiversity.

Second, a sense of habitat derives from the interplay of factors that sustain a self-supporting and integrated system and this is not easily summarized with a single attribute.

Third, some features under this “attribute” are difficult to appraise from a single quadrat. For example heterogeneity and pattern are better appraised, compared and contrasted using several adjacent quadrats, and this introduces the application of an array of sites at one location (see below after (iv)).

In terms of condition a better operational sense of habitat embraces diversity of resources and of opportunity for the biota and a greater likelihood of sustaining the full resident biota in situ into the future.

This diversity of opportunity is only covered in part under some of the attributes for example:
i) plant species diversity (see above) equates to a large portion of small-scale diversity in resources. A wide range of plant species provide a wide range of resources in both space and time. This is because plant species represent the primary resources of energy, nutrition and biomass in the system, and initially dictate the nature, availability and distribution, of such resources. Such provision can be broadly split into:

> a) reproductive resources, although there is often a peak of species flowering and fruiting in a given area, there is also often a proportion of species that do these things throughout the year (the heathlands of the south-west are a firm example (see Wills 1989 for example); though the same progressive annual pattern applies in the Kimberley (see Edgar 1987 for example)). Similarly fungi shadow the plants with which they are largely intimately associated. They have peak periods in which they fruit but species with underground fruit (and which are generally plant symbionts) can persist throughout the year and those which fruit after fire can respond to fire at any time (see Robinson et al 2007; and Robinson 2009 for example). Such material supports insects, lizards, birds and mammals.

b) vegetative resources, the foliage and other material of some plants is inherently more palatable, nutritious, and digestible, than others, and it too tends to have peaks of availability during the year, though there may be a general availability of this material for more of the year than with reproductive resources (Holm & Eliot 1980; Holm & Allen 1988). Such material supports grazing insects, some birds, and mammals. Much of this vegetative biomass passes to termites and so to other insects, lizards, birds and mammals.

ii) plant species diversity (see above) also translates to structural features as species develop and express their lifeform. However, the standard means of recording structure only takes into account vertical layers, and sometimes cover. Together these provide a very basic account of structural heterogeneity.

iii) to date there has been quite some focus on tree habitat, and especially hollows in older or dead trees and in logs. As attributes these characters contribute very little to a sense of spatial heterogeneity of resources;

This leaves out other characteristics which are more expressions of the vegetation's identity than they are of its condition. Such factors are often a reflection of the interaction of the plants and the constraints of the soil and landform and other biogeochemical factors. Such factors may be best assessed and recorded in tandem with condition. This means the addition of: specific data sheets; more quadrats; and more attributes. Attributes which embrace a wider sense of habitat include, but are not confined to:

a) continuity and patchiness.

Patchiness is covered by several sub-attributes here and also by fire.

Patchiness includes both temporal and spatial aspects it can be enforced in the relatively short-term by cyclic processes such as fire and fire traces and in the longer term is linked to locality and landform factors and reflects the resident vegetation type and strong geology-soil links.

Patchwork can include thickets of older growth and areas of open new growth; at what scale should patchiness be considered? For example are riparian thickets suited to Quokkas only patchy at the locality plus scale?

b) ecotones (including between patches)

c) pattern (eg regular versus irregular, clumped versus dispersed).

d) Diversity in vertical and horizontal space and diversity of resources (plant species & structural diversity > litter diversity >invertebrate diversity > +/- reptile & bird diversity - guilds). Such diversity of resources is critical to orchids and their pollinators This includes:

Layers, species cover, species height, and species density.

e) Interconnecting canopy at various levels for continuous foraging.

f) Fragmentation - lack of continuity and breakdown of systems processes. For example: Territory size is a pinch point with regard to resources when Carnaby's cockatoos are nesting as they only travel a max of 12km, so a fragmented resource inside that radius effectively reduces the resources available to them. Similarly Woylies may lack the full amount of resources they require where valleys have been cleared and the areas of drought reserves are missing

In the context of the fieldwork and literature on ecological and condition matters it is evident that there is scope for habitat issues to be better developed. Some of this is outlined in the following attributes.

A2) TREE HABITAT

This heading has been used to combine about three attributes in current use, namely: i) the presence of generally older trees with hollows (within a balance of ages and stages); ii) old dead trees; and iii) hollow logs. They have been combined here in order to satisfy requirements to streamline a basic attribute set, and also to reduce the emphasis upon this at the expense of other aspects of "habitat". This does not mean that these features lack importance in woodlands and forests.

[Note: *In practice it may not prove practicable to assess logs in the ground layer with hollows in the upper layers, and it is likely that the attribute may need to be split*. Its components are:
i) vertical (largely sivicultural & partly covered by that attribute); the parts are: a) a range of age/stages including mature/large/old trees; & b) trees that bear hollows and/or dead stags;
ii) ground level (and allied to litter and debris & prtly covered by that attribute); the parts are: a) logs with hollows; and b) debris > 10cm.]

"Tree habitat" is only part of the concept of habitat. For example although red-tailed phascogales (*Phascogale calura*) can use hollows in wandoo trees, they prefer other species that provide both thickets to nest in and continuous canopy for foraging (see that attribute; Burrows & Friend 1998). Other fauna are more dependent on tree hollows, for example Carnaby's black cockatoo is highly dependent on hollows in wandoo and salmon gum woodland for nesting; yet even so this is only part of resource utilisation, and a diversity of other plant resources within a territory are also critically important during nesting (Stojanovic 2009).

[Note that this attribute illustrates several difficulties with constructing condition scales based on habitat. First, it is hard to prevent emphasis on a simple gradient from "good" to "bad", when the development of heterogeneity is also important. Second, even when it is linear *this attribute is semi-compatible with a sense of heterogeneity and patchwork in the vegetation; this is because it reflects the acquisition of resources with time in patches, and the presence of a range of tree sizes which implies habitat diversity sustained by recruitment*.]

◇ Use of this attribute is discretionary.
This attribute has limited application at a state level and is best applied to habitat dominated by tree and mallee forms, especially eucalypts.

In south-west forest it is best used in tandem with the attribute sivicultural management of forests.

The part concerned with hollows will also have particular application in woodlands dominated by species with a strong tendency to form hollows due to their growth form (eg wandoo, river gums, white gums, and many slow-growing gums in semi-arid and arid areas). It seems largely irrelevant in terms of areas dominated by banksias because their wood does not readily form hollows. It is not applicable in shrublands of the coast, coastal plain, and semi-arid and arid areas. It may have limited application in mulga woodland. It will have limited application in some spinifex grasslands and interior dunefields.

Tree habitat. (Incl: a) trees; b) hollows; c) logs) Hollow size above DBH is: i) small >3-15cm; ii) medium >15-30cm; iii) large >30cm (for mallees: >3-9cm; >9-15cm; >15cm).	All young trees or no live trees. / No trees <&/or> Near absence of hollows./ No hollows <> Near absence of logs. All small. / No logs <> Mainly in dead trees	Mainly young trees. <&/or> Few hollows (scattered & isolated). <> Few logs. All small. <>	Mix of young & maturing trees. <&/or> Some hollows. (eg 1-2 trees) <> Some logs. Small & medium sizes. <> Mix in live & dead trees	Mix of young & maturing trees. <&/or> Frequent hollows. <> Frequent logs. Small & medium sizes. <>	Range of young to mature trees. <&/or> Hollows common. (eg 3-6 trees) <> Logs common. Small, medium & large. <> Mainly in mature trees

A3) INTERCONNECTING OVERSTOREY/MIDSTOREY CANOPY FOR CONTINUOUS FORAGING

Red-tailed phascogales are an arboreal marsupial predator that prefers the thick continuous cover of sheoak thickets in which to nest and from which to base its foraging. In remnant areas when intense fire depletes this part of the habitat for a time it relocates its nests to wandoo hollows. However, this puts the animals at greater risk of predation as the phascogale is more frequently forced to travel along the ground to in order to move from tree to tree and continue to forage (Burrows & Friend 1998).

Note that this attribute:
a) is essentially an expression of the characteristics of the vegetation type and so not inherently a condition attribute. There would always be vegetation types to which it was not applicable.
b) is inherently difficult to put on a scale without creating a simple gradient from “good” to “bad”, when the development of heterogeneity is also important.
c) requires external references points and a context in order to be meaningful. It may be best applied to a series of quadrats in an array to build a sense of heterogeneity and potentially a link to remotely sensed data.

A4) THICKETS OR REFUGE AREAS (INTER-RELATED WITH OPEN AREAS AND ECOTONES*)

A thicket is taken here to be a denser growth of plants, whether it is made up of understorey or overstorey, that acts as a refuge or shelter from predators, and a refuge or shelter from climatic extremes (the temperature and moisture levels may be moderated at the small scale). Although this is generally considered from the point of view of fauna habitat, the characteristics of such areas mean that they also perform similar functions for some plants. What qualifies as a thicket presents a challenge as it is dependent on the vegetation type. For instance in the areas where they form the dominant cover individual hummocks, tussocks, and bluebush and saltbush shrubs, may have some of the characteristics of a micro-thicket, and this stands in contrast to more obvious examples such as mulga groves or tea-tree thickets.

Note this is essentially an expression of the characteristics of the vegetation type and so not inherently a condition attribute. There would always be vegetation types to which it was not applicable.

A5) OPEN AREAS: PRESENCE OF AREAS OF YOUNG REGROWTH (INTER-RELATED WITH THICKETS AND ECOTONES*)

Young regrowth counterbalances the opportunites and resources represented by thickets. Patches where older woody growth has been removed play an important role in creating opportunites for flora and fauna in most bioregions. Many plant species regenerate in the openings and in the presence of the surfeit of resources that exist after fire (Burbidge 1944; Bell & Koch 1980; Bell et al 1984; Griffin 1984c). Similarly the young regrowth and seeds of many of these plant species may benefit grazing and harvesting fauna (eg Suijendorp 1967; Holm & Allen 1988; Walsh 1990; Burrows et al 2000; Bird et al 2005).

Note this is essentially an expression of the characteristics of the vegetation type and so not inherently a condition attribute. There would always be vegetation types to which it was not applicable.

A6) ECOTONES AND A MOSAIC OF PATCHES (INTER-RELATED WITH THICKETS AND OPEN AREAS*)

It is clear that habitat mosaics, which have historically been enhanced by fire, are an integral part of the maintenance of biodiversity as it encompasses both flora and fauna and that this precedes settlement (Burbidge 1944; Suijendorp 1967; Griffin 1984c; Walsh 1990; Burrows et al 2000; Bird et al 2005).

In an area where a range of medium body weight marsupials is present the management practice is to have a small-scale mosaic system instituted by means of fire, overlaid on the existing range of vegetation types and landscape elements (Richards et al 2009).

From monitoring of fauna in Banksia woodland over more than twenty years it has become evident that the interfaces or ecotones are important to the activities of resident species (M. Bamford pers. com.; more detail required).

Note this <u>is essentially an expression of the characteristics of the vegetation type and so not inherently a condition attribute</u>. There would always be vegetation types to which it was not applicable.

R) <u>TREND GROUP - REGENERATIVE CAPACITY</u>

R1) RECRUITMENT

Over time it is likely that the seedlings and juvenile forms of several plant species will be evident in a vegetation type; though at times recruitment may be halted due to drought or occur in waves with the consequence that the juveniles of some species are all of one age class (that is they form a cohort; this often occurs with wetland species such as *Allocasuarina obesa* and *Pericalymma* species). In relatively stable jarrah forest there is usually a high proportion of trees in the juvenile size classes (Abbottt & Loneragan 1986). In heavily grazed sites the juvenile size classes are absent, indicating little recruitment for several years; both predation of seedlings and factors such as soil compaction underlie such absence (Pettit et al 1998). Understorey species with underground organs from which they can re-sprout will take longer to succumb to predation of seedlings (Pettit et al 1998). In extensive, un-fragmented, semi-arid areas, sustained grazing at moderate to high intensity leads to a loss of the most palatable, nutritious and digestible species from the vegetation and the persistence of unpalatable, un-digestible, or plain noxious species with the net result of altered biodiversity (Hodgkinson & Harrington 1985).

Absence of seedlings and/or juveniles plants is likely to act as a warning that ecosystem processes are being disrupted. For example in remnants the effects of light, intermittent, and possibly recent grazing appear to be largely reversible in terms of biodiversity, but those of sustained grazing at moderate to high intensity essentially lead to localized extinction of plant species (Pettit et al 1998; Pettit & Froend 2000). This will depend to some degree on the vegetation type, for instance recruitment of salmon gum appears to be infrequent, and in such woodland water availability is a significant factor in early growth (Yates 1995). Similarly in older vegetation recruitment may be at low rates and over long timeframes

◇ In order to assess this attribute focus on the presence of seedlings and of saplings and the relative spread (whether they are widespread to scarce at the site). Secondarily, approximate guides to senescence, disturbance and weed presence are provided; these are indicative only (for instance, ultimately senescent *woody* vegetation is likely to collapse and, if there is sufficient viable seed in the soil, to regenerate from seed in the gaps - *it is difficult to reflect this in the scale*).

◇ In some situations there may be a positive response under this attribute by native species to disturbance, especially with those species that respond to seed being scarified by abrasion or heat.

Note that in a Pristine state regeneration is taken to be occurring in the appropriate timeframe, there are likely to be a varied range of ages/stages throughout the localized area, and the soil seed reserve is likely to be being steadily replenished.

Recruitment Consider: Seedlings; Saplings; Balance in the population age/stage arrangement: Whether cohorts of plants that have not yet set seed are present. Note: Senescence chiefly in woody species.	Low to no recruitment <&/or > No seedlings. <> No saplings. <> Most species appear senescent. <> Extensive soil disturbance (pervasive &/or repeated) or loss. Probable soil seed reserve is depleted. <> (high weed presence)	Mod to low recruitment (scarce) <&/or > Scarce or no seedlings. <> Scarce or no saplings <> Several populations / species appear senescent. <> Growing soil disturbance. <> (mod weed presence)	Moderate recruitment (localized) <&/or > A few species have isolated seedlings. <> A few species have isolated saplings <> Populations of some species *may* be senescent. <> Limited soil disturbance. Soil seed reserve may be intermittently replenished. <> (low weed presence)	Mod to high recruitment. (common) <&/or > Several species have a few seedlings. <> Several species have a few saplings. <> Limited senescence & reproductively mature. <> Minor soil disturbance. <> (low / no weed presence)	High recruitment (widespread). <&/or > Several species have several seedlings. <> Several species have several saplings. <> Limited senescence & reproductively mature. <> Soil intact. Soil seed reserve is likely to be steadily replenished. <> (weeds absent)

R2) INPUT REQUIRED TO PROMOTE REGENERATION

The input required to promote regeneration varies with the vegetation type and the nature, extent and duration of the disturbances and their impacts. For example jarrah, wandoo and sheoak woodland all showed different levels of resilience after cessation of moderate levels of grazing (Pettit & Froend 2000). Considerable effort is required to re-establish vegetation once the soil and/or substrate have been altered (see soil stability above). Some impacts such as secondary salinity are virtually intractable and the species compositional loss affects all biodiversity components that have been examined (plants, vertebrates, invertebrates McKenzie et al 2003; Gibson et al 2004).

Different vegetation types have inherent characteristics that affect their potential to regenerate, even without disturbance. *Eucalyptus salmonophloia* woodlands apparently have a limited capacity for regeneration from the soil seed reserve (Hobbs 1989). Wandoo tends to repress understorey which may be due to its expansive shallow roots (Lamont 1985) and to allelopathy causing strong inhibition of germination of other species (including weeds; Hobbs & Atkins 1991).

In terms of grazing in vegetation the general factors that enhance the prospects of recovery include relatively lighter intensity of grazing (an area is not saturated with activity), shorter duration (only a few years), vegetation that was initially intact (Pettit & Froend 2000), and no drought events (Hussey & Wallace 1993). How vegetation responds to removal of imposed grazing also depends on the local environment, the vegetation type, the grazing history, and the context (especially the degree of fragmentation). In the south west wheatbelt grazed salmon gum remnants that were fenced remained dominated by annual exotics, the native seedbank being apparently depleted (Hobbs 1989). In the outer jarrah forest re-establishment of sheoak woodland is slowest, followed by wandoo woodland, and then jarrah (Pettit & Froend 2000).

◇ This attribute is included should an indication of the magnitude of resources to encourage rehabilitation or restoration be required.
Consider the nature and extent of various impacts. Disturbance limited to a part of the vegetation or soil or that is intermittent or of low intensity and that can be addressed by halting the adverse activity warrants a “Good” rating. Similar sorts of disturbance that affects much (near half) of the area warrants a “Degraded” rating. Where disturbance affects more than the target area and/or involves fairly intractable changes such as salinity or hydrological change a “Very Degraded” rating is warranted.

Input required to promote regeneration	Major resources required to promote regeneration. (eg alter processes & nearby land use; such as falling or rising watertable; secondary salinity; major erosion or deposition; major clearing; major resource extraction; harvesting long-standing and recurrent; dominated by weeds).	Significant resources required to promote regeneration (eg the surface soil & the soil profile may need to be restored in places, and plant species may need to be planted or sown.)	Strategic resources may promote regeneration, rather than decline. (eg limit access or activities)	Scarcely any resources required to promote regeneration.	No resources required to promote regeneration.

R3) HEALTH OF PLANTS - GENERAL

This attribute is a general proxy for a few health-related attributes in common use (eg disease, insect damage, and plant parasites). Rather than recognising salient differences between such attributes an assessor will need to draw together a range of symptoms and make an overall appraisal.

The scales incorporate elements of the sorts of approaches that have been widely used (for example Jasinska & Tholen 2003; and especially Western Australian Department of Conservation and Land Management 1991). The latter source uses a scale that has also been used in long-term monitoring of vegetation bordering wetlands on the Swan Coastal Plain and in forest near Dwellingup. The latter involves “tree and stem condition rating” as follows: 0 = healthy, no dead leaves; 1 = occasional dead leaves; 2 = epicormic shoots (therefore stressed); 3 = tips of branches stressed or dying; 4 = entire or whole branches dying or dead (NB some lower branches excluded from this assessment); 5 = more than half tree dead; 6 = tree dead. Additional comments add extra information and differentiate between recent and old deaths.

◇ Try to separate stress and decline from the extent of death in an area if particular ages or stages of plants are affected in different ways.
Death can be rated on the separate attribute scale that follows.

◇ Start by considering which part of the general attribute best describes the *current* overall state of the population/s of *living* plants at the site.

◇ Examine the range of plant species present and identify which are showing signs of stress. Rely first on the state of species rating. Then consider the state of individuals. If the rating for the state of individuals diverges from the rating for the state of species by one category take the lesser of the two (that shows more impact), if by more than one category take the median between the two.

Health - General Of key species (esp. mature individuals). % plants with significant health problems (foliage loss, canopy decline, stem lesions, etc). Cause of stress, if known Trees/ mallees Symptoms __________ Cause _____________ Shrubs Symptoms __________ Cause _____________	High impact. (Severe stress.) <> State of species. Most individuals - of - Most prone species <> State of individuals - Many severely damaged, dying or dead.	High to moderate impact (Advanced signs of stress) <> State of species. Many individuals - of - Several species. <> State of individuals - Extensive damage incl: Most leaves damaged (or few left). Crown fragmented. Many canopy branches dead; One or more dead stems; Resprouting from damaged parts.	Moderate impact (Signs of stress.) <> State of species. Several individuals - of - Few species. <> State of individuals - Minor/moderate damage. Some leaves dead/dying. Minor branches damaged. Crown intact. Main limbs intact.	Low impact (Early signs of stress.) <> State of species. Isolated individuals - of - Few species. <> State of individuals - Minor damage. Some leaves damaged. Minor branches ~intact. Crown intact. Main limbs intact.	Majority healthy (Background levels) <> State of individuals - No obvious leaf or woody damage. *(or minority of each leaf 's surface affected)*

R4) DEATH OF PLANTS - KEY SPECIES

◇ Prioritise recent deaths for rating; that is deaths which have occurred in the last 1 to 2 years and are likely to still have their foliage present. Since no provision is currently made to separate recent and long-standing deaths it may be desirable to make notes of the relative number and how each such division would rate if considered separately.

[Note that at present death includes recent deaths and long-dead plants; so it may be necessary to include these sub-divisions in future.]

Death of key species (especially of mature individuals).	High incidence. <> Most individuals - of - Most species.	Mod/high incidence. <> Many individuals - of - Several species.	Moderate incidence. <> Several individuals - of - Few species	Low incidence. <> Isolated individuals - of - Few species.	Limited death <> Deaths scarce, uncommon.

R5) HEALTH OF PLANTS - DISEASE

Some major causes of disease-based death of native plant species in W.A. are fungal. One of the most devastating is dieback, a type of water mould; though other true fungi such as canker also attack plants and cause decline and death (Shearer & Dillon 1996).

Dieback threatens to have a devastating impact on over 2300 of the 5700 plant species in the Southwest Botanical Province which could be killed. It is prevalent in the higher rainfall areas of the south west (> 600mm per annum).

It is invading many native plant communities, including banksia woodlands, jarrah forest and coastal heathlands from Eneabba in the north to Cape Arid in the east (Dieback Working Group Flyer). In general, in old infected forest areas, there is a trend to a more open canopy, lower basal area and fewer plant species. In many areas, percentage ground cover and total plant species cover also fall. The current diseased front generally falls between the two extremes (Shearer et al 2009). Comparison of infested and un-infested banksias woodland shows a general decrease in plant species numbers (Shearer & Dillon 1996). This is quite apart from the direct impact on flora of significance because they are already restricted or otherwise unique or threatened.

Of the plant families examined the Proteaceae are the most under threat from these fungi, although Myrtaceae, Epacridaceae and Papillionaceae are also affected. “In large areas of south-western Australia, the Proteaceae are the most abundant plant group and so provide the fundamental elements of many plant communities. However, the Proteaceae are much less abundant at sites which have long been infested by *P. cinnamomii*, while plants which display low susceptibility to the disease, such as sedge and rush species, are more abundant. The destruction of large numbers of proteaceous and other susceptible species may cause permanent changes in structure and function of plant communities.” (Wills & Keighery 1994). This is made worse by the increased prospect that such disturbance may favour weed invasion and establishment.

At the site scale loss of component plant species affects the heterogeneity and availability of plant resources in space and time. For example population densities of litter invertebrates were generally lower in high jarrah-death areas than in healthy forest (Postle et al 1986). Likewise litter-preferring reptiles and shade-preferring birds where less common in high jarrah-death areas than in healthy forest, while reptiles and birds that frequented open areas became more common (Nichols and Muir 1989). Similarly the damage to forests also removes habitats for small mammals (Groves et al 2003). Of particular concern is the infection and dieback of plants from the genera Banksia, Darwinia, and Grevillea. This in turn impacts on animals reliant on these plants for resources such as nectar and pollen, such as the Pygmy Possum (*Cercartetus concinnus*) and the Honey Possum (*Tarsipes rostratus*) (DWG Flyer; Friend 1992). The impact is amplified by the decline in the number and range of species flowering throughout the year and hence the availability of nectar and pollen throughout the year. This point can be emphasized by considering the resources offered by *Banksia menziesii* that would be lost in any area infected with dieback (Lamont 1989; Shearer & Dillon 1996). First, because *B. menziesii* flowers in winter it is a key food source for nectar feeders when little else is flowering. Second, other food sources include moth and weevil larvae that inhabit the flower heads and are suitable cockatoo food, and seeds and seedlings that are eaten by granivores and herbivores. Third, there is the structural aspect of habitat provided by trees and their debris. A vicious cycle may set up in areas where proteaceous plants are dominant, whereby declining nectar causes a decline or local extinction of pollinators which in turn cause further decline of the plants (Wills & Keighery 1994).

Certain features will make areas less susceptible to dieback, they *may* include upland situations, free-draining soils, possibly the absence of a shallow water-table, and particular deep soil types (for instance two major calcareous sand systems on the Swan Coastal Plain appear to suppress dieback; Shearer & Dillon 1996).

The most aggressive of the dieback or *Phytopthora* species in W.A. is *P. cinnamomi*. This water mould has mobile spores that can spread in wet soil and from plant to plant through root to root contact. Human activity in infested areas is the main method by which diseased soil is moved from place to place. It can be spread by movement of infested gravel, road construction, or the activities of animals and off-road vehicles; it also spreads in horticultural mulches, mixes and soils that have not been sterilised. The risk of spread is greatest during spring and autumn (DWG Flyer). Using hygiene for protection is particularly difficult for remnant areas surrounded by intensive land use, this is because of the relatively larger exposed perimeter of small areas and proximity to urban and agricultural disturbance (Shearer & Dillon 1996).

The pathogen infects the roots killing tissue and starving the plant of resources and the plant may begin to show symptoms of 'dying back' (DWG Flyer). *Such progressive death of roots and vascular tissue may in turn be reflected in progressive crown death; though in many instances there is striking "sudden death" of plants. At first there will be isolated outbreaks but as the disease progresses there may be formation of a disease front*. *In the early stages deaths will appear recent, and in longer infected areas there will be a mix of recent and older deaths. The impact on the vegetation is generally rated on the mortality and the degree to which the disease has spread through the area, and through species and individuals in the area (Shearer & Dillon 1996).* The spread and impact of the pathogen can be slowed by: restricting access to un-infested areas, cleaning vehicles and boots before entering healthy sites, scheduling activities for dry soil conditions, controlling drainage, the use of dieback-free soil and plants, and the use of Phosphite (DWG Flyer).

◇ In the field dieback may be indicated by one or more of the following:
i) if species from the banksias family, heath family, pea family, hibbertia family or blackboys or zamias are dead or dying;
ii) if there is a pattern of spread from a centre, a "dieback front", as the disease spreads in water or from root to root;
iii) the area is low-lying, poorly drained, or damp; and
iv) evidence of an activity that introduced the disease (eg vehicles, tracks, stock; Hussey & Wallace 1993).

◇ Canker may be observed in the field by examining dead plants for characteristic straw-coloured decay expressed in lines or zones, and the presence of mycelial fans beneath the bark (if the fruiting bodies are absent; Shearer and Dillon 1996). They are also indicated by areas of dead or shed bark and exposed wood (Hussey & Wallace 1993). In addition the tree may initially exude gum in order to inhibit the invasion of the fungi. Canker fungi inhabit the bark and kill twigs in the crown and cause lesions in the bark of the main stem and roots of trees. They gain entrance through a wound, and the perennial species cause the bark to slough off leaving the wood exposed as a scar. If the tree is stressed the dead bark and wood may eventually girdle the stem and cause the death of the parts above the wound. This damage compounds as the dead area acts as an entry site for fire when the area next burns. The susceptibility of trees rises as they become stressed by other factors such as drought.

[Note: a basic guide to common pathogenic fungi such as Armillaria may be warranted as a resource.]
[A basic account of the general appearance of airborne fungi such as rusts and smuts may be warranted as a resource.]
(Note: The disease attribute may be assessed in part on the basis of percent of the area affected because it is based on the degree of alienation, rather like weeds.)
[The first and second facets are adapted from Shearer & Dillon (1996) and can be applied to dieback and canker.]
Note in the table Pristine is dieback free and lacking any form of imposed disturbance.

Health - Disease in predominant species Based on dieback. State if other __________	High impact. <> Consolidated (Most of the area.) (*eg >50%*) <> Most individuals - of - Most prone species. <> Most susceptible tree & understorey species affected.	High to moderate impact <> In several pockets &/or a disease front develops. (Much of area) (*eg >15-50%*) <> Many individuals - of - Several species <> Deaths common & majority (30-90%) of susceptible specie's plants affected.	Moderate impact <> Confined, likely to one pocket. (Part of area) (*eg >1-15%*) <> Several individuals - of - Few species. <> Odd, scattered deaths & minority (<30%) of susceptible specie's plants affected.	Low impact <> Isolated incidence. (Tiny area) (*eg 1%*) <> Isolated individuals - of - Few species <> Low impact. Few deaths.	Dieback free.

R6) HEALTH OF PLANTS – INSECT DAMAGE

This attribute is very much symptom based. In ecosystems unaltered by human intervention resident invertebrate 'pests' are present at background levels, boom and bust cycles excepted; however, successive or more severe outbreaks tend to be symptomatic of systemic change. For instance booms in insect damage are stimulated by such primary factors as loss of a range of bird species that fed on the insects, nutrient accumulation under rural trees, and watertable decline and water stress. This attribute is intended to cover all forms of insect damage including: galls, lerps, leaf miners, wood borers, etc.

In disturbed or fragmented landscapes raised levels of nitrogen in leaves have been implicated in the decline of eucalypt species as they become more attractive to insect herbivores (Landsberg 1990).

Tuart trees which are suffering water stress appear more susceptible to attack by specific tuart wood borers; whereas if the trees are not stressed the main resource used by the beetles is the leaves which are grazed by the adults. Under normal circumstances cockatoos feed on the adult beetles and help keep the numbers in balance (Jasinska & Tholen 2003), as other birds may also once have done (J. Dell pers. com.). Other insect species also have larvae which bore into tuarts. The presence of a bud weevil also appears associated with water stress in tuarts. In fragmented areas such as the coastal plain the local extinction of a range of fauna, especially birds, may have meant a general loss of checks and balances to such outbreaks (J. Dell pers. com.). Similarly in the wheatbelt borers are contributing to the decline of wandoo and marri (Hussey & Wallace 1993). To some extent they may be kept in check in areas where parrots and cockatoos are still active. At one time other fauna such as bilbies would also have removed borers from the roots of trees.

In the jarrah forest there are two insects that attack the leaves of trees and cause outbreaks that alter the status and appearance of the canopy. Both affect the amount of viable leaf tissue in the canopy. The jarrah leaf miner cuts holes through the leaves and the damage rises in proportion to the population size. With this species the area of active leaf progressively decreases, un-mined tissue browns, and premature leaf fall follows (Wills 2009). In contrast the gum leaf skeletoniser progressively grazes the tissue from the surface of the leaf, and the trees can end up looking as if they have been scorched (Farr 2009).

◇ Examine the range of plant species present and identify which are showing signs of stress. Rely first on the state of species rating. Then consider the state of individuals. If the rating for the state of individuals diverges from the rating for the state of species by one category take the lesser of the two (that shows more impact), if by more than one category take the median between the two.

Note that “Pristine” features limited insect damage and lacks imposed disturbance.

Health - Insect damage. Including: galls, lerps, leaf miners, wood borers, etc. May manifest as significant crown damage.	Insect damage high. <> State of species. Most individuals - of - Susceptible species. <> (Whole host populations) <> State of individuals - May be severely stressed or dying.	Insect damage mod/high <> State of species. Many individuals - of - Susceptible species. <> (Most of host populations.) <> State of individuals - Extensive damage incl: Most leaves damaged (or few left). Crown fragmented. Many canopy branches dead; One or more dead stems.	Insect damage moderate <> State of species. Several individuals - of - Susceptible species <> (Parts of host populations) <> State of individuals - Minor/moderate damage. Some leaves dead/dying. Minor branches damaged. Crown intact. Main limbs intact	Insect damage low. <> State of species. Isolated individuals - of - Susceptible species <> (Diffuse or minor.) <> State of individuals - Minor damage. Some leaves damaged. Minor branches ~intact. Crown intact. Main limbs intact.	Limited insect damage. <> <> <> State of individuals - No obvious leaf or woody damage. (*or minority of each leaf ‘s surface affected*)

R7) HEALTH OF PLANTS - PLANT PARASITES

Mistletoes are an indicator of decline in fragmented settings. The parasite takes water and nutrients from the host plant (usually a gum, sheoak or acacia) and severe infestations can debilitate trees. The birds which eat the fruit and spread the parasite are often confined to small areas and the infestations can be severe. But such infestations are also symptomatic of an absence of checks and balances that once controlled the numbers; which include grazing by possums and episodic fire (Hussey & Wallace 1993).

◇ Examine the range of plant species present and identify which are showing signs of stress. Rely first on the state of species rating. Then consider the state of individuals. If the rating for the state of individuals diverges from the rating for the state of species by one category take the lesser of the two (that shows more impact), if by more than one category take the median between the two.

Note that Pristine is similar to Excellent with no imposed disturbance.

Health - Plant parasites. Chiefly mistletoe. High densities of quandong my indicate limited dispersal or channeled dispersal by vectors (esp. along road reserves). (Nuytsia, & sandalwood generally not present at high densities)	High incidence. <> State of species. Most individuals - of - Susceptible species. <> (Whole host populations) <> Several mistletoe per host and large infested host clusters or belts	Mod/high incidence. <> State of species. Many individuals - of - Susceptible species. <> (Most of host populations.) <> Several mistletoe per host and infested host clusters	Moderate incidence. <> State of species. Several individuals - of - Susceptible species. <> (Parts of host populations) <> 1 to 2 mistletoe per host +/- infested host clusters	Low incidence. <> State of species. Isolated individuals - of - Susceptible species <> (Diffuse or minor.) <> Mistletoe ~1 per host	Limited parasitism. <> State of species. Scarce and scattered. <> <> Mistletoe ~1 per host

M) TREND GROUP - MAINTENANCE

M1) SURFACE STABILITY/INTEGRITY

Intactness of the soil's upper layers, the resident soil biota, and the arrangement of plant species above and below the surface, is integral to persistence of the vegetation. The arrangement of plants on an intact surface is representative of the integrity of the vegetation as it may have developed in tandem with various landforms over long periods of time. It is also fundamental to the concept of an area's resilience because the soil in most places houses a community of organisms and is a reservoir of biodiversity in its own right, it is a living matrix and it is created and maintained by representatives of most of the phyla of living things.

Disruption to the soil surface and upper layers directly impacts the resilience and ultimate persistence of native vegetation.

In a deep sense there are processes which tend to limit or disrupt the process whereby life builds increasing stability and complexity into the soil surface. Resources are conserved in the soil surface when the cover of perennial shrubs and herbs, plant stems, grass tussocks and woody material all help trap resources (Yates et al 2000). With low impacts and a relative abundance of resources such as water the development of a surface matrix is generally extensive (eg the south-west Yates et al 2000; Pettit et al 1998). Conversely extremes of pressure from factors such as aridity and/or grazing tend to limit the spread of the matrix across the surface and it tends to be focused into patches (in semi-arid and arid areas these patches have higher soil nutrient availability, water availability, and stability (see Ludwig et al 1997 for example); at its extreme persistent and high pressure from factors such as aridity and drought lead to desertification where the surface is no longer consolidated, does not retain moisture, and becomes mobile

Once disrupted the reconstruction of all of the components of the soil and especially the upper profile is difficult. There is a living matrix of plant structures that weaves through the soil. Any given area will carry a range of different species with a range of habits, stem forms and sizes and means of regeneration. Feeding roots will be in the upper soil layers and taproots and their equivalents will go deep into the substrate. This is quite apart from the contribution to the soil made by the microbial element, such as the hyphae of fungi.

Re-establishing all such living components after major disturbance (eg mining in jarrah forest) is a complicated matter. It requires multiple steps in order to begin to restore some of the parts to their rightful places. The recovery is very long-term. First, stripping the upper 10cm collects 90% of the store of seed in the soil (Koch et al 1996). Second, this can only be re-spread to 5cm depth because that is the maximum depth from which seeds can germinate (Grant et al 1996). Third, stripping small sods of the upper 40cm from nearby 'donor areas' collects most of the species that re-sprout from underground organs (especially those that are obligate re-sprouters - that is they regenerate by means of bulbs, tubers, rhizomes, and barely at all from seed; Norman & Koch 2007). Third, although much is done to reduce the impacts of the mining and rehabilitation, the disturbance still causes attrition. This is due to factors such as death of soil organisms that are buried deeper in stockpiles than they can tolerate, machinery damage to roots and underground organs, and changes in the moisture and temperature regimes (Meney and Dixon 1988; Koch et al 1996; Norman & Koch 2007). Such attrition, along with the "difficult to re-establish" nature of some species means that various intensive and technical ways of restoring species must be used (Norman and Koch 2007). The range of soil integrity factors can be depleted by various other means, for example persistent grazing leads to a lack of regeneration of perennial shrubs in sheoak soils suggesting the store of perenniating organs and seed has been exhausted (Pettit & Froend 2000). Relentless and intense grazing progressively disrupts soil stability factors: first, preferred species are grazed, then less palatable or nutritious species, and finally most species (except those that are noxious or have other forms of defense). In the interim disintegration of the soil crust, compaction of the rearranged surface, and other changes such as channeling of water all gather pace, with the ultimate consequence being that areas may be denuded and eroded (Mitchell & Wilcox 1988; Hussey & Wallace 1993; Pettit et al 1998; Van Vreeswyk et al 2004; Croft et al 2005). Similarly if there is a large *and* intense wildfire and the soil surface remains bare there is a great risk that the first heavy rains will wash away topsoil (Burrows 2009).

Similarly a series of changes to the physical and chemical makeup of the inorganic part of the soil also accompanies disturbance. Things such as compaction, pore size, particle size, free and bound elements and compounds, and pH may change. For instance after prolonged grazing by stock (and rabbits and kangaroos) the cover of jarrah forest vegetation is reduced, and soil compaction, water repellency, and nutrients also rise (Pettit et al 1998). Similarly logging operations alter such properties (Whitford 2009). The physical and chemical changes associated with agriculture are legion and in combination result in the alienation of native vegetation (Moore 2004; Hussey & Wallace 1993).

◇ Look for the soil surface stability components in the selected area.

<u>The components that promote soil stability, and integrity</u>.
In the undisturbed area get a sense for the components that are contributing to binding the soil. Depending on the vegetation type there will be varying combinations of:

- Stems, and other plant bases such as rhizomes, bulbs, corms and tubers;
- Surface feeder roots and root mats;
- Humus – soil organic matter built up in the upper soil layer;
- Duricrust – a crust that can incorporate mineral oxides (alcrete, ferricrete, calcrete) and algae (blue-green bacteria);
- Cryptogams (mosses and liverworts);
- Lichens; and
- Litter and debris.

Try to overlook litter and weeds and build a sense of how well the other components of stability are dispersed, and interlocked in the target vegetation. In terms of getting a view of the soil profile small and shallow excavations, animal diggings, and other exposed parts of the surface layer will help form such a picture. So will man-made disturbance in nearby equivalent areas which can expose the soil profile.

<u>Regarding litter</u>.
Try to separate the litter layer from the other components because it is most subject to fluctuation due to intermittent factors such as fire and weather cycles. That is not to discount the fact that, in the absence of these factors, or in the presence of fauna, it may become humus and a significant component of the upper soil horizon.

<u>The balance between weeds and native plants</u>.
For the purposes of integrity weeds can be viewed as contributing to disturbance as they alter the soil fabric, soil conditions (such as the availability of water and nutrients), the balance of soil biota, and the carbon cycle (and so the fire cycle). Recognise the contribution made by weeds to soil structure as outlined above and make allowance for this. The cover of components that are stabilising the soil will be all the native plants, cryptogams (lichen, mosses and liverworts), exclusive of native plant litter and debris, and exclusive of weeds and their litter.

<u>Extent of surface disturbance due to native animals & other natural causes</u>.
Get a feel for how vertebrate animal activity interacts with surface stability. Due to the absence of native medium body weight mammals from most of the mainland this is generally not “typical”. However, patches of more intense activity such as the rest areas of kangaroos, can illustrate how they dig. In some places they do break the surface to get plant material. As the main stand-ins for medium body-weight native mammals rabbit activity might be considered to be at some sort of equilibrium in terms of surface stability if it affects a small proportion of the surface area (possibly <5%). Extremes of such activity will manifest as denuded vegetation and extensive disturbance to the soil surface.

<u>Regarding naturally bare areas</u>
In the absence of man-made disturbance, accelerated erosion, and weeds, and given a fair complement of native plants, it is likely that bare areas of surface are a normal part of the unit. There may also be a general pattern to occurrences which is repeated or interspersed in the unit, rather than them being confined or focussed by activities or their consequences.

In many situations rock becomes a significant part of surface stability. There are a range of ways that it can be a factor, as a: primary outcrop; a significant part of the soil profile (packstone, mudstone & gravel); surface “gibber” plain (or colluvial strew or pavement); or secondarily consolidated composite material such as conglomerate and calcrete or travertine.

◇ When rating this attribute bear in mind that it is relative and depends on the vegetation type. Consequently low and high expressions of plant stems and other components in a south-west heath will be relatively higher than an arid shrubland. In turn the arid shrubland is likely to be quite patchy and some patches may be quite bare, and so these relative considerations will also apply between patches and their surrounds in arid areas.

Surface stability Contributing factors to a consolidated soil surface such as root mats (surface roots); fibre; humus; cryptogams; blue-green bacteria; oxide crusts. (Exclude naturally bare areas; eg outcrops, sand, dunes, riverbeds.) (Disturbance includes: earth movement; trampling; erosion & weeds)	Heavy disturbance to structure. _______ Low content	Moderate to heavy disturbance _______ Low to moderate content of surface roots & stems. <> Low to moderate organic matter present <> Low to moderate development of upper crust	Moderate disturbance to structure. _______ Moderate content	Moderate to low disturbance _______ Moderate to high content of surface roots & stems. <> Moderate to high organic matter present. <> Moderate to high development of upper crust	Surface seems stable. Little evidence of disturbance to structure. _______ High content

M2) LITTER

Litter is an attribute that illustrates ecological dynamics and complexities, and the requirement for a range of cycles and states, within and between vegetation types. It clearly illustrates the need for heterogeneity and patchwork over different timeframes and spatial scales.

It is hard to broadly typify litter for a range of reasons. It is not in a static or consistently reliable feature within or between vegetation types over time. It is highly dependent on time since fire in most (but not all) vegetation types [eg jarrah & karri forest and wandoo woodland (Sneeuwjagt & Peet 1998); intermediate rainfall woodlands (Burrows et al 1987); spinifex grassland (eg Suijendorp 1967; Griffin 1989)]. It is also highly dependent on the extent to which the sum of faunal activity is churning the soil. (This is referred to as “bioturbation” and is a consequence of the actions of a range of lifeforms including invertebrates (Majer et al 1997). To the casual observer it is most obvious when carried out by larger animals (Richards et al 2009). In some vegetation types the litter layer is cryptic, and is essentially concealed within the vegetation, (for instance in spinifex grassland material that would form litter is stored as hummock structural material, and in termite galleries). [Note that ultimately it may prove possible and desirable to have an index of litter for major vegetation units based on cover and thickness, and/or remote sensing indices because dead and live matter can be distinguished by this means to some degree; however, this would be resource intensive).]

Well-developed litter can play a significant role as a resource base for fauna. Litter comprises dead plant matter such as leaves, branches, stems, logs and bark. It provides shelter, and decomposing-plant-matter-as-food, for invertebrate fauna, which in turn increase as the litter layer develops and soil organic matter rises (Majer et al 1997). These grazer species in turn support predator invertebrates (McElhinny et al 2006). Complexity of litter makeup tends to reflect the diversity of plants contributing material (McElhinny et al 2006). There appears to be some correlation of structural diversity with litter diversity and in turn ground invertebrate diversity (Anderson 1986; Bromham et al 1999); structural diversity is important to ant diversity (Clough 2001). Consequently invertebrate abundance and richness can drop when plant litter diversity and the conditions which it provides, such as retained moisture, decline. Similarly litter cover and depth tend to correlate with reptile abundance (McElhinny et al 2006). A significant guild of birds are ground foragers in woodlands and forests of southwestern and southeastern Australia (Recher and Davis 1998).

However, at the other end of the spectrum some species benefit from features of bare areas such as the increased heating of the ground. This applies to invertebrates (eg ant species composition adjusts to bare areas; York 2000) and in colder, damper areas, to some reptiles (Brown and Nelson 1993). Similarly it does not always follow that ground foraging birds are reliant on litter as some woodlands and dry sclerophyll forests have little ground vegetation and birds have little option but to forage on the ground, whether it has well-developed litter or not (eg wandoo; Recher and Davis 1998).

Trapdoor spiders clearly illustrate the need for heterogeneity and patchwork of litter in time and space. Trapdoor spiders (Mygalomorphae) are the older counterparts of the familiar web-weaving spiders (Araneomorphae) and in their general behaviour and habitat preferences conform to a group that had its origins when the Australia was covered in wet-temperate forest or even part of the Gondwanan super-continent (Main 1987b). In line with such origins they persist because they can avoid dry periods by burrowing, and so tend to be sedentary for much of their lives. Naturally some species are more likely to be closer to older wet-temperate stock than others which have adapted to increasing aridity. It appears that some species are quite sedentary and long-lived and require quite stable environments, including a prolonged absence of fire or other disturbance. Their fecundity and density appears to be low and so their re-invasion of a burnt area is a slow process. Other species are more prolific and relatively more mobile and so are quicker to re-invade a burnt area (Main 1992). Great care needs to be exercised with the management of fire that affects the more sensitive species. It seems likely that some degree of correspondence between those habitats that inherently burn less frequently and such species exists (eg some wheatbelt woodland types; Burrows et al 1987). In fragmented areas these creatures are under most threat from fire in small remnants, where there is a high likelihood that any fire may burn the whole area. In the absence of unburnt refuge patches, with sufficient individuals to supply new stock, there is a high risk these species will decline. Consequently great care needs to be applied to fire management in small areas.

In theory a stable, thick, and extensive, cover of litter ought to be optimal for trapdoor species; as they make burrow lids and prey-detection twig-lines from litter, in turn these structures are less susceptible to bird attack when not in the open, and litter is likely to provide a supply of invertebrates (Main 1992). Clearly loss of cover in any burnt area impacts on the population and causes considerable mortality.

However, bare areas also play a role in the lifecycle of these spiders. Bare areas appear to be essential for tiny young spiders to commence burrowing as their small size means litter presents a barrier to entry to the soil. Fire can also mean that the regrowth on plants tended by ants, and a subsequent increase in ant numbers, and so more prey passing by established trap doors (M. Davis pers. com.).

Litter also interacts with plants in a range of ways, that is it has its advantages and disadvantages and presents a range of opportunities that are dependent on the state. Litter can inhibit or exclude germination (eg sheoak litter forms a blanket which suppresses weeds (Pettit & Froend 2000); in general extensive and thick litter suppresses grasses and herbs (Smith et al 1994)). Some native plants are much better at emerging from within thick cover of litter and understorey, for example orchids with spike-like tubular leaves (eg Prasophyllum species; Brown et al 2008). Both fungal mycelia and plants feeding roots may be better developed in areas with a thick and decomposing litter layer; often in association with each other and apparently utilising the micro-environment that helps maintain moisture in the soil. This is clearly the case for the suite of fungi that native animals such as those that the Woylie relies upon (Robinson et al 2007). Similarly orchids may rely on extended fungal mycelia in order to access soil organic matter (Brown et al 2008). The majority of fungal diversity in an area can be equally attributed to habitat that includes litter or dead wood (Bougher, et al 2007).

Under bare soil conditions peak temperatures and drying effects may be extreme (Yates et al 2000) and some plant species have adaptations that let them tolerate this better than others (Dodd et al 1984; Pate et al 1984; Weber et al 1984). Heavy litter burnt at an inappropriate (usually hot and dry) time of year can cause mortality of seed in the soil in the affected area (Whitford 2009),

Litter can also play a major role in surface soil stability and structure; though not to the same extent in all soils as organic matter may be low on a relative basis in sandy or arid soils (see Moore 2004 for example). Cover protects the soil surface from raindrop splash and surface sealing effects (Yates et al 2000) and higher soil organic matter content means soils have more stable aggregates and are less likely to slake in water (Tisdale & Oades 1982; Greene & Tongway 1989; Greene 1992). There is an overall positive feedback from the soil carbon store and a range of elements and nutrients that are involved in the undisturbed cycling of resources reside there (Yates et al 2000).

◇ Consider litter in terms of a few key aspects (other than absolute cover which is vegetation type and state dependent):

- How much is litter contributing to surface stability? To what degree is it being incorporated into the upper soil profile? To what degree is it sheltering the soil from extremes of temperature and moisture loss? What is its thickness and extent of cover in those patches where litter is present? This does not have to be through the whole area. But consider those patches or places where there is build up and try to reflect that.
  Such considerations about stability and build up may also be matched by litter age; with lighter, more recent falls of leaves likely to be less dull and less grey in colour than older, thicker material where cumulative build up has occurred.
- In terms of fauna a range of litter components from diverse sources (that is a range of layers and plant species) is likely to warrant a higher rating. This is because it seems that a range of options for fauna is supported when a range of materials make up the litter. It is appropriate in this regard to include loose or shedding bark around trees, as this is habitat to lizards and invertebrates (McElhinny et al 2006). A sense of habitat diversity is implied in a diverse mix of litter materials, though the diversity will reflect and be limited by the identity of the vegetation type (that is there will be more diverse components in woodland with shrubs than in grassland comprising one species).
- When exotic plant species start to dominate an area it also means that the litter layer will gradually change. It is likely that the ways in which some of the carbon, nutrients and water are stored in the area will change. For example the invasion of veldt grass in Bold Park means that the understorey and especially the herb species are suppressed, more dead biomass is held vertically in grass tussocks, and the cover and lack of cover, and the way it is arranged are all changed.
- An indication of whether the fire regime is encouraging a patchwork may be gained by inspecting an area in the year after fire. If there are smaller patches of pre-fire litter left throughout the area, or fairly extensive patches at the locality to sub-locality scale it is likely to indicate that the burning regime is encouraging resource heterogeneity. Such heterogeneity includes refuge areas for those species which are slower to reproduce and recover after disturbance.
  - With a patch-based matter such as this it may be wise to rate the attribute at three levels (ie the quadrat; array; and locality).
- The degree to which litter is functioning as a key link in a number of processes may be revealed by observation of mats of the fine, white, fungal hyphae amongst the litter, especially near the base of trees. Similarly a range of invertebrates in the litter (such as slaters, millipedes, silverfish, springtails, earwigs, termites, etc) is likely to indicate the microhabitat is being utilised by native species, but an overwhelming occurrence of just one species may well indicate an exotic invader that represents system imbalance. This links to bioturbation below.

The order of the facets of this attribute is as shown in the following text box.

a) stability

b) *fauna habitat*

c) exotic contribution

d) *fire*

e) presence of fungal hyphae
(diverse invertebrates)

Litter (May be rated as not applicable to naturally bare areas; eg outcrops, sand, dunes, riverbeds.) NB: b) *Diverse components are a mix of bark, leaves, twigs, branches (+/- debris-* larger material such as logs of >10cm) c) Exotic cover is often mostly from ephemeral, herbaceous, weeds.	Generally: Litter loosely strewn on surface. Light. (Recent fall) <&/or> Litter not stabilizing the surface <> No contribution of debris to cover <> Tending to dry out in soil surface <> *Few components from few plant layers & species* *(plant layers lost)* <> Total cover by exotic litter; even smothering. <> *After fire litter is uniformly removed.* <> no fungal hyphae a single species of invertebrate profuse	*After fire litter persists in patches(few, little area).*	At least in places: Litter accumulation in pockets. (Intermediate age) <&/or> Litter partially stabilizing the surface. <> Some contribution of debris to cover <> Some parts are protected from drying. <> *Range of components from a range of plant layers & species (plant layers +/- diminished)* <> Moderate cover of exotic litter (+/- thick patches) <> *After fire litter persists in patches(several, moderate area).*	*After fire litter persists in patches (several, moderate to high area).*	At least in places.: Litter firmly integrated into top layer. Thick. (Long-standing buildup) <&/or> Litter stabilizing the surface <> Debris firmly part of cover & decaying <> Tending to retain moisture in soil surface <> *Diverse components from diverse plant layers & species* *(plant layers intact)* <> Little cover of exotic litter (sparse) <> *After fire litter persists in patches (many, much of area)* <> fungal hyphae in litter several invertebrate species in litter

M3) BIOTURBATION

The term “bioturbation” refers to the turnover of the soil over time by animals as they go about their activities. It happens at a range of scales and is not confined to any one group. Most people will associate earthworms with this function, but many other invertebrates, and also a range of vertebrates carry out this function. It is inter-related with matters pertaining to soil stability, soil structure, soil function and to litter and the incorporation of organic matter into the soil.

Two invertebrate groups and one vertebrate group can be singled out in particular as markers for this attribute; namely ants and termites, and medium bodyweight marsupials (although other mammals, lizards and birds also contribute).

◇ Assess the two parts to this attribute (invertebrates and vertebrates) independently and then combine them based on whichever part appears to be exerting the most influence.
[Note this attribute may need to be split into invertebrate and vertebrate bioturbation.]

<u>Invertebrates</u>
Ants are important because they are significant agents of soil turnover (Lobry de Bruyn 1993) and can be amongst the most abundant and diverse species of fauna in the ground layer, in addition two major subgroups are inclined to move and bury seeds (Majer & Abbott 1989). They are probably the most consistently obvious group and a good primary indicator (Lobry de Bruyn 1993).

There are two ways that they may be approached in terms of condition assessment:
i) the first which is emphasized here, is where there has been either invasion and/or disturbance and the site is clearly dominated in terms of numbers and density by one species of ant and its trails and nests;
ii) the second may be to recognise some ants which are typical of disturbance; which relies on a basic understanding of common exotic species and/or the main genera of native ants.

[Note this is put forward as an approach that could be developed in future with the compilation of a basic exotic ant guide at regional or statewide level (it is clear that both approaches reflect the state of vegetation, or its likely decline once invaded; see Clough 2001.]

◇ To get a basic assessment of whether there are several species of native ants present it is necessary to look closely for their nests; especially if there is much litter, these will be most obvious after rain when they emerge to refurbish them. Ants can also be observed in transit, but it does not guarantee that the more mobile species are resident (Lobry de Bruyn 1993). Look closely at the surface and litter in a few areas because some species are small and/or cryptic. Extremes of heat and cold during the day or year are probably not the best times to attempt to assess this attribute.

[Note: there is scope to develop a basic guide to native ant nests because these appear to be distinctive, this could be compiled on a broad basis (Lobry de Bruyn 1993).
Note: a basic guide to native ant genera with pictures is also feasible as the total number of common genera in Australia is only about 50 (Anderson 2002.]

◇ Conversely if it appears that, after intensive searching, one species of ant is all that can be found, and this specie's nests and trails are at a high density and dominate the area, then, there is a high likelihood that the area has been disturbed and/or the species is an invasive exotic.

Similarly termites are major agents of soil movement across the continent and in many areas form a key part of the food chain (for example see Abensperg-Traun 1994). Activity in any one spot may be small, but over the long-term it is pervasive and persistent activity that means much of the soil profile is turned over and new spaces and channels may be created (Lobry de Bruyn 1993; TSCRC 2000). Termite modified soils differ from soil not being worked (for instance some have higher clay from deeper in the soil, more organic matter, lower pH and possibly altered cations; Lobry de Bruyn & Conacher 1995). Essentially termites move fine soil particles from much deeper in the soil to the surface layers and ensure the distribution of carbon and elements through the soil. This happens over intermediate timeframes. Termite modified soils in foraging galleries may be fairly readily accessible to plants and other soil organisms, but the soils in mounds may take 70 years or more to disintegrate and re-distrubute (Lobry de Bruyn & Conacher 1995). The soils in mounds are sufficiently altered that specific species of fungi are associated with them (Priest & Lenz 1999). The amount of biomass represented by termites varies, being only about 100 to 200gm/ha in some semiarid areas to the better part of several hundred kilograms in savannah areas with large termite mounds (Lobry de Bruyn & De Boer 1990).

Termites are important to a wide range of species (TSCRC 2000). For instance ants are significant predators, and the high diversity and abundance of lizards in Australia may be primarily due to termites forming the bulk of the food source in arid and semiarid areas (Abensperg-Traun 1994). In addition blind snakes, golden bandicoots, bilbies, echidnas, and small carnivorous marsupials such as dunnarts all consume termites; and numbats are almost entirely reliant on them as a food source (TSCRC 2000).

In addition to being good indicators of the integrity of the soil termites also indicate other factors. Some key genera reveal much about grazing pressure which excludes harvester termites, and fire which diminishes wood eating termites (Abensperg-Traun & Milewski 1995; Abensperg-Traun & Smith 1999).

◇ Termites are a secondary indicator, as finding them takes effort given that only a proportion of species build mounds (Abensperg-Traun & Perry 1998 is a good guide to WA mounds; a similar guide for the non-mound species would be complementary), and the majority of activity is often in subterranean galleries which are not always easy to intercept (Lobry de Bruyn 1993). The other signs to look for are papery honeycombing and gritty debris in old logs and stumps. (To get a better handle on termites as an indicator use a manual auger to take several core samples throughout the quadrat and note any species differences and the proportion of times that termites were found.)

◇ *Ideally* this attribute would be assessed during annual wet and dry periods, or at seasonal intervals (Lobry de Bruyn 1993).
◇ Take care, absence of evidence of termites may have more to do with intensity and duration of searching rather than absence, especially if in most other respects the vegetation appears to be in good condition.

NOTE: Termites may be best assessed collectively with other invertebrates. The presence of a combination of any of the following: silverfish, earwigs, springtails, millipedes, centipedes, slaters, mites, scorpions, cockroaches and spiders in or on the surface layer will tend to indicate condition is towards the excellent end of the spectrum. Many such species may be short range endemics (see for example Moir et al 2009; EPA 2009 - Guidance 20). In contrast the predominance of only one species at a high density and cover may indicate the opposite.

<u>Vertebrates</u>
Medium body weight marsupials are included as markers for this attribute for two reasons: first, so they can be considered in those places where they have been re-introduced; second, because several of them dig and/or burrow and are agents of bioturbation (eg bandicoots including the bilby). Emblematic of this group is the woylie which once occurred across much of central and southern Australia. It played a vital role in moving fungal spores (especially plant symbionts) and seeds, in incorporating biomass into the soil, and so in generally promoting plant community health and vigour (Mitchell & Wayne 2008; Richards et al 2009). Without medium body weight marsupial species such as the woylie in the environment it is likely that a significant part of the ecosystem functions performed by them are absent or even dysfunctional through much of the state (Burrows et al 2000).

This attribute can also be assessed collectively for other vertebrates. Collectively kangaroos or other macropods, lizards (the pre-dominant vertebrates in semi-arid and arid areas (for example see Abensperg-Traun1994)), and birds may all play a role in surface soil movement. So as a final part of considering this attribute it may help to appraise the degree to which the activity of these groups appears to have affected the soil. For instance in sandy areas lizards may burrow intensively, and the mallee fowl also may move much of the surface in areas where it still occurs.

◇ It is important to first become familiar with the signs and traces of feral animals, and to be able to tell these apart from native animal signs (see feral animals). One of the most common feral agents of disturbance is the rabbit. Rabbit activity can be recognised in the field because rabbits will tend to have dung piles, with round faeces that are not uniformly coated with a dark film. Rabbit diggings tend to be rounded and tunnel-like whereas the diggings of bandicoots tend to be acute or sharp. Kangaroos dig in broad pans and expose many roots.

◇ As a general rule the scale also incorporates a sense of this attribute being functional when turning over at a certain, sustainable, rate and dysfunctional when turning over at an accelerated, intensive way.

◇ NOTE *this comment may be better as an attribute - such as exotic invertebrates*: Note that bioturbation can have a pathological expression - namely the invasion of an area and the domination of its resources by an exotic species. Such a circumstance is likely to warrant a default rating of disturbed, *at least*. Leading metropolitan examples that are clearly utilising resources and are also likely to be strongly displacing native species are the portugese millipede (Bougher 2007) and the tramp ant (coastal brown, or big-headed ant) *Pheidole megacephala* (Clough 2001). The millipedes are becoming abundant in remnant vegetation, where they feed voraciously on the fruiting bodies of a range of fungi, with the likely consequence that the symbiotic relationships of the fungi with native plants will be disrupted. It is also likely, that given their numbers, they are displacing a range of native soil fauna, to similar disruptive effect. The ant is one of the world's worst invasive ant species. Believed to be native to southern Africa, it is now found throughout the temperate and tropical zones of the world. It is a serious threat to biodiversity through the displacement of native invertebrate fauna and is a pest of agriculture as it harvests seeds and harbours phytophagous insects that reduce crop productivity

Cross linkages with other attributes

Because of the integral role the upper soil layers play in carbon storage and nutrient cycling and the myriad community interactions that occur in this horizon the attribute bioturbation closely inter-relates with several others. For instance nutrient cycling might be recognised separately, but a large part of it transpires in the soil surface. Likewise native fungi are predominant in the soil and litter and play a vital role in the breakdown release, and movement of resources. In many instances fungi are essential to the establishment and survival of native plant species with which they form a symbiosis (orchids are highly dependent, but other species also rely on fungi to act like roots and extend their reach into the soil's resources).

Fungi are also intimately inter-related with those native animals that were an integral part of the whole dynamic of resource cycling and maintenance of the balance of relationships in the soil. The interaction between fungi and animals ensured the spread of spores, incorporation of carbon, pore spaces and aeration, and a varied micro-topography (which in turn assisted with water penetration and retention of water and nutrients (Yates et al 2000)).

The two parts to the attribute are as follows:

a) soil invertebrates   ______________ b) vertebrates

Bioturbation (Observe the nature, complexity, & processes) Backup to surface stability. Focuses on: a) primarily ants, then termites, (then other soil invertebrates); & b) vertebrates. [a) & b) may need to be split.]	Only one species of ant predominant and likely exotic <> Termites present (may be 1 species) <> No other soil invertebrates present (after intensive searching) or one species predominant & likely exotic ______________ Vertebrate activity may include ferals. +/- FERAL SPECIES <> Activity intense, &/or large in area. <> Heavy disturbance to surface / sub-surface / roots High density of faeces	______________	2 species of ant observed <> Termites present (1 or more species) <> 1 or more soil invertebrates present ______________ Activity of one to two vertebrate species NOT FERAL SPECIES <> Activity moderate &/or moderate in area. <> Moderate disturbance	______________	2 to several species of ants observed (look for differences in nests & in worker size & shape) <> Termites present (2 or more species) <> Several groups of other soil invertebrates present ______________ Activity of several vertebrate species NOT FERAL SPECIES <> Activity low/diffuse &/or small in area. <> Little disturbance to surface / sub-surface / roots Low density of faeces

M4) NATIVE FUNGI

The variety of fungi being uncovered as part of biodiversity inventory is steadily growing in W.A. (eg Syme et al 2008; Bougher 2007a; Bougher 2007b; Robinson 2009). Many fungi species form close associations with both species of fauna and plants; animals eat the fruiting bodies and disperse the spores, and the fungi act as root extensions that help extract minerals from the soil while the plants supply them with photosynthetic products (eg Wilkinson et al 1989; Brundrett & Abbott 1991; Bougher 2006; Robinson et al 2007; Bougher 2009). These close associations are important to plant species and communities across the continent (eg the Woylie (Mitchell & Wayne 2008) and potoroos (Garbutt & Unwin 2007)). Many other fungi play a role in decay and cycling of resources in the ecosystem.

Those types of fungi that comprise the bulk of the diet of woylies outline two ecological patterns relevant to the maintenance of their diversity. First, peak fruiting diversity appears to occur between peak winter rainfall and spring in winter wet areas (Christensen 1980; Bougher 2006; Robinson et al 2007). Second, these fungi tend to fruit more prevalently in forest on mid slopes and in valleys - suggesting that topography and so soil and litter moisture influence abundance (Robinson et al 2007). *It is a marked feature of the ecology that lower parts of the local landscape (mid slopes and below them into the valleys) are zones of fruiting abundance, as this strongly overlaps with resource and habitat partitioning linked to fire interval; where riparian areas are moister, and less frequently burnt, refuges. That is, the combined picture of fire-plant-fauna interaction suggests that these areas are physical and drought refuges, as fungal resources are most likely to persist during dry times where moisture is concentrated* (cf Burrows et al 1999 for instance).

Studies in the karri forest and other observations show that there is a suit of fungal species that only fruit in response to fire and the alkaline conditions it generates (that is without fire they remain in the asexual stage and do not undergo meiosis (Robinson 2009; Wills 1983)). A very significant part of the fungal diversity is therefore keyed to reproduce sexually only after fire, and *consequently the only way to have full fungal diversity expressed in the landscape is to have a balance of areas that are at a range of ages since fire including long unburnt and recently burnt* (Robinson 2009; see appendix figure ***). To add to this there a range of beetles and flies that are specialised to seek out the fruiting bodies of these fungi after fire in a range of vegetation (eg Schmitz et al 2007; Klocke et al 2009); it seems probable that fungal bodies once also helped sustain some mammals in areas left bare after fire.

◇ Clearly the prevalence of fruiting bodies of fungi will be more common in the wet periods of the year and assessment of this attribute in basic terms of whether there are several or few/no bodies evident is best assessed then. If underground fruiting bodies likely to suit bettongs and other fungus eating mammals are to be included in assessment, this is a better indicator in mid to lower slope or valley situations or possibly any feature that focuses or traps moisture in the soil near vegetation.

◇ Other indicators that some of the groups of fungi are intact at the site will include: i) the presence of one or more orchid species; ii) the presence of white mycelium in some of the patches of litter in the site; iii) earth-borer beetles could be suitable guides given that their mounds are distinctive and they feed on underground fungi (and importantly mychorrhizal and truffle species (Houston 2009); iv) in those areas where medium body weight mammals are still present, examination of their diggings for fungi; v) a focus on “truffle-like” fungi that fruit underground which could be achieved by examining (usually raking the litter to 10 to 15cm of the soil) in the two patches where litter is best developed and likely retains moisture, ie under trees and/or shrubs (Robinson et al 2007). Under dry conditions this may be the default option, backed up by assessment only in the parts of the topography most likely to retain moisture.

◇ It may be appropriate to record N/A (not applicable) if the season is not suited to an appraisal.

[Note: regarding iii) above, a guide to the mounds formed by earth-borer beetles and how these differ from ants and scorpions could be a useful resource (Houston 2009)]
[Note: regarding v) above, a basic guide to the most common genera of these truffle-like fungi would be a useful resource document.]
[Note: a complementary guide to the main pathogenic fungi, principally Armillaria, would help ensure that these species are not included in a basic appraisal.]
[Note: a basic guide to broader groupings of fungi may help support this function. At present more detailed guides such as Bougher 2007b are likely to be useful.]

In the following scales Alienated equates to fungi being absent and Pristine to present throughout the area.

Native fungi. Presence.	Low incidence No species evident 1 or more pathogenic species present	Few individuals. One species. &/or Isolated incidences	Moderate incidence Few individuals. Few species. &/or Tending to be confined	Few individuals. Several species. &/or Scattered through area.	High incidence Several individuals. Several species. &/or Spread through the area.

M5) NUTRIENT CYCLING

Nutrient cycling is an integral part of vegetation maintenance. In most plant communites maintenance is tied to pools of nutrients in the soil and biomass, and proportionate rates of loss and gain to these pools. In Western Australia the weathered landscape means most ecosystems have low background levels of nutrients and are susceptible to any surplus input (Specht et al 1977; Bell et al 1984). Many plant species are adapted to low nutrient conditions and do not tolerate surfeit of such resources (Groves and Karaitis 1976; Specht et al 1977). Surfeit of nutrients also favours weed invasion (Hobbs 1989). Such surplus may originate outside area from anthropogenic sources or the vegetation may become more vulnerable to invasion after episodic release of nutrients due to fire.

This attribute is covered in part by other attributes, see wetland eutrophication, pollutants, sivicultural management, harvesting of biomass, acidity buildup, and nutrient export.

The assessment of this attribute may have a place at the end of the overall procedure. This is because it is conceptually a secondary attribute, in part covered by and interdependent with other attributes along the lines of:

	YES	NO
Fire cycling (patchwork in place; not uniform/large and/or not fragmented)		
Fauna cycling (range incl. med. body wt. sps.)		
Fungi cycling (diverse fungi)		
Flora cycling (+/- weeds)		
Soil flora and fauna		
Mineralization (background level of soil intact)		
Nitrogen fixation (background level)		

Changes to nutrient pools and the rates of loss or gain can occur for three main reasons:
I) Nutrient export.
This occurs due to factors such as:

i) Fire which causes redistribution of elements. Loss of volatile elements is significant where the areas burnt are large, and/or the fire is intense. Loss of surface ash is significant if the surface remains bare and dry for long so that ash blows away or is washed away if the first rains are heavy. In well vegetated areas such loss and gain from other areas may balance out. In fragmented areas with small remnants there may be no equivalent counter exchange from burnt adjacent patches.

A patchwork of fire is important to retention of nutrients as it moderates the rate of nutrient export; in any area:
a) having only a proportion of fuel combusted means elements are not all volatilised at once;
b) an established patchwork of fuels may reduce overall fire intensity and consequently loss of nutrients due to volatilisation (note that time of year also moderates this); &
c) having only a proportion of the fuel surface bare and ash covered means the amount that is blown away, washed away in solution and bound to sediment, and leached into the watertable is minimised.

ii) Harvesting and net export of nutrients and/or cations are removed and this alters the acidity and availability of nutrients. Such export may also have unpredictable effects on the degree to which elements including nutrients are “sorbed” to soil constituents.

iii) Soil erosion. This process can mean loss of nutrients as they are dissolved or carried away in suspension.

II) Nutrient import.
This occurs due to factors such as:
i) Airborne pollution (gases, particulates, aerosols and dust, most of this cannot be blocked when carried high in the atmosphere); &
ii) Water borne input by surface flow, channel flow, or watertable contamination.

III) In-situ changes to nutrient cycling due to factors such as:
i) The buildup of exotic flora and fauna in the soil (weeds, soil invertebrates, soil microflora including pathogens).
ii) The import and export in the excreta of feral animals and stock.

There are ameliorative efforts that may generally be applied in order to prevent import or export or altered cycling, they include: i) buffers from surrounds such as windbreaks/windrows for airborne material, and nutrient sinks for waterborne material (eg Lund et al 2001); ii)
fencing out stock and feral animals; iii) weed control; and iv) refinement of fire regimes.

W) TREND GROUP - WEEDS

W1) ENRICHMENT PLANTING / SOWING

In many areas it will pay to be aware that vegetation may not be original.

There are now significant areas of vegetation that have been reconstituted in various ways. This ranges from rehabilitation following activities such as mining where the intent in some operations is to return a certain proportion of the original plant species (and ultimately, ideally all such species; eg Alcoa's mining rehabilitation (Norman & Koch 2007)), to infill planting of remnants or re-establishment of patches in largely alienated areas (Hussey & Wallace 1993). The extent to which the source or provenance of plants is specific to the local area and also specifically appropriate to the soil and landscape varies. Though in the former case there has been a progressive improvement in the control of provenance by means of rapid return of topsoil, and subsequently in the success of return of species and/or growth forms.

The emphasis on provenance has steadily increased, but is not consistently applied or understood, nor was it a major consideration in much early work. Consequently early post-mining rehabilitation in the jarrah forest emphasized timber production and used several exotic species (WaterCorporation 2005), much reclamation work used provenances of widespread species from throughout their geographic range (much tree seed stock of mixed provenance was supplied by Alcoa in conjunction with a screening program (see Van Der Moezel et al 1989a, 1987b, & 1991); similarly the Department of Agriculture has consistently promoted use of mixed provenances of saltbush

(Barrett-Lennard et al 2003); or much that was otherwise exotic or low value in terms of conservation of biodiversity (Safstrom 1999). Similarly there are extensive lengths along Albany Highway, Great Eastern Highway in the agricultural zone, and many of the metropolitan freeways where sowing or planting of a select mix of non-local provenance and/or species and a limited range of species across a wide range of situations took place in the 70s, 80s, 90s and even later.

A range of cues will help to determine whether the area has been subjected to enrichment of one form or another:

- *At the site cues may include*: discontinuity in general form and different content of species; uniform age class of the dominants in reclaimed areas; perhaps fewer species in the reclaimed areas; a high likelihood that there are more weeds in the understorey; evident differences in the soil surface and makeup; signs of rehabilitation earthworks; signs of former extraction activities; and other changes such as salinity or flooding.
- Before commencing assessment it will help to have become familiar with local dominant species and faithful or "indicator" species and also to be familiar with the predominant weeds in the area.
- Talking to landholders and land managers may provide the necessary background; in rural areas a chat with landholders can often provide some background to an area.
- Records may exist in files in government agencies, Natural Resource Management groups (such as Land Conservation District Committees), and on aerial and other remote images of the area; and contact with such groups may prove beneficial.

In practice it will be easier to rate introduced native species that clearly do not belong in the vegetation type, landform, or local area, than to differentiate widely-sourced stock from very-local stock for any species. In case of any doubt use "good" as a default.

[Ideally a centralized resource of maps and plans of major rehabilitation undertakings, such as by those by Department of Main Roads would help with assessment. Such a resource would complement condition assessment and natural resource management.]

Enrichment planting / sowing Non-local plants versus Local native plants – <u>that is very local, locality, seed stock</u> Default to good if uncertain.	Planting extensive – Only non-local plants	Planting or sowing extensive – Only local stock	Mix of self-regeneration & planting or sowing (local stock).	Mainly self-regeneration (mostly undisturbed) and some (infill) planting with local plants.	Only self-regeneration (undisturbed soil surface, and community).

W2) WEEDS

Some key reasons that intact and vigorous native vegetation may retard weed growth near them (see Hussey & Wallace 1993) include:

- Competition for resources of water, nutrients and light;
- Change in soil pH;
- Alteration of the microclimate;
- Smothering and/or inhibiting substances produced by leaves branches and roots.

  For example Wandoo woodland tends to be moderately resistant to weed invasion. The reasons for this are mixed and include poor soil wet-ability, competition from the extensive shallow root system of wandoo, and a degree of allelopathy-toxicity from wandoo foliage (which displays little effect on the germination of native species at low concentration (Lamont 1985), but strong inhibition of weeds (viz. wild oats; Hobbs and Atkins 1991). Sheoak (*Allocasuarina fraseriana*) achieves the similar effects by sheer accumulation of leaf litter.

Introduced species affect native species in turn (Hussey & Wallace 1993); they:

- Compete directly with established plants, inhibiting growth and displacing species;
- Change the species composition of an area;
- Inhibit regeneration by native species;
- Alter nutrient cycling within native communities;
- May change soil characteristics;
- May alter the fire regime;
- Alter the resources available to fauna by:
  - Changing the habitat, for example from shrubs to grass;
  - Changing the food availability, for example by losing nectar-producing native shrubs and ground layer plants.

In order for weeds to invade an area there must be both the release of resources, often intermittent in Australia, and the availability of exotic seed (Davis et al 2000). The likelihood of invasion increases when there are permanent sources of exotic seed nearby, such as alienated or repeatedly disturbed areas, or there are repeated introductions of seed by animal or physical vectors.

> Disturbance favours invaders by reducing the cover or vigour of native competitors that usually dominate the resources and/or by increasing resource levels, that is essentially creating an open surplus (Hobbs 1989). Disturbance may be to the soil (physical disruption and fragmentation, including erosion and sedimentation), the hydrology (including salinity and pollution) and/or to the species themselves (such as grazing and harvesting).
>
> The combination of disturbance and additional nutrients increases the prospects that a community will be invaded, even though natives may benefit from the initial addition of resources (Hobbs & Atkins 1988).
>
> In dry regions increased water supply increases invasion of vegetation, either as a direct effect of water supply or through improved access to

mineral nutrients (eg invasions of Californian grasslands by exotic grasses followed wet years (Hobbs & Mooney 1991).

In fragmentated regions the capacity of remnant vegetation to resist invasion from disturbed areas varies. In the south-west the very patchiness and range of niches which partly supports high diversity of native plants also favours invasion of a range of exotic species (Tianhua He & Lamont 2008). While such invasion may not be at high density or cover, it highlights the effects of fragmenting, isolating and exposing areas of vegetation to continual intrusion of exotic seeds. Similarly studies of mallee remnants show weed seed sources and nutrient enrichment enhances invasions at remnant edges, though the mallee vegetation itself is fairly resistant to invasion provided disturbance apart from fire is minimized (Gosper et al 2009). Some of the vegetation that is most resistant to weeds can be found in areas on the eastern coastal plain with a combination of some or all of the following factors: dense cover of plant communities, seasonal inundation and the dry impenetrable nature of clay-based soils in summer (Department of Environmental Protection 2000). On the coastal plain the vegetation most susceptible to invasion is in seasonal wetlands and on Quindalup and Spearwood dune systems (Gibson et al 1994).

Weeds usually also benefit from a competitive advantage over native species because they are generally unconstrained by the predators and diseases that subdued their individuals and populations in their country of origin; the classic example of this in Australia was the prickly pear (Andres & Goeden 1971).

Generally weeds are difficult to remove once introduced, and they inhibit native species regeneration from seed. *Allocasuarina campestris* seedlings do not survive the summer in competition with weeds (Hobbs & Atkins 1991). In jarrah woodland remnants, where moderate grazing was removed, the number and cover of annual weed species remained at grazed levels despite recovery of native species numbers and cover to pre-grazing levels (Petit & Froend 2001). Similar trends apply to wandoo and sheoak woodlands; gradual recovery of natives can occur if grazing is not prolonged or intense but weeds remain a significant and persistent component (Petit & Froend 2000). In grazed fragmented areas in the south-west invading annual weeds are at a competitive advantage to perennial species; rapid development and onset of reproduction in winter/spring means that they proliferate when grazing pressure is least (as pasture is bountiful) and they lie dormant as seed when pressure is most (ie over summer; Pettit et al 1998).

Most of the preceding annual species are not highly competitive, and the absence of disturbance will tend to remain as minor components of the vegetation; it is only with disturbance that they will become predominant.

On the other hand some species of exotic plants are highly competitive with native species and tend to acquire and dominate resources such as water, nutrients, and sunlight, by crowding out other species. Several such species may initially enter an area via a disturbed patch but will then steadily spread and in many cases virtually smother an area; examples include: bridal creeper, watsonia, veldt grass, and pelargonium species.

◇ The relative abundance of all weeds is assessed by determining the extent to which weeds are prevalent in an area (usually in the understorey, however, there may be exceptions such as tree lucerne, mesquite, or pines).
[Note the split between more invasive and less invasive species is primarily of help in getting orientated as outlined above. If required it is possible to rate weeds twice ('a' for disturbance opportunists and 'b' for more invasive species respectively). It is easier to recognise weed species associated with disturbance compared to those that invade readily, if there is uncertainty and an absence of background on invasive weed species record a ‘b’ in the not applicable (N/A) column]

Note that at either end of the scale Pristine represents complete absence of weeds and Alienated represents complete weed cover or dominance.
[Note this attribute could be supported by a regional or sub-regional guide to the most common weeds.]

Weeds associated with disturbance (Disturbance opportunists)	Weeds common in area, replacing native species <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <90-60%	Balance tipping to weeds <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <60-30%	Weed presence building, under equity (+/- spot occurrences) <&/or> Many individuals, (few to several species). <&/or> Cover/abundance of weeds <30-15%	Weed presence low <&/or> Several individuals, (few to several species). <&/or> Cover/abundance of weeds <15-2%	Weeds scarce, uncommon (or absent) <&/or> Few individuals, (1 (to 2) species) - only in disturbed pockets <&/or> Cover/abundance of weeds <1%

D) <u>TREND GROUP - DISTURBANCE (THREATS)</u>

Disturbance is a large category. Here it is taken to be alteration of or interruption to natural processes with consequent impacts. Some of the general disturbances include: clearing; grazing; earthworks/soil movement; soil degradation; erosion (by water and wind); deposition; and an altered water balance (that is hydrological change that includes water logging and secondary salinity).

D1.1) GENERAL DISTURBANCE SCALE

A general disturbance scale is provided as an umbrella for ranking most of the attributes based on soil disturbance at once (it may also accommodate hydrological factors such as flooding; though this is not recommended).

	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT
Overall disturbance (to the soil surface.) (This opposes soil seed bank integrity)	High level <> Extensive area (consolidated) <> Repeated/ongoing (frequent)	Mod/high level <> Growing area (melding) <> Intermittent (sporadic)	Moderate level <> Limited area (scattered) <> Single incidence (infrequent)	Mod/low level <> Minor area (isolated) <> Single incidence (infrequent)	Low level

D1) EROSION OR DEPOSITION DUE TO DISTURBANCE

This attribute addresses accelerated erosion rather than natural erosion occurring in area’s that lack human intervention. Accelerated erosion usually follows the disruption or loss of protective soil cover due to human intervention in the soil, vegetation or landform (McDonald 1990).

Erosion and deposition (or aggradation), alter the soil. Erosion changes the structure of the soil at the place of origin by removing part of the profile. Deposition changes the structure of the soil at the place of accumulation. In both cases the differential movement of constituents causes sorting and often means that the nature of the soil is also changed at both places.

Water erosion occurs by two main means - either by channel or by sheet flow. It can move a wide range of particle sizes, including large rocks, though the smallest particles remain in suspension longest and so tend to travel farthest. It can also dissolve some constituents of the profile such as calcium and silica and transport these elsewhere.

Channel flow is often referred to as gullying and the formation of the smaller rills and can be evident on farmland. It usually develops where most of the vegetation has been removed and so channels propagate and spread like tendrils as the water cuts through the profile and erodes away the banks making yet wider channels with time.

Sheet flow is more likely on slopes as water travels overland in a blanket bearing a certain amount of the surface soil with it and spreading layers and ripples at points over the profile as it travels downwards. Key indicators of sheet erosion include soil deposits in downslope sediment traps such as fencelines or dams, and pedestalling (lone plants left on carved-out turrets of soil), root exposure or exposure of subsoils. This may be pronounced after the first heavy rains on any sloping area that has been denuded of vegetation and lacks any other means of surface stabilization. It can be noticeable after intense wildfire that is severe enough to consume much of the vegetation and leave much of the soil surface bear.

Wind erosion primarily applies to finer particles such as sand, silt and clays and is the main agent under drier conditions. At a local scale it may be evident that such particles are airborne over short distances and key signs will include bare areas with exposed surface particles that may have ripples in them, and mounding of sand around any nearby protuberances such as rocks, stumps, fencelines, and the bases of plants. The latter is an example of wind deposition.

Water-borne sediment deposition can be found along watercourses on their banks and floodplains and in the receiving basins of other water-bodies. In disturbed areas any depression may become a point of deposition.

In some places scalds develop due to the removal of surface soil by water and/or wind that may expose a clayey subsoil which is devoid of vegetation and fairly impermeable to water. Scalds are most evident in arid or semi-arid regions. It is often hard to determine whether wind or water was the main agent.

◇ Examine the site and assess the extent to which it is affected by either form of erosion or deposition. If both erosion and deposition are present make a record for each in the same attribute row, and annotate the record accordingly.

[NOTE: It will help if further details are recorded (see McDonald et al 1990). In particular whether the erosion is:
Active - one or both of the following apply: evidence of sediment movement; sides &/or floors of the erosion form are relatively bare of vegetation.
Stabilised - one or both of the following apply: no evidence of sediment movement; sides and/or floors of the erosion form are revegetated.
Partly Stabilised - evidence of some active erosion and evidence of some stabilisation.]

Erosion/deposition due to disturbance / changed land use a) Erosion of soil Overtaken by wind (eg blowout) or water (gullying & sheet) erosion. <&/or> b) Depostition of sediment Overtaken by wind (eg dune-like) or water (sediment) deposition. State which __a_or_b__	Severe Extensive (consolidated) <> (eg >50% of site)	Moderate to severe Growing (melding) <> (eg >15-50% of site)	Moderate Limited (scattered) <> (eg >5-15% of site)	Minimal Minor (isolated) <> (eg 0-5% of site)	Low to none

◇ Erosion may be broken down into recognised types by use of the following scales (adapted - see McDonald et al (1990) for more detail).

Wind Erosion (McDonald et al 1990) Dry soil movement, blowouts, & mounding or sand around objects.	Severe / Very Severe Most or all of surface removed leaving hard material. / Deep layers exposed viz. hard matter incl. rock & pan. <> (eg >50% of site)	Moderate to severe Most or all of surface removed leaving soft or loose material. <> (eg >15-50% of site)	Moderate Some loss of surface. <> (eg >5-15% of site)	Minor (Isolated) <> (eg 0-5% of site)	No wind erosion
Scalding (McDonald et al 1990) Exposure of a clayey subsoil or pan.	Severe <> (eg >50% of site)	Moderate to severe <> (eg >15-50% of site)	Moderate <> (eg >5-15% of site)	Minor (Isolated) <> (eg 0-5% of site)	No scalding
Sheet erosion (McDonald et al 1990) (On wide surfaces with rippling of sediment & deposits in sediment traps such as fencelines & farm dams.)	Severe Incl.: loss of surface horizons, exposure of subsoil horizons, pedestalling, root exposure, large deposits in downslope sediment traps	Moderate to severe Inc.: Partial exposure of roots, moderate deposits in downslope sediment traps	Moderate Incl.: shallow deposits in downslope sediment traps. (Often easily obscured by regrowth).	Minor (Isolated)	No sheet erosion
Rill erosion (McDonald et al 1990) A small channel up to 0.3m deep.	Severe Numerous rills forming corrugated ground surface	Moderate to severe Common rills	Moderate Occasional rills	Minor (Isolated)	No rill erosion
Gully erosion (McDonald et al 1990) A channel more than0.3m deep. (Record depth: 1) ,1.5m; 2)1.5-3.0m; 3) >3.0m)	Severe Gullies continuous or discontinuous & either branch away from primary drainage lines and onto footslopes, or have multiple branches within primary drainage lines.	Moderate to severe Gullies are linear, continuous & restricted to primary and minor drainage lines.	Moderate Gullies are isolated, linear, discontinuous & restricted to primary or minor drainage lines.	Minor (Isolated)	No gully erosion

D2) INFRASTRUCTURE DISTURBANCE CORRIDORS

This attribute covers any form of linear infrastructure whether formal (roads, service corridors (rail, power – gas & electric), surface drainage & sub-surface drainage, fencing & walls) or informal (tracks; off-road vehicle disturbance; paths & recreation).

Such areas act as barriers to the processes that would have maintained the biota in the area. The more substantial the barrier, the greater is the disruption to processes. For example corridors can disrupt seed dispersal, pollination, fauna movement, fauna mortality, soil movement and formation, and water movement. In terms of pollination, not only are pollinator's movements disrupted, but some native species pollen is wind-borne and heavy and so relies on close proximity of plants for effective transfer (Fang 1969).

◇ This attribute has been condensed. To assess it fully it is necessary to accord a score for each of the four parts.

Consequently consider and score:
a) the density of corridors (are they common through the area or scarce);
b) the nature of the barrier (is it tall, wide, deep, and/or does it have heavy traffic?);

c) the nature of compaction, and how this may affect water movement. For example in arid and semi-arid areas ill-defined, sub-surface water flow is a feature of ancient and collapsed drainage lines. A compacted road or railway can often block sub-surface movement of water along broad, ancient, valleys and along footslopes, causing death of trees on the 'downstream' side (Dames & Moore 1984; Fox & Cary 1985). In some circumstances a dam-like effect may cause localized inundation;
d) the degree of recurrent disturbance that is apparent. For example: High for firebreaks near infrastructure and habitation; High for major gravel roads; Moderate to high for minor gravel roads; Moderate for sealed roads.

Infrastructure disturbance corridors - characteristics FORMAL: Roads, Service corridors (rail, power – gas & electric) surface drainage & sub-surface drainage fencing & walls INFORMAL: Tracks; Off-road vehicle disturbance; Paths & recreation Note which points apply: a) b) c) d)	Density high <&/or> Strong barrier – wide &/or heavy traffic <> Substantial foundations & compaction Surface hydrology disrupted Soil movement /formation disrupted <> Very regularly renewed & maintained	Density mod to high <&/or> Mod to strong barrier – either wide or heavy traffic <> Some foundations & compaction Surface hydrology altered Soil movement/formation altered. <> Regularly maintained	Density moderate <&/or> Moderate barrier – mod width &/or mod traffic <> Some foundations & compaction Surface hydrology intact Soil movement/formation intact <> Rarely maintained	Density low <&/or> Weak barrier – narrow &/or low traffic <> No foundations & Little compaction Surface hydrology intact Soil movement/formation intact <> No recurrent disturbance	a) b) c) d)

D3) INVASION CORRIDOR

Because these corridors act as invasion routes for exotic species (flora, fauna and disease) the infrastructure corridor attribute can be supplemented with the following companion.

For instance fragmentation by roads allows ready access for predators such as feral dogs and foxes and this has been a significant factor in the decline of potoroos in Victoria (Garbutt and Unwin 2007).

Infrastructure disturbance corridors - invasion route a) exotics b) disease	Exotics predominant along corridor <&/or> Disease predominant along corridor	Exotics prolific along corridor. <&/or> Disease prolific along corridor	Exotics frequent along corridor. <&/or> Disease frequent along corridor.	Exotics scattered along corridor. <&/or> Disease scattered along corridor.	Exotics scarce to absent (along corridor) <&/or> Disease absent (along corridor)

D4) CLEARING

◇ This attribute is intended to reflect the extent to which the vegetation has been cleared, rather than the soil stripped. If soil has been removed or replaced this can be scored by means of the attributes: "erosion/deposition" and "resource extraction".

Assess this attribute simply on the basis of what is found at the site. Consider the relative extent of clearing, its apparent age and frequency. A single, recent incidence, is less likely to impact the resilience of the community than longstanding and/or repeated clearing at a short interval of less than three or four years. In this regard the impacts are much like fire. Grazing may qualify as passive clearing if it has denuded an area (Pettit et al 1998).

Note “ALIENATED” is totally cleared and “PRISTINE” is without any history of clearing.

Clearing (The focus here is on clearing of vegetation rather than soil.)	*Heavy clearing.* <> Longstanding <> Repeated/ongoing (frequent) <> (eg >50%)	Partial (*to heavy*) clearing. <> Intermediate in age (or a mix of old and new) <> Intermittent (sporadic) <> (eg >15-50%)	Partial clearing. <> Recent ($\le$2 years) <> Single incidence (infrequent) <> (eg >5-15%)	*Little clearing.* <> Recent ($\le$2 years) <> Single incidence (infrequent) <> (eg 0-5%)	*Little or no clearing*

D5) RESOURCE EXTRACTION

This attribute refers to the removal of the substrate. This may range from stripping of the surface layers to extraction of bedrock.

Removal of topsoil has a very significant effect on the community at a site, and removal of deeper layers only compounds this effect. The topsoil contains a range of things other than the inorganic components, including: organic matter, nutrients, seeds, and microflora and fauna that are integral to the function of the soil. The basic horizons of soil are as follows (McDonald et al 1990):

> O - the organic materials in varying stages of decomposition that have accumulated on the inorganic soil surface.
> A - one or more surface mineral horizons which usually differ in colour from those under them, either with some organic buildup or less clay minerals than the layers beneath them (with B the A horizon forms the solum);
> B - one or more mineral soil layers (with A the B horizon forms the solum);
> C - below the solum (combined AB) and taken to be little affected by the soil-forming processes that have formed the AB layers. Often reflects geological influences such as sedimentary layers, or ghost rock such as saprolite. When wet such material can be prised apart.
> D - is for any contrasting layer below the C horizon;
> R - continuous masses of rock such as bedrock.

Stripping of the topsoil tends to have absolute effects on vegetation. It need happen only once and unlike disturbance to the vegetation that leaves the topsoil in place, the effect is complete loss of resilience in the stripped area. Once topsoil has been removed the re-establishment of plant species is dependent on the re-development of topsoil, and in many cases the subsurface, over the very long term, and on the proximity of alternate sources of native species to replace loss of the soil seed reserve. The proximity of sources of competing exotic species will also have bearing. Un-fragmented areas tend to have better capacity to counterbalance disturbance and weeds in these regards (eg see Hussey & Wallace 1993; Overton & Lehmann 2003).

◇ In most cases the extent to which the topsoil (the upper A horizon, usually A1 and possibly part A2) has been disrupted and/or removed and/or replaced will be the most significant factor to examine.

Secondarily take into account the extent to which the other layers have been removed.

This attribute may be complemented in two ways - either by applying landscape attributes or using a combined attribute such as resilience.

On the scale Alienated means that obliteration of the surface soil is complete.

Resource extraction (Soil surface generally cleared) Mining_______________ Construction__________ Material _____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________	High impact Extensive (consolidated) <&/or> A horizon removed <> (B horizon removed) <> (C horizon removed) <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <&/or> A horizon removed in part <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <&/or> A horizon disturbed <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction

D6) OTHER SURFACE DISTURBANCE DUE TO STOCK, FERAL ANIMALS OR MACHINERY

◇ Attempt to gauge the extent, intensity and frequency of movement of stock, feral animals or machinery. Look for signs of disturbance In the early stages this may only manifest as a few isolated tracks, gradually developing into well-worn paths and ultimately to widespread disturbance. Include turnover and mixing, and/or compaction of the surface (Pettit et al 1998; Whitford 2009). Score accordingly.

On the scale Alienated means that obliteration of the surface soil is complete.

Other surface disturbance (Due to stock, feral animals, or machinery)	High impact Extensive (consolidated) <> A horizon disturbed repeatedly/frequently <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <> A horizon disturbed intermittently <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <> A horizon disturbed infrequently <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction

D7) WATERLOGGING OR DROUGHT

First decide which of these attributes applies to the site. A low-lying area, especially a sump or drainage depression or floodplain in higher rainfall areas such as the south-west and Kimberley is more likely to be subject to intermittent flooding, whereas drought effects are most likely to be observed in areas of low relief which are not too far above the watertable. In the metropolitan area drought is exemplified by widespread death of mature banksias trees in the northern area or Gnangarra Mound as there has been a widespread fall in the watertable of the order of metres (Groom et al 2000). In semiarid and arid areas drought-like effects, with death of trees and shrubs, can often be seen around windmills and bores due to a drop in the watertable. On the other hand dead stags of trees above the waterline are typical of recently flooded areas.

In flooded areas an indication of a shift to a wetter regime may be indicated by encroachment of rushes such as Juncus pallidus, and the presence of annual chenopods, and then other Juncus species in wetter situations. A clear indication of persistent inundation would be gradual colonization by bulrushes (Typha species) in an area where they were once absent.

◇ Record an “a” and/or a “b” in order to account for which attribute is being scored.

[Note that this attribute may be better split in order to be used.]
On this scale ALIENATED is with all of the site affected.

a) Waterlogging (usually seasonal) or b) Drought Record if a) or b).	>50% of site affected a) Waterlogging - swamp tolerant plants have replaced original species. <or> b) Drought - Graveyard death of overstorey (and perhaps some deep-rooted understorey)	10-50% of site affected Waterlogging Pockets of dead local plants, swamp tolerant plants replacing original species. <or> Drought - Whole patches with dead overstorey (and perhaps some deep-rooted understorey).	<10% of site affected Waterlogging Scattered individual plants stressed or dying <or> Drought - Scattered individual overstorey plants stressed or dying.	Site little affected Isolated individual plants may be stressed.	Site unaffected

D8) WATERLOGGING OR DROUGHT - HISTORY IF KNOWN

◇ Make a judgement on whether decline or death of species appears recent or longstanding. For instance if the change is recent it is likely that bark and small limbs will remain on dead trees, or large shrubs. If it is of moderate duration it is likely that the bark and smaller limbs will have deteriorated. If it has been decades or more whole trees may have collapsed. Background information, where available, will also help with this assessment, as will aerial and satellite images from a series of different years.

Waterlogging Or Drought History if known	Long-standing (decades or more)	Of moderate duration (several years)	Recent		

D9) SECONDARY SALINITY

In order to assess salinity it is important to appreciate that some salinity is 'natural' or benign and was in place before wholesale clearing of the landscape and rising watertables released additional salt that was once held at depth to the surface. "Primary salinity refers to soils, and landscapes which were saline in their virgin or uncleared state. Secondary (or dryland) salinity is the development of salinity after clearing and is associated with the presence of saline groundwater." (Moore 2004)

> "Primary salinity is generally confined to the Zone of Ancient Drainage and areas where the annual rainfall is below 350mm. The origin of the salt was predominantly cyclic … or some may be saline sediments and wind blown material from salt lakes and the Australian desert regions … Soils derived from …" wind blown playa lake material … "often contain high concentrations of salt. These soils can be found in any position in the landscape…" At a general level, cyclic deposition of salt over time and over wide areas, means that many soils in lower rainfall areas had or have high salt concentrations in the subsoil in their uncleared state; especially finer-textured soils. (Moore 2004)

The relevant locations and landforms are those that are low-lying and receive drainage, and/or those that are low-lying and close to the watertable and are most susceptible to more recent mobilization, accelerated movement, and concentration, of salts as a result of altered land use.

Areas of primary salinity, that were a normal and significant part of the landscape and vegetation prior to settlement, still persist in some locations. Such areas can contain a great deal of resident diversity (such as Kondinin saltmarsh; Mattiske Consulting Pty Ltd 1996; and see Lyons et al 2004). Such areas are: i) often to the side of main flow channels and so just slightly higher in the profile; ii) lack dissecting channels; iii) have a range of salt tolerant species (several or more; principally smaller species of samphires); and iv) may have adjacent native dry-land vegetation on higher ground. Areas of secondary salinity are: i) likely to be found in the main drainage areas; ii) can often be dissected at their heart; iii) typically have one or two common samphire species which are dominant (prolific invasive species that profit from the disturbance); and iv) are less likely to be bordered by intact native vegetation. Primary salinity is also more likely to have remained stable in the medium term, whereas secondary salinity is likely to have expanded and encroached on low-lying areas and associated vegetation.

◇ If an area reflects primary salinity rely on assessment of it by means of condition attributes on composition and structure, preferably in conjunction with full plant diversity analysis. *Record that the area is subject to primary salinity in the n/a not applicable column.* This better reflects the relatively stable nature of areas of primary salinity.

◇ If an area reflects impacts of secondary salinity assess it by means of the table provided.

[Note: *This scale needs refining. It is adapted from ALR? The proximity and severity scales may need to be truncated and/or re-aligned.]*

ALIENATED	PRISTINE
(Proximity) Riparian <&/or> (Secondary) Salt outbreaks at site – severity high [‘S3’] Heavily impacted. Invasive salt tolerant plants have replaced original species.	*Absent (or only primary with intact diversity)* [+] <&/or> No (secondary) salt outbreaks

Salinity - secondary P/A ________________ *Proximity of (secondary) salt outbreak to drainage line* FRAGMENTED CHARACTER	*(Proximity) <200m* <&/or> (Secondary) Salt outbreaks at site – severity moderate [‘S2’] Moderately impacted. (May be) Salt tolerant plants replacing original species.	*(Proximity) <500m* <&/or> (Secondary) Salt outbreaks at site – severity low [‘S1’]	*(Proximity) <1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity high [‘S3’]	*(Proximity) >1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity moderate [‘S2’]	*Distant (or only primary-with intact diversity)* [+] <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity low [‘S1’]

D10) SECONDARY SALINITY - HISTORY IF KNOWN

Make a judgement on whether the change appears recent or longstanding. Cues to look for may include:
i) whether there has been decline or death of species. For instance if the change is recent it is likely that bark and small limbs will remain on dead trees, or large shrubs. If it is of moderate duration it is likely that the bark and smaller limbs will have deteriorated. If it has been decades or more whole plants may have collapsed;
ii) whether 1 or 2 common salt tolerant species have spread into the area and are replacing a range of other species. Invasive species, such as samphires, are likely to originate from the lowest-lying, most disturbed areas.

Background information, where available, will also help with this assessment, as will aerial and satellite images from a series of different years.

Salinity - secondary; history if known	Long-standing (decades or longer)	Of moderate duration (several years)	Recent (1-2 years)		

D11) SECONDARY SALINITY - REMEDIATION MEASURES

[Note: This is a provisional attribute meant to allow for ameliorative measures put in place in fragmented areas in order to combat salinity.]

[OPTIONAL] Salinity - secondary; remedial action - salt affected (Note local refers to plants from seed with local provenance).	Directing drains & saline flows into reserves.	Redirecting saline flows away from reserves (incl. deep drainage). Planting salt-tolerant non-local species in saline areas. Mechanically lowering the watertable. Fencing saline areas to exclude stock &/or pests. Letting the first flows of the season flush through.	Planting deep-rooted local species higher in the profile. Planting salt tolerant local species in saline areas.		

D12) WETLAND EUTROPHICATION

All wetlands and waterways are susceptible to eutrophication, the ecological changes that result from excess levels of nutrients, often resulting in prolific aquatic plant growth and algal blooms.

Eutrophic conditions can be set up fairly readily by the release of any nutrients above the generally low background levels prevailing in the state. Most of the state is geologically extremely weathered and consequently background nutrient levels are low in the ancient soils. Native plants are efficient at tightly cycling nutrients and storing them in a pool within their standing biomass. Naturally some of this is lost after fire; some material consistently in smoke and as ash on the wind, and some only if the first post-fire rains to fall on the ash-laden bare soil were exceedingly heavy. Such loss is an order of magnitude less than ongoing artificial inputs from agriculture, horticulture, habitation and industry. The main nutrient implicated is phosphorus although other nutrients such as nitrogen also play a role in eutrophication.

Estuaries in the South West are particularly vulnerable to nutrient enrichment, as they have evolved under naturally low nutrient conditions and many catchments now support intensive land uses (Davies-Ward & Finlayson 1997).

About one-third of monitored rivers have low levels of the nutrients nitrogen and phosphorus. Low nutrient levels are typically found in rivers with forested catchments. High levels of nutrients are usually found in waterways draining cleared urban and agriculture catchments, such as along the Swan Coastal Plain. Many of these waterways have catchments with coastal sandy soils that are well known for leaching nutrients. Waterways in the Wheatbelt and rangelands are not well monitored for nutrients, partly due to their remoteness and the intermittent nature of flows (Davies-Ward & Finlayson 1997).

Excess nutrients come to inland waters from either point or diffuse sources. Point sources (such as septic tanks, sewage treatment plants, landfill sites, industrial waste, and intensive livestock industries including piggeries, dairies and feedlots) can contribute high levels of nutrients from small areas. In contrast, diffuse sources including urban gardens, stormwater and farmland generally contribute nutrients from a widespread area (largely from fertilizer).

Nutrient transport through catchments can be very fast in areas with sandy, wet soils. In contrast, soils with a high clay, loam or iron content help to bind nutrients and minimise algal bloom risk to inland waters, unless the soils are eroded and the nutrients are carried away with the soil particles.

Other factors contributing to general eutrophic conditions include:

- Clearing of vegetation or harvesting of crops that reduces uptake of soil nutrients, which may subsequently be lost to inland waters.
- Erosion or acidification processes that lead to nutrient loss.
- Uncontrolled livestock access to waterways and wetlands which can damage fringing vegetation and contribute nutrients from faecal waste.
- Altered water regimes, particularly when water levels are significantly reduced and waters stagnate, and the risk of algal blooms rises.
- Situating nutrient-intensive land uses in close proximity to sensitive environments.
- Accumulation of fine sediment (with phosphorus attached).
- Continual accumulation and decay of organic matter.
- Loss of fringing vegetation leading to increased water temperature and light availability, and so enhanced risk of algal blooms.

Excess nutrients in water often result in algal blooms, proliferation of weeds and pests (e.g. midges and mosquitoes), and other ecological changes. If persistent, this may result in a simplification of an ecosystem and a loss of biodiversity. Some species of algae (e.g. blue-green algae) produce toxins which can be harmful or even fatal to humans, fish and animals. Fish deaths are also commonly associated with decomposing algal blooms, which causes de-oxygenation of the water. Many algal blooms also cause unsightly water discolouration and foul odours as they decay.

◇ Signs that wetland vegetation, and potentially its fringing vegetation, have altered are algal blooms (under the right conditions), and Bulrush (Typha) congestion of water bodies, and channels. The former indicates that the quantities of available nutrients has increased, and the latter is a likely indicator that water levels (and the duration of saturation or submergence) and/or nutrients have increased.

Algal blooms are clearly a state wide indicator, with signs such as water discolouration (often green), green filamentous platforms, and the possible presence of gas bubbles and an odour. There is also the prospect of greater turbidity, or cloudiness, in the water. This is not to be confused with brown tannins in many waterbodies which have their origin from plant matter.

Typha build up in association with eutrophic changes is evident in the southwest, but is likely to have wide application as an indicator.

There is a clear replacement series in many freshwater basin wetlands in the southwest with persistently saturated or submerged soils that involves Typha. Background to this includes that:
i) Typically the undisturbed versions of these wetlands in high rainfall areas tend to be dominated by the native rush *Baumea articulata* (and often *B. arthrophylla*). In undisturbed examples throughout the southwest this is still the case (E.M. Mattiske & Associates 1986; Lyons et al 2004 - Jarrah Forest, southern Avon 1 and Esperance Sandplain bioregions);
ii) During monitoring work at Kemerton wetlands it was evident that the first areas invaded by Typha within the mineral lease were disturbed ponds on the verge of in-filled areas, and the disturbed, saturated and minerally enriched waste settlement pond. In contrast the undisturbed wetlands and damplands lacked Typha, and featured: local melaleucas with *Lepidosperma* sp fringing deeper wetlands, *Baumea articulata* dominant in the intermediate basins, melaleucas and *Cyathochaetea* in one sump, and palusplain mixed shrubland over much of the rest of the flats (Arbotech Pty Ltd 1997 - in background material; Mattiske & Associates 1993);
iii) In advanced cases Typha was either in competition with *Baumea articulata*, or an outright dominant, where drains bearing stormwater and nutrients, or animal effluent, such as piggery waste, was directed to Perth wetlands (E. M. Mattiske & Associates 1987 and subsequent report; Thompson's Lake and Neerabup respectively).

> Long term monitoring of nutrients in wetlands is mostly limited to specific research studies in the Perth urban area (see Davies-Ward 1997 for citations). For example, previous studies have found very high nutrient levels in Lake Monger, a small urban lake close to Perth city. With fertilising of nearby lawns, phosphorus concentrations of up to 0.8 mg/L were recorded and the lake experienced frequent blooms of Anabaena and Microcystis species (Lund, 1995). The lake has since received significant management attention, rehabilitation and nutrient reduction efforts. Other past studies of wetlands on the Gnangara Mound found elevated phosphorus levels; for example, Gingin (0.46 mg/L), Nowerup (0.36 mg/L), Carabooda (0.29 mg/L), Neerabup (0.24 mg/L) and Coogee (0.14 mg/L) all linked to semi-rural land uses (Wrigley et. al, 1991). However, many Perth wetlands have since experienced significant catchment land use change and some are now receiving more management attention. Some Perth urban wetlands, such as Lake Joondalup and Lake Goolelall, experience ongoing midge problems linked to eutrophication.
>
> In ecological terms, phosphate plays an important role in biological systems, and is a resource in high demand. It is integral to energy storage, the construction of DNA, and to structural material such as bone (Wikipedia 2009; Moore 1998). Consequently, it is often a limiting reagent in environments, and its availability may govern the rate of growth of organisms. Addition of high levels of phosphate to environments and to micro-environments in which it is typically rare can have significant ecological consequences. For example, booms in the populations of some organisms at the expense of others, and the

collapse of populations deprived of resources such as oxygen (ie eutrophication). In the context of pollution, phosphates are a principal component of total dissolved solids (TDS), a major indicator of water quality. Note that TDS may be a useful indicator on this scale, and be applicable in parallel to algal blooms.

The contribution of herbicides to such eutrophication should not be overlooked. One of the most widely used herbicides, glyphosate degrades into inorganic phosphates/phosphoric acid in the soil and the environment (Leymonie 2007); again releasing the readily available forms of P that stimulate growth in low nutrient receiving environments. It can be placed alongside fertilizers and washing agents as a significant source.

Wetland eutrophication Degree	Algae dominant &/or Typha predominant Benthos algal/detrital	Algae common &/or Typha common Benthos algal/detrital	Occasional algal blooms &/or Typha present	Native rushes common (except Typha)	Native rushes dominant (except Typha)
Extent	90->60% of site	60->30% of site	30->15% of site	15-0%	

D13) POLLUTANTS

Pollution is taken as being surplus external input of nutrients (see eutrophication) and other chemicals. This attribute is included in order to accommodate the impacts of such inputs from all anthropogenic sources, including: horticulture; agriculture; plantations; industry; rubbish dumps; mine waste and tailings; sewerage; and urban, rural, mine, and industrial drainage and sumps.

The impact of surplus nutrients on native vegetation is usually significant against the context of the generally low nutrient background, such as on sands and laterites (Lamont 1983). Disruption to nutrient cycling is a key cause of deterioration of remnants (Hobbs, 1993). High levels of N and P can directly affect the survival of some native species, with Proteaceous species being highly susceptible (Groves and Karaitis 1976; Specht et al 1977). Raised nitrogen levels in eucalypt leaves also predispose species to insect grazing (Landsberg 1990). In a fragmented rural situation the chief sources of nutrient input to many remnants will be drift from fertilizers applied to adjacent pasture (mainly P) and invasion of legume pasture species and livestock, rabbit and kangaroo excreta (mainly N; Pettit et al 1998). Also see eutrophication.

It is unlikely that the resources will be available to properly assess effluent or emissions for constituents (such as solvents, pesticides, herbicides, etc); however, this attribute is included in order that some account can be made of this attribute where the context and proximity indicate that pollution may be a contributing factor to the present state of the vegetation and flora.

Clearly some attributes will be easier to assess visually such as: dust on vegetation (for instance near heavily used unconsolidated roads, mining, and bare paddocks); decline in areas bordering drainage and sumps; or decline associated with leachate fronts from dumps of all sorts (eg gold tailings with high sulfur content and cyanide among other things). In the middle ground aerosols will be evident if the source (such as boom irrigation or herbicide application) is in operation.

Gaseous emissions are clearly difficult. They may be inferred as a cumulative background factor for some common materials such as NOx and SOx in the wider metropolitan area, and they are clearly a factor in the development of acid soils on a world-wide basis where urbanization and industry have been long-standing. To make a reasonable case that there *may* be some effects of emissions from nearby sources it will be necessary to locate background material such as environmental impact and monitoring reports; especially as outfall is dependent on many factors such as the nature of the emissions, stack height, and diurnal and seasonal conditions including wind direction and the presence of inversion layers.

◇ This attribute is assessed on context and visual, historical or other evidence that any of the following sources are contributing to impact at the site.
Pollutants are taken as entering an area in three ways, either:
a) water borne as:
- i) surface water (including direct seepage, leaching, from sumps, dumps, and tailings areas; all urban, mine, rural, and industrial drainage);
- ii) the watertable (namely contact with a contaminated water table);

b) or airborne via the atmosphere as:
- iii) aerosols (such as agricultural and horticultural irrigation and sprays);
- iv) as gaseous emissions (such as urban and industrial sources (including NOx, SOx and ozone)); and
- v) as airborne particulates (dust, silt, soot and ash (including long-chain hydrocarbons)).

c) (in remnants) via animal exreta, especially grazers.

◇ Assess the context of the site and rate according to the likelihood that any of the above sources of pollutants exist at or near the site.

Pollutants -external input of nutrients & other chemicals. From anthropogenic sources: habitation, horticulture, agriculture, plantations, industry, (including: rubbish dumps, mine waste & tailings, sewerage, and all urban, rural, mine & industrial drainage and sumps). Type of pollution ________________ a) Waterborne - surface water, seepage, or the watertable b) Airborne - aerosols, gaseous emissions, and particulates. c) Animal excreta	Major waterborne At site In contact with sources <&/or> Receives urban or industrial drainage <> Sustained contact with a contaminated watertable <> Mass decline and death of all plant species on contact with contaminated water or watertable. Major airborne Major impacts of particulates. Thick film. Consolidated/Most of area. High cover. <> Sustained contact with a plume <> Mass decline and death of all plant species on contact with a plume. High frequency of droppings/activity	Moderate waterborne Near site <200m Surrounded by sources <&/or> Presence of urban or industrial drainage <> Regular episodic contact with a contaminated watertable <> A front of decline and even death is evident through part of the site from a source. Moderate airborne Moderate impacts of particulates. Medium film. Melding/Part of the area. Moderate cover. <> Regular episodic contact with a plume <> A front of decline and even death is evident through part of the site from a source. Moderate to high frequency of droppings/activity	Low waterborne Locality >200m - <1000m Down gradient of adjacent sources <&/or> Down gradient of urban or industrial drainage <> Intermittent contact with a contaminated watertable <> Scattered pockets & low cover. Some decline and even isolated death may be evident near the source. Low airborne Low impacts of particulates. Thin film. Scattered. Low cover. <> Intermittent contact with a plume <> Scattered pockets & low cover. Some decline and even isolated death may be evident near the source. Moderate frequency of droppings/activity.	Minor waterborne Distant sources. Up gradient of any sources <&/or> Up gradient of any drainage <> Watertable not contaminated / landform not in direct contact with watertable. <> Minor decline and negligible death. Minor airborne Negligible effects of particulates. Low frequency of droppings/activity.	<<a) Waterborne <<b) Airborne << c) Animal excreta

D14) RUBBISH DUMPING

◇ To assess this attribute record the nature of the material/s dumped at the site, and then score on the basis of the best fit according to the pattern of spread, extent of cover, and depth of cover.

Rubbish dumping Material ____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________	Consolidated High cover Thick depth 90->50%	Melding Moderate cover Moderate depth 50->15%	Scattered Low cover Thin depth 15-0%	Isolated Negligible cover	

D15) SIVICULTURAL MANAGEMENT

Management of forests and woodlands for production brings to bear a full suite of interventions specific to the activity. These can lead to changes in composition, structure and function.

Management of forests and woodlands for production may bring particular selection pressures to bear on the plant species within them. *It seems likely that the genetic composition will be altered with time*; and that this needs to be reflected with an attribute. In terms of the main tree or mallee forms this may result from: i) selective removal of set age classes and consequent changes to the extent to which they leave progeny; ii) selective retention of set individuals, with consequent changes to the extent to which they leave progeny; and iii) as a result of i & ii changes to the particular individuals and generations cross-pollinating at the site. Similarly practices such as post-harvest sivicultural burning of debris has in the past caused intense localized heating of the topsoil and may have contributed to a decline in the understorey of shrubs with subterranean storage organs (Burrows *et al* 2002). Harvesting has generally favoured the retention of the less merchantable species such as marri over jarrah, and altered the abundance of understorey, both by altering competition for resources and by damage to non-target perennial species (WaterCorporation 2005). In some areas of jarrah forest, it is not just harvesting that alters structure and composition, as thinning is also conducted to alter stocking rates and the incidence of multi-stemmed resprouts; this is not such an issue in karri regrowth which tends to be self-thinning (WaterCorporation 2005).

During harvesting the operation of heavy machinery damages soil by compacting the surface layers, mixing topsoil with subsoil and destroying soil structure (Whitford 2009). The effects are variable and depend on the nature of the harvest and its intensity. On a relative basis the compaction in jarrah forests across the seasons is moderate, whereas that found in karri forests harvested when soil is moist is high. Significant compaction endures for more than 50 years and it takes well in excess of this for soils to return to their pre-harvest state. The first few passes of heavy machinery over a new track create most of the soil compaction and the latter passes add only incremental amounts. Soil compaction is highest where traffic is highest, the main tracks and log landings, and so their extent indicates the highest impacts. It has been shown that soil compaction can be correlated to the extent of soil disturbance.

Other ramifications of sivicultural activity include the construction of roads, man-made disturbance leading to the spread of dieback (an aggressive water mould), methods of control of dieback such as phosphite, altered means of soil turnover and changes to the composition and balance of soil microorganisms (such as widespread loss of species such as the Woylie that spread native fungus spores through the soil (Richards et al 2009; Christensen 1977)). Particularly as the latter pertains to mycorrhizal fungi, those that derive photosynthates from the plant in exchange for extending the reach of the plants roots and the plant’s uptake of nutrients such as phosphorus (Abbott and Robson 1982; Brundrett & Abbott 1991). A resident population of soil fungi has the ability to exclude introduced fungi (Abbott and Robson 1982). Consequently in the absence of changes to the system there is likely to be positive feedback from spread of indigenous fungi and maintenance of a community of such species as they help to both maintain the vigour of plant species by way of nutrition, and suppress or exclude the introduction of some less favourable species of fungi. Given this context, the use of phosphite in a dysfunctional part of the system rife with dieback and likely historically subject to a range of disturbance (such as loss of the animal vectors that helped maintain the balance of indigenous soil fungi), takes on another meaning. Because this compound not only stimulates the plant's defences when absorbed into phloem, it is also slowly converted to nutritionally valuable phosphate, which may make inputs equivalent to mychorrhizal inputs. This conversion happens slowly when phosphite is sprayed on leaves and oxidizes in contact with air or in the soil as microbes metabolise it to phosphate (Lovatt & Mikkelson 2006). It is not as immediately available as phosphate.

Over the long term there are three other possible consequences to the application of phosphite; *they will both qualify as adverse trends in their own right*. First, there may be a cumulative increase in the total pool of P and at some point (depending on the soil's ability to adsorb the P) this may cross the threshold that low nutrient environments historically operated with. This is may change the balance between species, including favouring invasive species and those species that can use surplus nutrients most effectively, it may also start to suppress species that are sensitive to higher nutrient levels (especially Proteaceous species; Groves & Keratis 1976; Specht et al 1977). Second, because phosphite is more soluble than phosphate (Lovatt & Mikkelson 2006), it is likely to travel further before it is oxidized and is incorporated in calcareous soils, otherwise precipitated, adsorbed by soil particles, or incorporated into organic matter. That is, there is a higher likelihood it will end up in the watertable or in low-lying areas where water accumulates such as sumps and wetlands. Third, because phosphite is commonly applied as the potassium salt there may be some accumulation of that element. Note that should herbicide such as glyphosate be required, it will add to the input of P (see eutrophication).

◇ Consider the range of facets to this attribute as they may apply to the site. Identify the most obvious parts and record which apply. Take the rating to which the most facets apply as the overall score.

Note that in the scale Pristine lacks any disturbance and so can be taken to have structure and composition determined by natural cycles in processes.

Sivicultural management of forests	High intervention - of numerous forms.	Moderate intervention - of several forms.	Low intervention - of one or more forms.	Limited intervention (mainly fire regime).	Limited intervention (mainly fire regime).
regeneration & lifecycles influenced by practices such as stocking rates, harvesting & associated disturbance, and fire regimes	Recent & repeated. High age/class selection. (Mainly small stems & a range of stump sizes)	Medium age & moderate repetition Moderate age/class selection.	Long-standing & low repetition. Low age/class selection. (Mainly medium stems & medium or large stumps)	Otherwise infrequent. Limited age/class selection.	Otherwise uncommon. Age/class self-regulating (Some large stems & scarce very large stumps)
	Age/class uniformity (seed or habitat trees excepted). Form and genetic composition selected			Age/class largely heterogeneous (selective removal)	Age/class heterogeneity
	High cover/density: - harvester movement; - extraction tracks; - log landings	Moderate cover/density: - harvester movement; - extraction tracks; - log landings	Low cover/density: - harvester movement; - extraction tracks; - log landings	Limited cover/density: - harvester movement; - extraction tracks; - log landings	
	Highly Compacted surface Churned top & subsoil Disrupted soil structure	Moderately Compacted surface Churned top & subsoil Disrupted soil structure	Low incidence Compacted surface Churned top & subsoil Disrupted soil structure	Limited Compacted surface Churned top & subsoil Disrupted soil structure	
	High intensity Post- harvest fire	Moderate intensity Post- harvest fire	Low intensity Post- harvest fire	Limited intensity Post-harvest fire	
	High intensity Understorey rolling Scattering of debris	Moderate intensity Understorey rolling Scattering of debris	Low intensity Understorey rolling Scattering of debris	Limited intensity Understorey rolling Scattering of debris	
	High use of chemicals eg phosphite	Moderate use of chemicals eg phosphite	Low use of chemicals eg phosphite	Limited use of chemicals eg phosphate	

D16) HARVESTING OF BIOMASS

Removal of biomass in woody material alters the structure and composition of a site and affects the physical provision of habitat; it also effects broader function in various ways (eg via removal of compounds see acidity build-up and nutrient export; and see Watercorporation 2005).

◇ Signs that indicate harvesting include:

- Stumps (or possibly logs). One or more rounds of harvesting may be indicated by a range of ages and sizes, indicating more than one round of harvesting. The oldest stumps are the most deteriorated and/or largest;
- Stem sizes. Fairly uniform stem sizes are likely to indicate harvesting, as most trees established after harvesting. Smaller stem sizes (say ≤15cm) are likely to represent relatively recent harvesting, and common larger stems (say ≥50cm) older trees and the passing of time since harvesting and/or few rounds of harvesting.
- Multi-stemmed repsrouts from a single base (or coppicing) can be quite common in harvested areas as the original plants attempt to regenerate. Note that this can have the effect of making the stem diameters in the area seem smaller on average than might have been the case had most trees been single stems.
- Recent logging activity will be marked by log landings and tracks, and both logging and other wood removal may be marked by sawdust if very

recent and by fresh colours on cut log ends (reddish rather than grey hues), and an absence of charring.

Note that in the scale Pristine represents no likely no history of harvesting. It is also likely that there are some trees of larger diameter, and that mature, or maturing, trees are present in the population

Harvesting of biomass	Heavy	Moderate to heavy	Moderate	Limited to moderate	Limited.
a) Logging	Ongoing logging. <> Several rounds of logging evident. <> Mix of small, medium & larger older stumps, may be evident. <> Most trees of small diameter. (+/- young) <> Multi-stemmed coppicing from stumps common.	Ongoing logging. <> More than one round of logging evident. <> Mix of small, medium & larger older stumps, evident. <> Most trees of small diameter. (+/- young) (eg ≤15cm) <> Multi-stemmed coppicing from stumps common	Logging relatively recent, and may be ongoing. <> More than one round of logging evident. <> Mainly medium stumps (/logs). <> Mix includes trees of medium diameter. (eg 30-40cm) <> Multi-stemmed coppicing from stumps evident.	Some time since logging occurred. <> More than one round of logging evident. <> Mix of medium & old & large stumps. <> Scarce trees of larger diameter. (eg ≥50cm) <> Scattered multi-stemmed coppicing from stumps	Long-past logging. <> Only one round of logging evident. <> Mainly scattered old & large stumps. <> A few trees of larger diameter (+/- mature) <> Trees generally single stemmed. Little multi-stemmed coppicing from stumps.
b) Firewood, fencepost & craft wood removal	<AND/OR> Area denuded. Likely recent & regular (sawdust & cuts).	<AND/OR>	<AND/OR> Select sizes and patches of logs & stumps removed	<AND/OR>	<AND/OR> Logs, stumps, & debris present. Likely old & irregular.
c) (Wildflower harvesting)	<AND/OR> Uniform and heavy harvesting	<AND/OR>	<AND/OR> Patches harvested	<AND/OR>	<AND/OR> Scattered light harvesting

D17) NUTRIENT EXPORT

The export of material has functional ramifications such as depletion of pools of compounds that once circulated in the system.

Net export of nutrients may not be as pronounced as cation export in wood products. Much of the pool of limiting nutrients, such as P, will be returned to the system in discarded foliage and limbs. Cumulative loss from that contained in xylem and phloem is likely to be lower than that of cations. In addition removal of some material may promote mineralization and/or microbial release of nutrient compounds (Moore 2004).

[Note this attribute may be viewed to be covered by biomass harvesting.]

Nutrient export	Heavy logging. Repeated harvesting & export – high likelihood of loss	Moderate to heavy logging	Moderate logging Moderate harvesting & export – moderate likelihood of loss	Limited to moderate logging	Limited. Limited harvesting & export – low likelihood of loss

D18) ACIDITY BUILDUP

The export of material has functional ramifications such as depletion of pools of compounds that once circulated in the system.
[Note this may be viewed to be covered by biomass harvesting.]

There are four ways acidity can start to build up in susceptible soils under plantations of trees (or other areas that are cropped); they are via:

1) The withdrawal of water (via evapo-transpiration). This lowers the watertable and also reduces soil moisture both of which have the effect of exposing material in the soil to oxygen (for example acid sulphate exposure in peat soils; Appleyard 2008);
2) The removal of wood products or other biomass. This causes a net export of the cations that plants have stored in their tissues and consequently a net build-up of hydrogen ions in the soil. It is this net concentration of hydrogen ions that causes acidity.

> The process involves plant tissue becoming alkaline, while the soil is acidified in the region of the roots. Plants actively absorb positively charged nutrients (e.g. NH_4^+, K^+, Ca^{2+}, Mg^{2+} and Na^+) and have to balance the excess of cations in their tissues by excreting hydrogen ions (H^+) from the roots.
>
> Ordinarily the local pool of elements can be viewed as having a dynamic balance of 1:1 (mixed cations in biomass : hydrogen ions in the soil). With the removal of most biomass and the consequent requirement of plants to extract another quota of cations the local ratio now moves towards 1:2 as another quota of hydrogen ions is exported to the soil in order for this to work. Another round of harvest moves this towards 1:3, and so on. In practice this is modified by the nature of the cation in question, whether any major sinks are present in the soil, and how readily such sinks exchange the cations or are mineralized (Moore 1998).
>
> Export of biomass also precludes some local recycling of the pool of cations that may episodically help buffer the soil, via decay, termites, fire and other processes. If the plant material is retained in situ the net effect is zero (although there can be a redistribution of H^+ in the soil profile).
>
>> In an agricultural setting this removal can be as grain, hay, silage, meat and wool. In a plantation it is as wood. Assuming biennial crop rotation the amount of potassium removed by harvesting two rotations of pine stems may be equivalent to about 16 years of farming (if the whole pine is removed it is about double; that is 20 to 30 years of soil depletion and net change). A 5 t/ha hay crop will remove 60 kg/ha of potassium from the paddock (Farmnote 97/2001). Removal of the stems from Pinus radiata plantations in New Zealand (ages 13, 29 &

42) removes 294, 285 and 221 kg/ha respectively (whole pine removal equates to 504, 464, and 343; Madgwick 1994).

3) Addition of 'nutrients' (such as fertilisers, which are often applied to plantations; this may apply to N, P, S and other elements).

Nitrogenous compounds.
Ammonium fertiliser is acidifying. While nitrate fertiliser mainly serves to leave hydrogen ions (H+) in the leached zone as the highly soluble NO3 migrates down the profile and causes other cations (Na+, K+ or Ca+) to be leached with it in order to maintain neutrality (Moore 1998). (Note that equivalent considerations apply to industrial and urban emissions of nitrogenous compounds of general format 'NOx'.)

Sulphurous compounds.
Elemental sulphur has to be converted to sulphate ions by microbes before plants can absorb it, and this conversion releases H+. The soluble sulphate ions are leached in association with other cations and so the soil and leached zone becomes acidified. This contribution is less than the N & C cycles (Moore 1998). (Note that equivalent considerations apply to industrial and urban emissions of sulphurous compounds of general format 'SOx'.)

4) The more ubiquitous interception of NOx and SOx that has been progressively put into the air with increasing urbanisation and industrialization.

Cumulatively this has several consequences:

- Increased acidity in both the soil and the groundwater (and changes in availability of several nutrients).
    - In general aluminium toxicity is the major problem in acid soils in WA (though this varies with soil type; Moore 1998).
    - In the groundwater the upper portion gradually becomes acidic (Appleyard 2008).
- There are other fundamental ramifications of changed soil acidity, chief amongst which is that the availability of a range of nutrients is dependent on soil pH. Over the long term such fundamental change is not just a determinant of plant health or viability, but of whether resident local species or even communities will be able to endure in the wild at all. Availability of a range of elements changes at either end of the pH spectrum. For example acidic adsorption affects Mo, and acidity also slows nitrification, whereas alkaline adsorption affects Cu, Zn (to carbonates), and to some extent B; alkalinity also causes precipitation of Zn compounds, and lowers Mn availability (Moore 1998).
- Changes to the spectrum of microbes in the soil, including fungi, and the possibility that in some instances pathogenic and disease causing agents will proliferate.
- Changes to soil texture and other physical properties.

Such effects will be less pronounced in soils that have a greater capacity to buffer build-up in hydrogen ions. For example it is likely that clay soils will take longer to express the symptoms of acidity than sandy soils with little such buffering capacity.

Regional example of former pH ranges typical of the Swan Coastal Plain.
In a non-swampy situation anything below a benchmark pH of 6.5 may be indicative of acidification (Appleyard 2008). Typical Swan Coastal Plain pH ranges are: i) Calcareous sediments from 7.0 to 8.0 (Ascot Formation and Tamala Limestone); ii) Groundwater from depth, at the base of the deposits, from 6.5 to 7.5 (Bassendean Formation at Gnangara); iii) The shallow, near surface, watertable within sand from 4.0 to 6.5 (Bassendean Formation), this acidity is attributed to contact with organic acids from decomposition in swampy environments.

Acidity buildup Most likely in clay-free, un-buffered, soils	Heavy logging. Repeated harvesting & cation export – high likelihood of acidity buildup	Moderate to heavy logging	Moderate logging Moderate harvesting & cation export – moderate likelihood of acidity buildup	Limited to moderate logging	Limited. Limited harvesting & cation export – low likelihood of acidity buildup

D19) ACID SULPHATE SOILS

This is a provisional attribute. Acid sulphate soils in wetlands exposed to air could be incorporated here.

D20) FERAL ANIMALS PRESENT - VERTEBRATES

D20_1. Feral animals and vegetation condition

Currently there are 56 invasive vertebrate species listed in Australia (Invasive Animals CRC 2007). Introduced vertebrate species have caused deleterious environmental impacts to Australia's biodiversity, and are responsible for almost half the known mammalian extinctions worldwide in the past 200 years (Invasive Animals Cooperative Research Centre, 2007). These Introduced pests have impacted on native fauna through predation and competition for resources (food, water and refuge) and contributed to the extinction of plant species as a result of overgrazing, soil compaction and damage to vegetation which inhibits recruitment of particular plants. Feral animals are also implicated in the degradation of water bodies and soil erosion. The environmental, social and economic cost attributed to introduced animal pests in Australasia is almost AuD$800 million annually in agricultural losses, control and management regimes, and research (Invasive Animals Cooperative Research Centre, 2007). Introduced species generally have few natural predators, are often prolific breeders, and have adapted to a wide tolerance of conditions, consequently eradication programs are costly and time-consuming.

Environmental impacts of domestic stock are not dissimilar to the degradation caused by introduced 'wild' animals and so have been included in this attribute. It should be noted that domestic stock (eg sheep, cattle, horses, domestic goats) occur as both an economic entity (and therefore presumably can be controlled), and as feral animals in the wild.

D20_1.1. <u>Threats posed by Feral animals</u>

The abundance and frequency of feral animals and introduced domestic stock is directly associated with negative impacts on vegetation condition. Negative impacts include:

- a decline in native plant and animal populations through predation, loss of habitat, and competition for resources (food, shelter, water, nesting sites)
- introduction of weed species (via faeces or transported in hair or fur) and the spread of *Phytophthora* dieback
- soil disturbance (including compaction) contributing to erosion (through loss of vegetation, paths created by hoofed animals, diggings)
- water pollution (fouling of water bodies)
- carriers of disease, affecting native animals and domestic stock

D20_1.2. Scale of Threats

a. Species

The size and nature of a feral animal will have a direct correlation with vegetation condition:

- Large or small
- Herbivore or carnivore
- Hoofed or soft-footed
- Territorial or roaming
- Burrowing or digging etc

b. Species abundance

The population size of a particular feral species is significant in assessing the impact on vegetation condition. The greater the number of individuals of a species, the greater the impact it will have on vegetation integrity.

c. Residence time

Impacts on vegetation condition will depend on the residence time of a particular species. The longer the duration, the greater will be the impacts to the bushland.

d. Size of remnant and degree of fragmentation

Small remnants of bushland, particularly those in heavily fragmented areas, are likely to be more vulnerable to deleterious impacts from feral incursions than larger intact remnants as a result of heavier grazing pressures, and the cumulative impacts of other pressures such as edge effects.

e. Vegetation community type

Certain types of vegetation are more vulnerable to disturbance from feral animal impacts than others. Vegetation structure also determines its suitability to feral animals for refuge, breeding, predation etc.

f. Soil type

Soil structure plays a significant role in the degree of impact resulting from feral animals. Sandy soils are generally more prone to erosion and structural damage than clay and rock.

g. Local climate

The local climate affects the success and persistence of feral species in a particular area.

D20_1.3. Common Vertebrate Pests in Western Australia

Feral animals associated with a decline in vegetation condition in Western Australia include (but are not restricted to) feral cats, foxes, feral goats, rabbits, pigs, donkeys, horses, camels, wild dogs and domestic mice.

Feral cats

Feral cats *(Felis catus)* are now widely spread throughout the Australian continent, sometimes with densities as high as one cat per square kilometre when food sources are plentiful (Hussey and Wallace, 1993). They are solitary animals, predominantly nocturnal, and can grow to much larger sizes than their domestic counterparts. Cats are opportunistic, carnivorous predators capable of catching animals up to the size of a brushtail possum, but mostly prey on small to medium native mammals, rabbits, mice, centipedes, grasshoppers, beetles, spiders, lizards and birds (Hussey and Wallace, 1993). They can survive with minimal water, since much of their water requirements are met through food sources (Invasive Animals CRC 2007). Feral cat populations can increase rapidly since they become sexually mature in their first year, and are capable of producing two litters per year with an average of 3 to 5 kittens per litter.

Under the *Environmental Protection and Biodiversity Conservation Act 1999* predation by cats is listed nationally as a Key Threatening Process (Invasive Animals CRC 2007). Feral cats compete with native fauna for prey, and reduce the numbers of small and medium-sized native fauna species through predation. They also transmit potentially fatal diseases to native fauna, livestock and even humans (Invasive Animals CRC 2007).

The presence of feral cats is difficult to determine, since they are rarely sighted, are secretive, and leave very little evidence behind. Signs to look for include scats, particularly around rabbit warrens, and paw prints. However, it should be noted that cats usually bury their faeces.

For further information on identifying scats, tracks and paw prints of feral cats refer to Morrison (1981) and Triggs (1996).

Environmental Impacts	Signs of Presence
1. compete with native fauna for prey 2. reduce numbers of small and medium-sized native prey species, including ground-dwelling birds 3. transmit potentially fatal diseases to native fauna, livestock and even humans	1. scats (particularly around the entrance to rabbit warrens) 2. paw prints

Table x. Environmental impacts caused by feral cats, and signs of feral cat presence.

Foxes

Other than in its most northern reaches, the distribution of foxes *(Vulpes vulpes)* in Australia is wide and closely resembles the distribution of rabbits (DAFWA, Farmnote 115/2000). They are highly adaptable, and persist even in arid and alpine areas (Invasive Animals CRC 2007). Foxes are solitary animals (other than during the breeding season) and generally hunt at night, but will venture out in daylight hours during times of need. They are territorial with a home range of between 260 and 1600ha dependent on the availability of resources, and can travel up to 10km in a night (DAFWA, Farmnote 115/2000).

Foxes are omnivorous, with a preference for rabbits, sheep (mostly as carrion) and mice (DAFWA, Farmnote 115/2000) but will prey on small and medium sized native species in addition to fungi, berries, flowers high in nectar, tortoises, frogs, gilgies, centipedes and scorpions (Hussey and Wallace, 1993). As with feral cats, foxes reach sexual maturity in their first year, producing one litter annually with an average of four or five cubs per litter. However, it is possible for a vixen to produce up to 10 cubs in one litter (DAFWA, Farmnote 115/2000). Predation by foxes is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Invasive Animals CRC 2007). They compete with native fauna for prey, and are significant predators of small and medium-sized native fauna. Declining numbers and even extinctions of small mammals and ground-nesting birds have been attributed to fox predation (Invasive Animals CRC 2007).

Fox dens, scats, prints and sometimes evidence of caching (hoarding food for later use, generally by burying) are signs that may indicate the presence of foxes.

For further information on identifying scats, tracks and paw prints refer to Morrison (1981) and Triggs (1996).

Environmental Impacts	Signs of Presence
1. compete with native animals for prey 2. reduce numbers of small and medium-sized native animals through predation	1. fox dens 2. scats 3. paw prints 4. cached food

Table x. Environmental impacts caused by foxes, and signs of fox presence.

Feral goats

Feral goats *(Capra hircus)* are declared animals under the *Agriculture and Related Resources Protection Act 1976* in Western Australia (Department of Agriculture and Food WA, 2000). They occur in large numbers in the southern rangelands from Exmouth in the north-west to Norseman in the south-east, and in lower numbers in isolated pockets of high rainfall areas in the south-west where they are generally restricted to conservation estates (Woolnough et al, 2005). Feral goats persist in small herds when water is in good supply, but congregate in large herds near water as conditions become drier (Hussey and Wallace, 1993). They are herbivorous with a much wider range than sheep and prefer to graze on shrubs, but will graze on grass, herbs, and newly regenerating vegetation. Goats are prolific breeders, and populations can increase rapidly. Female goats are capable of breeding at six months with twins and triplets common, and can produce twice a year in favourable conditions (John James, 2000).

Woolnough et al (2005) suggest that environmental damage attributed to feral goats may be seasonal, and appears to be greater in spring and summer when the availability and quality of food and water resources is in decline. Feral goats strip leaves and bark from shrubs, and can completely wipe out native plant species that fail to recover from heavy grazing. The formation of tracks, soil disturbance (from hoofs), and overgrazing result in significant soil erosion from wind and water (Department of Agriculture and Food WA, 2000). Additionally, they compete with native animals for food, shelter and water, and cause damage through trampling of native vegetation. Feral goats foul waterholes and may be implicated in the spread of weeds via their dung (Woolnough et al, 2005). Competition and land degradation by feral goats is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Feral goats have different behavioural characteristics to sheep. Due to the extended reach afforded by raising up on their hind legs, feral goats have the ability to graze higher than sheep for food. They are also very determined animals, and capable of damaging fences (Department of Agriculture and Food WA, 2000). Other evidence of feral goat presence includes scats, tracks and soil disturbance from hoof damage.

Environmental Impacts	Signs of Presence
1. compete with native species for food 2. vegetation destruction as a result of trampling 3. inhibit regeneration of native vegetation due to grazing pressures 4. increased risk of soil erosion resulting from grazing, trampling of vegetation and soil compaction	1. scats/droppings 2. tracks and soil disturbance from hoofs 3. trampling of vegetation 4. grazing on shrubs, higher than would be for sheep 5. damaged fencelines 6. fouled waterholes

Table x. Environmental impacts caused by feral goats, and signs of feral goat presence.

<u>Rabbits</u>

Apart from the northernmost reaches, rabbits *(Oryctolagus cuniculus)* are widely dispersed throughout Australia. They thrive in areas of uncleared scrub interspersed with cleared areas of pasture where they have both refuge and food sources. The cool Mediterranean climate of the south-west of Western Australia provides an ideal setting for the proliferation of rabbits, where a doe (female) is capable of 6 or 7 litters each year (Department of Agriculture and Food WA, 2000). Females breed as early as four months of age and, over an 18 month period, 184 individuals can arise from one pair of rabbits due to high fecundity rates (Invasive Animals CRC 2007).

Rabbits are herbivorous, with a preference for grass and young shoots but will graze on bark, roots or any plant material available during drought (Hussey and Wallace, 1993; Department of Agriculture and Food WA, 2000). They can climb trees and shrubs to reach leaves and twigs, especially in drier areas where water availability is much reduced. Impacts by rabbits are often greater during drought and after fire, when resources are scarce. Overgrazing by rabbits can prevent regeneration of native plant species resulting in loss of vegetation cover. This, and soil disturbance from warren diggings, contribute to soil erosion and weed invasion. Competition and land degradation by feral rabbits is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act).

Aside from sightings of rabbits, signs to look for include rabbit warrens, scats, and evidence of grazing. Rabbits graze closer to the ground than stock, and tend to graze within close proximity of refuge areas (Department of Agriculture and Food WA, 2000). Rabbits are also capable of ringbarking trees and shrubs by stripping bark.

Environmental Impacts	Signs of Presence
1. compete with native fauna for food 2. grazing damages native vegetation and inhibits regeneration of native species 3. increased risk of soil erosion as a consequence of heavy grazing 4. warren construction damages native vegetation 5. dung piles and soil movement (through warren construction) promote weed invasion	1. rabbit warrens and scratchings 2. scats 3. evidence of grazing 4. ringbarking of trees and shrubs

Table x. Environmental impacts caused by rabbits, and signs of rabbit presence.

Feral pigs

Feral pigs *(Sus scrofa)* have a wide distribution throughout Australia, preferring the medium to high rainfall areas where thick vegetation and access to water are abundant. In Western Australia, feral pigs predominately occur in the jarrah forest and adjacent agricultural areas of the south-west, to the north of Perth in coastal agricultural areas, and in the Kimberley (Department of Agriculture and Food WA, 2000).

Feral pigs live in small herds of sows and young, and forage mostly at night. Sows reproduce in their first year, with an average of 5 or 6 young per litter, and are capable of producing two litters each year (Hussey and Wallace, 1993). They are omnivores, feeding predominantly on plants (particularly roots and tubers), but will also eat insects, earthworms, reptiles, birds and their eggs, small mammals and carrion (Hussey and Wallace, 1993; Department of Agriculture and Food WA, 2000).

Environmental damage resulting from feral pig presence can be significant. Feral pigs predate on native fauna, and compete with native fauna for food. Rooting and wallowing are particular activities that destroy vegetation (including riparian vegetation) and disturb soil, resulting in soil erosion, changes in the composition of plant communities, loss of habitat for native fauna, and weed invasion (Department of Agriculture and Food WA, 2000). Feral pigs foul water courses and may also be implicated in the spread of *Phytophthora* dieback (Hussey and Wallace, 1993; Department of Agriculture and Food WA, 2000). Predation, habitat degradation, competition and disease transmission by feral pigs is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

Evidence of feral pig presence is characteristic and conspicuous. Diggings from rooting and wallowing are often extensive, and it is possible for feral pigs to turn soil to a depth of 20cm (Department of Agriculture and Food WA, 2000).

Environmental Impacts	Signs of Presence
1. compete with native fauna for food and habitat 2. reduce numbers of native fauna through predation 3. rooting and wallowing destroys native habitat 4. increased risk of erosion and water pollution 5. spread of *Phytophthora* dieback	1. diggings from rooting and wallowing 2. dung 3. vegetation destruction as a result of trampling and foraging 4. fouled waterholes

Table x. Environmental impacts caused by feral pigs, and signs of feral pig presence.

Feral Horses and Donkeys

Feral donkeys (*Equus asinus*) occur in large numbers in the pastoral regions of Western Australia, most particularly in the Kimberley where their distribution closely follows that of cattle, and in smaller numbers in the Pilbara and Goldfields (Department of Agriculture and Food WA, 2000). Feral horses (*Equus caballus*) are less abundant than donkeys, their distribution and abundance being greatest in the rangelands and eastern pastoral leases of Western Australia (Woolnough et al., 2005).

Donkeys are well adapted to arid environments. As with camels, they can reduce evaporative water loss when dehydrated and reduce the water content of their faeces, enabling them to withstand long periods without drinking (Dept of Agriculture WA, 2000). Donkeys forage on a wide variety of vegetation, and tolerate much coarser vegetative material than horses. Their home range varies between an average of 3 and 32 square kilometres depending on the availability of food and water. Although horses inhabit a wide range of environments, they prefer grasslands and shrublands where water supplies and pasture are plentiful (Department of the Environment and Heritage, Canberra, 2004). Although horses cannot survive as long as donkeys without access to water, both species will travel further than cattle in search of water (Department of the Environment and Heritage, Canberra, 2004).

Both feral donkeys and feral horses live in small social groups generally with a dominant male (stallion), several female (mares) and their offspring, or in bachelor groups (Department of the Environment and Heritage, Canberra, 2004).. Donkeys become sexually active in their second year, producing one foal each year in favourable conditions. Horses produce one foal every second year.

The environmental impact resulting from feral donkeys and horses is most evident during times when water and food resources are scarce. Damage from their hard hoofs results in soil erosion, soil compaction and trampling of native vegetation. This, combined with overgrazing, inhibits regeneration of native plant species. Donkeys and horses compete with native fauna for food and water, and transport weed seeds via their dung, manes and tails.

Environmental Impacts	Signs of Presence
1. compete with native animals for food (ie pasture stock) 2. soil erosion as a result of overgrazing and soil damage from hoofs 3. soil compaction 4. spread of weeds via dung, manes and tails	1. dung 2. pads or trails 3. grazing pressures 4. trampled vegetation 5. fouled waterholes

Table x. Environmental impacts caused by feral horses and donkeys, and signs of their presence.

Camels

Feral camels (*Camelus dromedarius*) are widespread through the arid and semi-arid areas of the Northern Territory, Western Australia and South Australia, and into parts of Queensland (Department of the Environment, Water, Heritage and the Arts, 2009). They are particularly well-adapted to living in arid environments where they can survive long periods without water, but will drink every day if water is available (Department of Agriculture and Food WA, 2000). Their tough coat insulates them from extremes in temperature, and provides a hardy barrier to thorns and spinifex (Department of Agriculture and Food WA, 2000).

Camels have no natural predators, and have a lifespan of around 50 years. They live in non-territorial groups of ten or so animals consisting either of bulls only, cows and their calves, or winter-breeding groups comprising a mature bull with cows and calves (Department of the Environment, Water, Heritage and the Arts, 2009). Feral camels roam widely, and can travel as far as 70kms in a day. Females begin to breed in their third or fourth year producing a single calf after a gestation period of 13 months, and continue breeding for up to 30 years (Department of the Environment, Water, Heritage and the Arts, 2009).

Feral camels are browsers, grazing on grass and vegetation to a height of 3.5m. They are responsible for significant environmental impacts, particularly where densities are greater than two animals per square kilometre. Camels compete with native fauna for food, and there is evidence that they may be responsible for the extinction of particular native fauna where water resources and refuge have been compromised by camels during times of drought (Department of the Environment, Water, Heritage and the Arts, 2009). Browsing and grazing results in damage to vegetation through trampling, defoliation of trees and shrubs, and loss of recruitment of native plant species. Soil disturbance from camels' hooves results in a greater risk of wind and water erosion, and also inhibits water infiltration through the soil profile.

Signs of camel presence may include scats, soil disturbance from hooves, trails and tracks, damage to vegetation caused by trampling and grazing, and fence damage. Their presence is often particularly evident around waterholes, especially during drought.

Environmental Impacts	Signs of Presence
1. compete with native fauna for food and water resources 2. trampling of vegetation results in loss of habitat for native fauna 3. grazing damages native vegetation and inhibits regeneration of native species 4. erosion through soil disturbance 5. fouling of waterholes	1. scats 2. hoof prints 3. tracks and trails 4. damage to vegetation caused by trampling 5. fouled and trampled waterholes 6. defoliated shrubs and trees 7. heavily grazed grasses and herbs 8. broken and damaged fences

Table x. Environmental impacts caused by camels, and signs of camel presence.

Wild Dogs

The term 'Wild dog' refers to dingoes, feral domestic dogs, and hybrids resulting from cross breeding of the two. Although the dingo is believed to be a descendant of the Indian wolf, *Canis lupus pallipes,* it is generally classified as a sub-species of the domestic dog *Canis familiaris*, and commonly referred to as *Canis familiaris dingo* (Department of Agriculture and Food WA, 2000). In Western Australia dingoes are classified as 'unprotected native fauna' under the *Wildlife Conservation Act 1950* and protected in land managed for conservation, but are a declared pest in areas of livestock production (Invasive Animals CRC 2007). However, studies by Corbett and Wilton (cited in Invasive Animals CRC 2007) suggest that few pure dingoes persist in the wild, most being hybrids due to the rapid rate of cross breeding between dingoes and feral domestic dogs.

Dingoes are distributed throughout most of Western Australia, their numbers closely correlating to pastoral activities and control regimes, and adapt readily to extremes of heat and cold. They are rare or absent from the closely settled areas of the south west (Woolnough et al., 2005). Conversely, the number of wild dogs is greatest close to settled areas below the 26^{th} parallel (Department of Agriculture and Food WA, May 2006).

Unlike wild dogs, dingoes have a single, well-defined breeding season, whelping between June and August each year (Department of Agriculture and Food WA, 2000). However, if there are a large proportion of hybrids in the population, this seasonal cycle becomes disrupted (Department of Agriculture and Food WA, May 2006). Dingoes and dogs become sexually mature between nine and twelve months with varying degrees of breeding success, and share the same gestation period of 63 days with an average of five pups per litter. They are social animals that form distinct hierarchal packs of a dominant male and female, and their offspring of several years (Department of Agriculture and Food WA, May 2006).

Dingoes have a flexible diet, which usually reflects availability and abundance of food sources. They will hunt alone when targeting small prey species such as lizards, but will hunt in groups for larger animals like kangaroos or cattle (Department of Agriculture and Food WA, May 2006). In parts of Western Australia, euros and red kangaroos are preferred food sources, although dingoes are known to eat insects, carrion, rabbits and some relatively rare native species such as echidna and rock wallabies (Department of Agriculture and Food WA, May 2006). In agricultural areas, dingoes and dogs have been known to attack for reasons other than food, which can result in heavy stock losses.

In determining the presence of wild dogs, look for scats (generally bigger than that of a fox or cat, and usually contain traces of hair), tracks (common along access tracks and roads), paw prints, and ground scratchings (particularly near scats and urine) (Department of Agriculture and Food WA, May 2006).

For further information on identifying scats, tracks and paw prints refer to Morrison (1981) and Triggs (1996).

Environmental Impacts	Signs of Presence
1. compete with native fauna for food, water and shelter 2. predate on native fauna, insects and reptiles	1. scats 2. paw prints 3. tracks 4. ground scratchings and other marks,

	especially where scats and urine have been deposited

Table x. Environmental impacts caused by wild dogs and dingoes, and signs of their presence.

<u>Domestic Mice</u>

The domestic house mouse (*Mus domesticus)* was introduced into Australia during early European settlement. Mice occur in plague proportions in agricultural areas around every four years, and when favourable climatic seasons provide abundant food and habitat (Invasive Animals CRC, 2007). During plagues densities can reach more than 750 mice per hectare, but commonly occur at less than 10 per hectare (Invasive Animals CRC, 2007).

Mice have a lifespan of four to six months (although live up to 12 months in the field) and have a high fecundity rate, becoming sexually mature at six weeks with a gestation period of three weeks (CSIRO 2009). Nine or ten young are produced in each litter, and females re-mate within 3 days of giving birth. It is therefore possible for a population to increase by 500 individuals in just 21 weeks from one breeding pair of mice (CSIRO, Misc Publication 30/2005).

Domestic mice are omnivorous. They eat invertebrates, sometimes in significant numbers, and there is evidence to suggest they may feed on small reptiles such as skinks and geckos (Newman, 1994, cited in Burbidge et al., 2004). Domestic mice compete with native fauna for resources (food and refuge), and predate on small ground-welling vertebrates and invertebrates, particularly when food sources in crops are scarce (Burbidge et al, 2004). Adverse environmental impacts arise through the heavy use of pesticides and unregistered chemicals to control mouse populations (CSIRO, 1994). In agricultural areas, the implementation of extreme mouse control strategies (such as overgrazing and burning of stubble) may exacerbate erosion through the loss of top soil (CSIRO, 1994).

Unless sighted, the presence of mice can be difficult to determine. Signs of large numbers of mice in native vegetation may include:

- numerous, active burrows particularly where there is long grass such as along fencelines;
- hovering birds of prey (eg kestrels, kites) especially over fencelines and in adjoining paddocks;
- signs of gnawing on plants;
- frequent daytime sightings
- mouse droppings on soil or plants;
- typical ‘mousey’ smell (DAWA, No44/2003)

Scats from mice are small and may not be evident, especially in dense bushland.

Environmental Impacts	Signs of Presence
1. compete with native fauna for food and refuge 3. predate on ground-dwelling vertebrates and invertebrates 4. chemical and pesticide use for control purposes 5. erosion from extreme farm management eradication strategies	1. active burrows 2. hovering birds of prey 3. worn runways 4. scats

Table x. Environmental impacts caused by domestic mice, and signs of their presence.

D20_1.4. Domestic Stock

Domestic stock generally refers to hoofed animals such as cattle, sheep, domestic goats and horses. These species are likely to be found in remnant vegetation when alternative food sources are scarce, when shelter is required during adverse weather conditions, or as escapees resulting from fence damage.

In addition to competing with native fauna for resources, grazing and browsing from domestic stock causes significant environmental degradation as a result of damage to vegetation and soils, and the introduction of weeds. The spatial and temporal rate of environmental decline correlates to the type and numbers of domestic stock present, their residence time, the size and vegetation type of the remnant, and local climate.

Continued access by stock to remnant vegetation will result in the permanent loss of native plant species (Scougall and Majer, cited in Hussey and Wallace, 1993). Stock will graze on any palatable vegetation including seedlings, shrub foliage and even bark (Hussey and Wallace 1993). Large animals cause physical damage to trees and shrubs when reaching or scrambling for edible foliage, and destroy small plants that are trampled under hooves. Sheep, cattle and horses have been known to ringbark trees and shrubs either by chewing, or rubbing up against them (Hussey and Wallace 1993). Soil compaction and deterioration of soil structure from hoofed animals can lead to erosion and inhibit water infiltration through the soil profile. Stock also introduce weeds through faecal matter, or when seeds are transported via hair and coats. The resulting decline of community integrity and/or loss of plant regeneration creates an aging plant community that will eventually die out if grazing continues (Hussey and Wallace 1993).

Hoofed domestic animals that are not excluded from areas of natural vegetation may be responsible for:

- significantly increased grazing competition for native fauna
- loss of plant species as a result of overgrazing
- trampling causing vegetation destruction that results in habitat loss for native fauna

- soil compaction, which inhibits water absorption and regeneration of native plant species
- the creation of trails that may induce water erosion
- soil erosion as a consequence of vegetation loss and destruction
- soil disturbance and increased nutrient loads from stock droppings, resulting in a greater propensity to weed intrusion

Environmental Impacts	Signs of Presence
1. compete with native fauna for food and water resources 2. trampling of vegetation results in loss of habitat for native fauna 3. grazing damages native vegetation and inhibits regeneration of native species 4. erosion through soil disturbance 5. fouling of waterholes	1. scats/dung 2. hoof prints 3. tracks and trails 4. physical damage to vegetation caused by trampling, ringbarking, chewed bark etc 5. fouled and trampled waterholes 6. heavily grazed grasses and herbs 7. 'browse lines' on trees and shrubs 8. damaged fences

Table x. Environmental impacts caused by domestic stock, and signs of domestic stock presence.

D20_2. Before you start

D20_2.1. Timing and Frequency

The timing and frequency of scoring feral animal presence as an attribute of vegetation condition is fundamental in providing the best possible data for assessment purposes. In a given year the abundance and frequency of feral animals will wax and wane depending on the availability of food, differences in breeding regimes for different animals, timing of local baiting schemes, level of predation, etc. Other than the availability of food and shelter, fluctuations in abundance and frequency of domestic stock are less likely to be influenced by the same variables as for feral animals, since domestic stock have few natural predators (with the exception of foxes), are not a target for baiting programs, and generally produce fewer offspring due to controlled breeding regimes. (are fecundity rates of domestic hoofed animals less than feral hoofed animals due to breeding regimes?).

Ideally, observations and recordings should occur in each season over a year (ie 4 times per year) to account for seasonal changes and other cyclic and/or unusual events that influence feral animal presence. If baiting and/or trapping regimes are in place, scoring will need to be done both before and after pest control events. When frequency of scoring is limited, it is preferable to score at a time when food sources are scarce and, subsequently, competition is high, such as during the dry Mediterranean summer period in Western Australia's south-west. It is during these periods of paucity that negative impacts on native vegetation (as a consequence of feral animal incursion) will be particularly evident.

D20_2.2. Resources and techniques

The objective of this attribute is to observe and record the diversity and abundance of feral animals and domestic stock to an accuracy commensurate with availability of time and resources. Clearly, the greater amount of time available and the more people on hand, the more accurate the observations will be. However, where time and resources are restrained this attribute should focus on those exotic animals that are most common, and those that are responsible for the greatest degree of damage to native vegetation within the study site.

Prior to recording, it is recommended that time be spent traversing the assessment site (75m x 75m) to obtain a preliminary indication regarding feral animal incursion, even where time is limited. By spending an initial period of observation, a snapshot of indicators over the entire study area will help formulate an overall timeframe needed for a more detailed assessment relative to time availability. Focussing too much time in one area may result in the remainder of the study area being compromised if time runs short. It is advisable to carry a camera and record photographic evidence of any findings, especially those that are inconclusive. Jotting down rough notes during this initial observation period is also beneficial.

Scores for this attribute should be divided into:

a) the principal assessment site (cell B2: 25m x 25m)
b) the greater assessment area (75m x 75m, which includes cells A1, B2 and C3)
c) surrounding native vegetation to a distance of one cell either side.

Observations within each of these study areas will include actual sightings of feral animals or domestic stock and/or indicators of their presence, such as tracks, scats and diggings.

1. Interpreting attributes

Attributes to be recorded include:

Sightings of the animal itself: alive and/or dead. This includes skeletal remains.

Tracks and trails: recent or old, present throughout or isolated. Tracks may be in the form of trampled vegetation, or frequented, compacted trails bereft of vegetation, such as those formed by sheep. Refer to Morrison (1981) or Triggs (1996) for further information.

Paw prints/hoof prints: refer to Morrison (1981) or Triggs (1996). Sometimes prints can be identified in the sand around warrens and dens where vegetation has been removed or buried. If unsure of the type of animal a print belongs to, it is advisable to photograph them for a positive identification. Remember to include a ruler or other familiar item (such as a pen, water bottle lid etc) in the photo to help estimate size and proportion.

Diggings, rootings, foraging: recent or old, present throughout or isolated. Look for disturbed undergrowth or turned soil. The presence of weeds may be indicative of old or previous disturbance.

Grazing: high or low intensity, present throughout or isolated. Evidence of grazing can often be difficult to determine. Look for:

- grass blades that are abnormally even and short, often grazed to ground level
- bunches of leaves and stems removed from shrubs
- defoliated shrubs, especially lower on the plant, leaving only the trunk
- ringbarking, scratchings and signs of chewed bark
- coppicing, where new shoots emerge from the base of a plant that has been heavily grazed on the trunk and stems
- browsing lines on shrubs and trees, where the lower foliage line appears to be trimmed level by hoofed animals.

Scats/dung: recent or old, present throughout or isolated. Refer to Morrison (1981) or Triggs (1996). If unsure, it is advisable to either photograph the evidence or take samples for further identification. The presence of weeds may be an indicator of older deposits.

Kills/food debris: look for remains of animal kills including fur and hair

Identifiable fur/hair belonging to the feral animal. May be caught on plants or twigs as animals move through vegetation

Dens, roosts, warrens, burrows: recent or old, present throughout or isolated. Look under fallen trees/logs, and under bushy shrubs that provide camouflage and cover. For smaller vertebrate pests check areas where weeds are abundant, such as under fencelines.

Vegetation trampling: look for understorey that is damaged from animal movement or activities such as wallowing by pigs.

Fouled water bodies: feral animals such as pigs and goats often congregate and subsequently defecate near water bodies, especially in times of scarcity.

Table x. Attributes for identifying feral animal presence/incursion.

	Feral Cats	Foxes	Feral Goats	Rabbits	Feral Pigs	Donkeys	Horses	Camels	Wild Dogs	Dingoes	Mice	Other	Other
Sightings:													
alive													
dead													
Tracks:													
recent													
old													
present throughout													
isolated													
Paw/Hoof prints													
Diggings etc													
recent													
old													
present throughout													
isolated													
Kills/food debris													
Grazing													
grasses & herbs													
shrubs & trees													
ringbarking													
Scats/dung													
fresh													
old													
Dens/warrens recent old present throughout isolated													
Vegetation trampling Terrestrial Riparian													
Water fouling													
Damaged fences													
Other													

Note that Pristine means that there is no history of feral intrusion.

Feral vertebrate animals present. Indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens/warrens.	Recent ≥ old activity <&/or> Present throughout <> High intensity <> Several species Several signs/species <> (eg>50% cover)	Recent & old activity <&/or> Activity across the site <> Moderate to high intensity <> Several species Few signs/species <> (eg >15-50% cover)	Old & recent activity <&/or> Activity scattered <> Moderate intensity <> 1 (to 2) species 1 (to 2) signs/species or 1 species several signs <> (eg >5-15% cover)	Very old activity <&/or> Activity isolated <> Moderate to low intensity <> 1 species Few signs <> (eg 0-5% cover)	No activity

D21) FERAL ANIMALS PRESENT - INVERTEBRATES

This attribute is partly covered under bioturbation (esp. invasive ants).

The widespread honey bee is considered in more detail.

European Honeybees

The European honeybee *Apis mellifera* was first introduced to Western Australia in 1846 (Smith, 1963 and Chambers, 1979; cited in Wills et al, 1990). Commercial beekeeping began in the 1880s, and by 1896 there were 2,267 registered hives in the state (Smith, 1963; cited in Wills et al., 1990). Historically apiarists favoured local stands of Jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*) and wandoo (*E. wandoo*) but today the industry is largely migratory and moves according to the changing seasons to maximise the flowering times of *Eucalyptus* species (Wills et al., 1990).

Commercial apiarists are dependent on native plant communities as the major source of pollen and nectar (Wills et al., 1990). Although the honeybee was thought to be one of the least harmful exotic introductions, there is now evidence to suggest that the European bee impacts on the integrity of native vegetation, particularly when resources are scarce. The formation of *feral* bee colonies, and the ever-diminishing areas of native vegetation available to apiarists as a result of land clearing, has resulted in consternation over the potential impact of the European bee on native plant and animal species (Wills et al., 1990).

Threats posed by the European bee

Honeybees compete with native fauna for food and shelter, and reduce the pollination success of particular native plants (Hussey and Wallace, 1993). In large numbers they compromise the food availability of other nectar-seeking insects such as native bees or jewel beetles, and birds such as honeyeaters (Hussey and Wallace, 1993). Competition between native and honeybees was demonstrated by Wills et al (1990) who found a 70% overlap in the resources used by honeybees and native bees over a seven month survey period in the Northern Sandplain 300kms north of Perth. Competition is particularly significant after fire or when resources are scarce. Feral honeybees will use tree hollows, overhangs and crevices in rockpiles to construct hives, to the exclusion of other native fauna (Hussey and Wallace, 1993).

Native fauna have evolved to be successful pollinators of Western Australian plants. Honeybees interfere with the pollination of particular native plants, thereby reducing seed set in these species, because of:

- Competitive displacement of native pollinators
- Reduction of pollen loads available for native pollinators, or
- Ineffective pollination of native plants by honeybees

(Keighery 1985; Paton 1986; and Hopper 1987, cited in Wills et al., 1990)

Studies conducted in eastern Australia by Pyke and Balzer (1985) (cited in Wills et al., 1990) found significant declines in the numbers of native bees near experimental honey bee hives, suggesting the former had been displaced either directly or indirectly through inter-species competition. Pollination competition may result in a lowered abundance of reseeding species, causing a loss in genetic diversity, and even extinction in small populations of founding species (McClanahan 1986, cited in Wills et al., 1990). To compound this, pollinators preferentially forage on clumps of plants with the largest floral displays. If plants that usually grow in clumps become scattered or rare, it is likely they will receive fewer pollinators and seed set may be further reduced (Wills et al., 1990).

Although honey bees will travel up to 7km for nectar, their normal foraging radius is approximately 2km (Hussey and Wallace, 1993). They are limited by the need for a year-round supply of surface water to maintain a constant level of humidity in hives (Hussey and Wallace, 1993). Consequently, remnant vegetation that is more than 2km from a constant supply of surface water is likely to remain free of honeybees.

Environmental Impacts	Signs of Presence
1. compete with native fauna for food and shelter 2. displace natural pollinators 3. reduce pollen loads for natural pollinators 4. reduce the pollination success of some native plants due to ineffective pollination	1. sightings of individuals, swarms or nests are likely to be clearly evident.

Table x. Environmental impacts of European honeybees, and signs of their presence.

The attribute scale needs to be formed for this sub-attribute.

D22) TOTAL GRAZING

Grazing by all forms of animals is a longstanding and integral part of once extensive systems; as a factor it has always been a dynamic part of the interactions between the fauna and flora and other key factors, including very long-standing and recent forms of human intervention (mainly fire: Burrows et al 2000; Burbidge & Johnson 1983; Bird et al 2005; Christensen 1980). There are certain levels of predation that individuals, populations and communities of plants can endure before there are evident changes (Suijendorp 1967; Wilson et al 1976; Mitchell & Wilcox 1988; Pettit et al 1988). In general the grazing that can be sustained is self-limiting, being restricted by the rate, quality and amount of nutritious plant matter that appears; this is often conceptualized as a “carrying capacity” on pastoral lands. There is a spectrum of plant resource available to grazers. Some species are highly nutritious, palatable, and digestible, and others have none of these features and are highly resistant to grazing (even by goats); a few species are also highly toxic. For many species it is the young growth or regrowth that is most nutritious and which is selectively grazed; all things being equal this tends to spread grazing over the resource base. In semi-arid and arid areas species which are typically highly nutritious, palatable, and digestible, often may only be found in an ungrazed state where they are barricaded by thickets and debris (examples include ruby saltbush, *Rhagodia eremaea*, and *Austrostipa elegantissima*). Species that occur on better alluvial and colluvial soils, and are hence exposed, tend to respond to rising grazing pressure and/or disturbance by declining; *Chrysopogon fallax* is an example. (Collectively such species may be referred to as “decreaser” species; Mitchell & Wilcox 1988). Those that increase include Hakea and Senna species (“increaser” species). The response to grazing in semi-arid and arid area’s is partly determined by the bioregion, but mainly by the fact they are still extensive systems, with the prospect of heavily grazed areas being replenished not just by weeds but by native species from the surrounds (be they increasers or decreasers). In fragmented areas it is different with the likely replacement species for denuded areas being exotic species from the surrounds. This applies to much of the southwest rural and metropolitan areas (eg Pettit et al 1998); many of these invaders are annuals that persist in the soil as seed and avoid the extreme grazing pressure that occurs over summer.

It is when grazing becomes concentrated and/or sustained that individual plants, populations, and communities decline. This stocking rate can be raised above the carrying capacity by various means. Anything that increases the number of grazers per unit area will achieve this. The combined impact of stock, feral animals, and native grazers, can be raised by various means. For stock provision of fencing and water points tend to focus grazing. For feral and native grazers fencing, waterpoints, and accessibility of pasture or agricultural land adjacent to vegetation can all tend to focus and concentrate grazing activity. The simple lack of checks and balances on feral animals in many areas (eg lack of predators) can mean that the impacts increase with each year, see feral camels for example.

Intense and/or sustained grazing tends to progressively remove plant species; largely due to characteristics of the plants. Initially the most desirable plant parts and plant species may be preferred, but ultimately, as competition for resources increases most plants and most species will be targeted (Wilson et al 1976; Pettit & Froend 2000). In arid and semi-arid areas it is the species that make poor fodder that are last to decline. In jarrah forest the perennial plants that survive longest tend to be those that can re-sprout and emerge from seed. Those that rely only on seed are subject to the decline of the seedbank if grazing is sustained and adults are consumed. Those that rely on re-sprouting may not get sufficient opportunity to build up the reserves that let them re-sprout under grazing, as this takes more than one season. Trees too are affected, for although adults may survive, sustained grazing removes seedlings and saplings.

◇ There will be an optimum time to assess this attribute (although practicalities will mean that other factors such as timing floristic assessment, logistics are likely to dictate timing. The greatest impacts are likely to be evident when the grazers have gone through periods of duress. In the winter-wet south-west it will be in autumn after the summer drought period when stress on grazers and their targets will have peaked. In the Kimberley it will be at the end of winter and before the wet season. In the semi-arid and arid areas it will be several months after any significant rainfall, and preferably within a hotter period.

◇ Walk over the site taking some time to locate and note any plants that have been grazed. Such signs will include: leaves nipped through (sedges, rushes & grasses), leaves eaten off, stems nipped through, leaves and stems removed, most of the leaves and stems are stripped leaving only thick trunks (Croft et al 2005). In advanced cases where there has been extreme pressure from drought on grazers, and/or extended impact of stock and/or feral animals there may be a noticeable browse line on taller foliage, physical damage to due to scrambling into plants (goats commonly do this), or even ringbarking (Hussey & Wallace 1993).

Relative degrees of grazing (adapted from Croft et al (2005)) are:
Light intensity grazing. There is some loss of foliage, or broken branches, but the plant retains its basic growth form.
Moderate intensity grazing. There is obvious loss of foliage. In grass, sedge and rush species there is even, short, grazing and seed heads are absent. In shrubs much mature foliage and young growth has been stripped, and twigs and branchlets may be trimmed (in response to such damage the plants may sprout from shoots on the woody stems; that is epicormic sprouts are present).
/or/ shrubs or trees are stunted in height or distorted in shape due to grazing.
/or/ there is a browse line on mature trees and shrubs.
High intensity grazing. The plant is chronically cut back and basically denuded. Shrubs and trees are trimmed back to the main branches and regrowth is on mature branches and is often epicormic.
/or/ the plant has been severely structurally damaged and branches or stems are broken or crushed.

◇ To assist the assessment list the species that were found grazed. It may help to list the percent of each species that was grazed and or the proportion based on a rough tally; along the lines of:

	Percent or Tally				
Grazing	High intensity	High/mod intensity	Moderate intensity	Mod/low intensity	Low intensity
Species 1					
Species 2					
Species 3 …					
Total					
(When totalled ~to.)	(~Very Degraded)	(~Degraded)	(~Good)	(~Very Good)	(~Excellent)

Any species with a very high intensity of grazing, that is with most of its individuals heavily grazed, is likely to have regeneration complications and may decline. The overall ability of an area to sustain or recover from grazing will depend on the extent, intensity and duration of the grazing (see resources required to promote regeneration).

Indicators of stock or feral grazing may include: tracks with a broken surface and evident travel from a point of origin, whereas native animals tend not to break the surface to the same degree; prints; and scats (see feral animals).

Note that a high incidence of ticks at a site is a strong indication of native mammal grazing (especially macropods).

Note that Pristine means grazing is at appropriate levels, and that even spread permits vegetative and seedling regeneration, in the absence of imposed disturbance.

Total Grazing	Grazing heavy.	Grazing moderate to heavy.	Grazing moderate.	Grazing low to moderate.	Grazing at appropriate levels.
Note overgrazing from all sources (stock, feral & native)	<> Most species grazed. (Mainly unpalatable species grazed)	<> Many species grazed.	<> Several species grazed. (Some unpalatable species grazed)	<> Several species grazed.	<> Select species grazed (Mainly palatable species grazed)
	<> Individual plants heavily pruned.		<> Individual plants moderately pruned		<> Individual plants lightly pruned
	<> Regeneration from seed little or none.	Regeneration from seed little or none.	<> Generally seedlings affected.	Some seedlings affected.	<> Few seedlings affected.
	<> Most of area damaged (eg >50%); intense.	<> Much of area damaged (eg >15-50%); intense.	<> Little of area damaged (eg >5-15%).	<> Minor area of damage (eg 5-0%).	<> Grazing spread evenly / less evident.
(If stock or feral animals are present italics may apply).	<> *Soil surface highly disturbed.*	<> *Soil surface moderately disturbed.*	<> *Soil surface slightly disturbed.*	<> (*Soil surface little disturbed*)	<> (*Soil surface intact*)

D23) GRAZING BY STOCK &/OR FERAL ANIMALS

In practice it is likely to prove difficult to separate the grazing impacts of native and other animals. Some indication of the impacts of stock &/or feral animals is provided by that attribute.

M6) NATIVE FAUNA PRESENT - VERTEBRATES (SPECIFIC INDICATORS)

A general attribute for all native vertebrate fauna may not provide much information. It is more likely that a carefully targeted selection of set groups of faunal indicators, supported by guides and/or training in identification, will provide meaningful condition indicators.

M7) INDICATORS (EMUS & OTHER VECTORS)

The selection of attributes based on faunal indicators is potentially of fundamental importance to native vegetation persistence due to the role of animals as vectors and regulators of processes, which in their absence become disrupted or disturbed. The roles of vectors include the spread of spores, pollen, seeds, and fruit.

In terms of vectors there is potential merit in creating at least a basic list of the main dispersal agents that can still range over wide areas including those areas that have been fragmented. Essentially such fauna serve to reduce genetic isolation of plants. Powerful examples may include cockatoos and parrots, and in forest, extensive areas and the margins of agricultural areas, emus. In terms of pollination there is clearly a need to integrate and extend information on forage ranges of birds and insects (for instance it is likely that the wasps that pollinate orchids require a mix of resources in the vicinity). Similarly insects which help disperse fungal spores which are essential to maintenance of the soil community may or may not be able to keep small and/or isolated areas linked genetically to other remnants (for example pyrophilic beetles which seek out fire and fungi can travel many kilometres (D. Klocke and H. Schmitz pers. com.)). In those areas where there have been reintroductions of medium body weight mammals like the woylie actively spread many fungi and maintain soil health (Richards et al 2007).

Similarly many species have regulatory effects as they go about their business. Such as cockatoos, parrots, and kurrawongs, eating insects that attack dominant plant species; the insects include borers or gall-forming larvae. In those areas where there have been reintroductions of medium body weight mammals it may help to extend the attribute to this service as animals like the bilby actively seek out larvae from roots and help maintain soil health (whereas feral rabbits are restricted to causing root damage; Hussey and Wallace 1993).

This will not be entirely without qualification. For example cockatoos can also spread pine cones into native vegetation in the same way that they spread native seeds, with consequent introduction of the exotic species. Similarly small passerines spread bridal creeper berries, and budgerigars spread buffel grass seed.

M8) NATIVE FAUNA LIKELY HABITAT - VERTEBRATES

Without specialist knowledge this attribute has the potential to be highly speculative. It is probably not suited to general use.

M9) NATIVE FAUNA PRESENT - INVERTEBRATES

A general attribute for all native invertebrate fauna may not provide much information. It is more likely that a carefully targeted selection of set groups of faunal indicators, supported by guides and/or training in identification, will provide meaningful condition indicators.

This attribute may be best confined to vectors (see indicators emus & other vectors, and in part, indicators- orchids). Other aspects are addressed under bioturbation.

M10) NATIVE FAUNA LIKELY HABITAT - INVERTEBRATES

Without specialist knowledge this attribute has the potential to be highly speculative. It is probably not suited to general use.

M11) INDICATORS - ANTS AS VECTORS

This attribute is partly covered under bioturbation. It has potential to be developed and supplied with general resource material.

M12) INDICATORS - ORCHIDS

The long-term persistence of orchids is dependent on close associations with specific insects and fungi, consequently they are potentially powerful indicators of the persistence of a suite of conditions that favour the orchids, their pollinators and their fungal symbionts (Brown et al 2008). In other words there is still relative ecological diversity and integrity at the locality. The presence of orchids is likely to indicate that fungal symbionts are resident. To be certain that the pollinators are still present it will be necessary to either observe them in action or to establish that the orchid populations are stable and there is recruitment; otherwise there is risk that some species are regenerating from tubers in the absence of sexual reproduction.

M13/M14) **FIRE**

F.1) INTRODUCTION

F.2) RECONNAISSANCE AND FIRE

F.3) INTERPRETING TIME SINCE FIRE

F.4) SELECTING THE APPROPRIATE BASIC FIRE SCALE

F.4.1) NAVIGATING THE MIDDLE GROUND

F.4.2) DEFAULT OPTION FOR SCALE SELECTION

F.5) WORKING WITH THE SELECTED CONDITION SCALE

F.6) KEY ASPECTS OF FIRE

F.6.1) INTENSITY OF FIRE

F.6.2) TIMING OF FIRE – TIME OF DAY AND SEASON

F.6.3) FREQUENCY OF FIRE

F.6.3.1) THE MINIMUM INTERVAL BETWEEN FIRES

F.6.3.2) THE MAXIMUM INTERVAL BETWEEN FIRES

F.6.4) SCALE OF FIRE

F.6.5) PATTERN OF FIRE

F.6.6) PLANT RESPONSE TO FIRE

F7) FIRE-RELATED TERMINOLOGY

F.1) INTRODUCTION

Fire is a factor that illustrates the dynamic nature of ecology. It is not static in time or space and consequently there is a never-ending veneer of fire traces of different ages in standing vegetation across most of the continent. Aspects of how the vegetation responds to fire then relate its relative impacts in time and space.

Fire is an inescapable factor in the ecology of most of the vegetation of Australia. This is because of the unrelenting and pervasive influence of seasonal dry periods and intermittent drought. Fire: i) has arisen in vegetation due to lightning strikes over eons; ii) occurred over several thousand years due to indigenous people's fire-stick practices; iii) is consequently practiced for conservation management that attempts to emulate conditions within the embedded tolerances of the biota; iv) also occurs in order to reduce hazard; v) but also arises due to mishap or misdeed.

Although fire occurs in most vegetation types on the continent, there are exceptions; particularly relatively damp or bare areas, where fire rarely if ever intrudes. Examples include: i) areas of persistent high moisture or rainfall (eg montane dew forests); ii) 'permanent' wetlands; iii) bluebush, saltbush and samphire areas; and iv) cliffs, rock outcrops, gibber plains, and mobile dunes. For the vast majority of remaining vegetation types it is a question of the periodicity of fire. In some vegetation types the interval between fires is typically very long (several decades or more) because very little flammable material builds up within them. For example some smooth barked eucalypt woodlands of the wheatbelt or of the western woodlands, where fire may be unlikely to occur at intervals less than 40 or 100 years respectively. By contrast, in several predominant, and broad, vegetation types there is a similar pattern of fuel accumulation whereby the amount built up can, and is more likely to, carry fire within an interval of about 4-20 years (Walpole-Nornalup National Park Association (1995)). Other vegetation *can* burn on intervals of three years or less (eg Suijendorp 1967; Radford & White 2008).

In fire prone vegetation the short and long-term effects of fire on the biota are governed by the prevailing frequency, interval, intensity, timing/season, scale and pattern of burning.

Once understood, these components can be used to inform the range of tolerance of the biota and the likely appropriate "fire regimes" that have arisen or may arise. Note that while the "fire regime" at a locality may have certain fundamental ecological constraints (such as incident radiation, rainfall, soil type and nutrient levels), it is by no means as uniform as the term may suggest.

In order to assess the condition of the vegetation it is essential to begin to get an appreciation of the interplay of these components in the vegetation type/s in question. This is in order to recognise the signature effects of fire and so:

i) separate the effects of fire from other factors;
ii) recognise the present state of the vegetation;
iii) recognise which effects have more bearing on condition; and

iv) potentially build a sense of whether the balance is in favour of the conservation of biodiversity or other purposes.

Abridged account of the attribute

At its simplest the purpose of this section is to be able to fill out the single attribute related to fire in the main table so that it can be factored in with all the other aspects of condition.

	Very degraded	Degraded	Good	Very good	Excellent
FIRE ATTRIBUTE	Homogeneity				Heterogeneity

To do this several steps are required involving choosing one of two support sheets (shown immediately below), this is then given the most common score according to the main condition scale (from Very degraded to Excellent) and transferred to the main score sheet for all attributes.

Please take the time to appreciate what is implied by the use of the term frequency (see Conceptual outline of the attribute below) and that fire is a multi-faceted attribute for which this serves as the conceptual entry point or reference point. It is important that the assessor develops a sense of the interplay of all the facets of fire and this is just one way to begin engagement with this topic.

Please also appreciate that the single ecological theme that emerges consistently through the general fire attribute and many of the other attributes is that of heterogeneity and its role in the development of the biota and biodiversity. The approach here attempts to emphasise and honour this.

The two choices of recording sheet for fire, either frequency rising or declining, are shown below.

FIRE FREQUENCY RISING & INTERVAL CONTRACTING		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
Fire scars on woody dominants									
Small-scale uniformity and openness of vegetation.									
Presence of epicormic or basal sprouts on trees/woody plants									
Biomass stored in vegetation. Plant litter.									
Presence of perennial seeder species. Presence of senescence.									
Presence of fire-ephemeral and ephemeral species.									
TOTAL									

FIRE FREQUENCY DECLINING & INTERVAL EXPANDING		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
Fire scars on woody dominants									
Small-scale uniformity and openness of vegetation.									
Presence of epicormic or basal sprouts on trees/woody plants									
Biomass stored in vegetation. Plant litter.									
Presence of perennial seeder species. Presence of senescence.									
Presence of fire-ephemeral and ephemeral species.									
TOTAL									

Orientating and assessing the individual parts are outlined in the sections below.

Conceptual outline of the attribute

The attribute that covers the broad factor of fire is in the early stages of development. It is a singular omission from other condition schemes.

The content provided is intended to serve a number of purposes:

- To make preliminary provision for this pervasive factor and its influence on condition;
- To assist with the recognition and separation of features that reflect vegetation type (or identity) from vegetation state due to fire;
- To provide introductory background on fire as a factor;
- To ensure that the opportunity provided by a site visit is used to get a *basic* idea of the current influence of fire in the vegetation type/s in question, especially in the absence of fire records;
- To instill a sense of pattern and process due to fire, and encourage complementary observations and comments to be made.

◇ The main aspects of fire as a factor are outlined in the following text, and it is important to become familiar with these.

◇ It is also essential that the assessor has a clear concept of small-scale vegetation types and how to delineate them in order that site characteristics due to type can be separated from the overlay of each discernable fire-trace and its pattern and extent. See orientation above. As stated, only when the assessor can reliably and repeatedly delineate similar vegetation types should they attempt to assess this attribute.

◇ The first major cue to a fire trace[1] is that it tends to cut across vegetation types. Notice that in some instances fresh fire traces in the vicinity may well not have consumed whole vegetation types, leaving some parts of the vegetation unburnt and others bare, at this stage the boundary of the burn will be clear.

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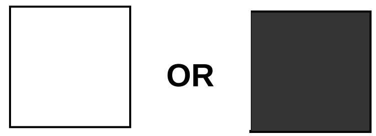
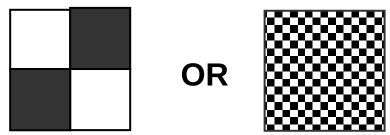
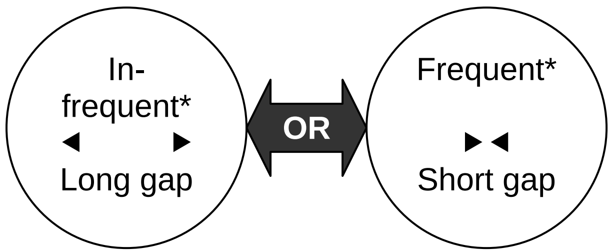
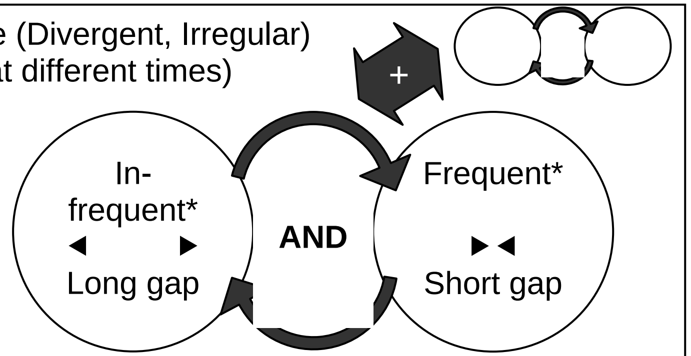
[1] Trace is used here to describe the general ‘footprint’ left in the wake of fire and which is most obvious immediately after its occurrence. It is use in preference to ‘fire scar’ for two reasons. One is to avoid confusion with specific scars on objects and plants. The other is to sidestep the implication that the word scar has of damage that may be beyond repair or that is unsightly, when in nature time and regeneration tend to mean that this is generally not the case. The media will often take this to an extreme and claim that vegetation has been destroyed, when in fact most intact Australian vegetation is highly resilient after fire.

TABLE : Simplified representation of alternate regimes of fire in space and time. ('Space' can be viewed as the structural arrangement of biomass, especially of understorey in a given area. 'Time' refers to the actual occurrence of fire in a given area. The table is not meant to imply a simple direct relationship between a spatially patchy pattern of fires and variability of occurrence of fire; although some agreement is likely. *With time it will be increasingly difficult to discern cues to the historical occurrence of fire due to factors such as one or more waves of regeneration, and weathering of charcoal, scars and debris.)

	HOMOGENEITY	HETEROGENEITY
SPACE (Key: more recently burnt □ longer unburnt ■	Uniform (Pervasive> Extensive) 	Patchy (Mixed, Irregular) 
TIME OVERVIEW	Uniform (Convergent, Regular) (Burnt at the same time) 	Variable (Divergent, Irregular) (Burnt at different times) 

TIME COMPONENTS	*COMMON REGIMEN*			*REGIMEN 1 + REGIMEN 2 + …etc*		
	TIME SINCE LAST FIRE	LAST INTERVAL	PREVIOUS INTERVALS*	TIME SINCE LAST FIRE	LAST INTERVAL	PREVIOUS INTERVALS*
	LONG OR SHORT ◄ ► ►◄	MEAN INTERVAL* LONG OR SHORT ◄ ► ►◄		LONG OR SHORT ◄ ► ►◄	MEAN INTERVAL* LONG OR SHORT ◄ ► ►◄	

◇ Essentially the attribute has dual elements (refer to the table above):

1. To the left (relative) uniformity is implied in terms of a pervasive structural state (of wide extent) and convergent fire intervals for most of the vegetation;
2. To the right it implies (relative) patchiness and divergent fire intervals (&/or timing) for parts of the vegetation.

The attribute, with its left to right arrangement of uniformity to non-uniformity, encompasses:

a) pattern (degree of patchiness)

An obvious cue within a vegetation type (at a site or locality scale) will be whether the understorey is relatively uniform or whether it is more irregular or patchy (in terms of plant cover, biomass and litter and *stage of regrowth or development after fire*).

Do not confuse this with heterogeneity due to vegetation type. During reconnaissance it should have become apparent that there are characteristic degrees of heterogeneity or patchiness due to type which are connected with the way plants are dispersed through the vegetation. This reflects a range of factors such as soil type & depth, micro-topography, microclimate, competition between species, and patterns of dispersal.

Patchiness is likely to be expressed at a number of scales (for example patch size may vary from small clumps of undergrowth that may remain unburnt to much larger areas).

b) an overall sense of recent fire occurrence at the site comprising the time since fire (and then possibly the deeper frequency).

Consider:
i) primarily, the relative time since the last fire (relative to the extremes - either recently burnt or long unburnt);
ii) secondarily, any evidence of whether the preceding interval/s were relatively short or long (ie whether mean frequency of fire at the site over a period was relatively high or relatively low).

This latter cue is intertwined with pattern. Extreme structural uniformity may be partly enforced by frequent fire or infrequent fire (in the latter case a greater likelihood of an intense and/or extensive fire may tend to reinforce this effect).

> The key matters underlying this conceptual arrangement are:
>
> A) Essentially fire frequency is the number of fires experienced by a particular vegetation community within a given time period (Morrison et al 1995). This concept can be resolved into a number of interacting variables, including:

i) time since the most recent fire;
ii) the length of the (preceding) inter-fire intervals; and
iii) the variability of the length of the (preceding) inter-fire intervals.

Fire frequency may account for about 60% of the variation in species composition of fire-prone shrubland communities (Morrison et al 1995). Recent (<30 years) fire frequency produces effects on composition that can be attributed both to the time since the most recent fire and to the length of the intervals between fires. These effects are equal in magnitude but are different in nature. Increasing time-since-fire is associated with a decline in fire-tolerant species. The abundance of herbs and small shrubs decreases, while that of larger shrubs increases. Shortening inter-fire intervals are associated with a decrease in the fire-sensitive species, particularly Proteaceous shrubs that often dominate dry sclerophyll shrublands (eg Morrison et al 1995; Burrows and Friend 1998). Consequently neither end of the spectrum suits all constituents of the community. Thus, increasing variability of the length of the inter-fire intervals is associated with an increase in the species richness of both fire-sensitive and fire-tolerant species, implying that such variation of the intervals through time helps sustain a wide variety of plant species in a community. Conversely it appears that a prolonged period without fire gradually erodes the floristic variation associated with different inter-fire intervals.

B) The species richness of fungi also responds positively to increasing variability of the length of the inter-fire interval in karri forest (Robinson 2009; see figure).

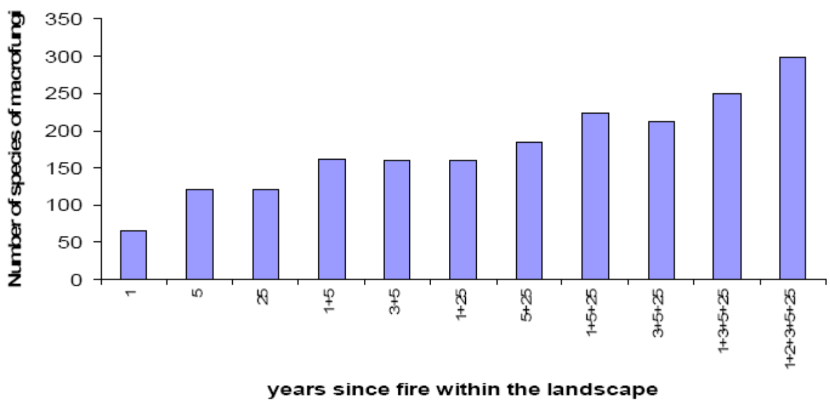


Figure 1. The potential number of macrofungal species that may colonise karri forest following either a single fire event across the landscape or multiple fire events within different patches of the landscape

This work shows that to ensure fruiting and sexual reproduction in a range of fungi fire is essential. Without it they either do not fruit or fruit very rarely which also food resources for vertebrates and reduces opportunities for a whole range of invertebrates that are dependent on the fungi of burnt patches for their reproduction.

C) The balance between seeder and sprouter species over the long-term also appears to be reinforced by fire in more than one dry sclerophyll bioregion (Wisheu et al 2000). Within south-western Australia a number of fire response categories have been recognised (Bell et al 1984). Four of these predominate in much of the vegetation (Pate et al 1990), namely obligate seeders killed by even the mildest fires and regenerating thereafter by seed; faculatative seeder-sprouters, surviving mild fires by resprouting but succumbing to intense fires and regenerating well from seed in both circumstances; autoregenerating long-lived sprouters surviving fire by resprouting with low to moderate ability to regenerate from seed and obligate vegetatively reproducing sprouters surviving fires by resprouting and reproducing almost wholly by any of a range of vegetative means. The latter three form the general group 're-sprouters'. Other fire-response categories relate to annuals and short-lived perennials that avoid fire in time by completing their life cycle during inter-fire periods (Pate and Dixon 1982; Bell et al 1984; Pate et al 1985).

D) The complementary way of assuring a range of intervals in proximity at a locality is via spatial heterogeneity (ideally by subdivision at the locality scale as well as at larger scales), and this can be conceptualised and implemented as patch burning (Griffin 1989; Burrows, Burbidge & Fuller 2000; Radford and White 2008).

E) Natural spatial heterogeneity in the vegetation due to its makeup also translates to heterogeneity in fire intensity and this partially supports the co-existence of a range of plant species (albeit more strongly in small scale fires than in wildfires (Atkins and Hobbs 1995)).

F) Ultimately the conjunction of all such elements and the juxtaposition of a range of stages, circumstances, and opportunities, are at the forefront of management of the flora and fauna and the maintenance of biodiversity, if not some ecological processes (for example see Radford and White 2008).

No single fire regime will suit all faunas. In the jarrah forest there are two gross divisions (Burrows et al 1999). Generally, fauna which inhabit less flammable parts of the landscape (riparian zones, broad valley floors) prefer mature, long unburnt vegetation so these habitats should be burnt less frequently but more intensely to ensure regeneration. Some species prefer recently burnt vegetation. An interlocking mosaic of burns at different ages and seasons, including recently burnt and long unburnt, is most likely to enhance biodiversity at the regional level.

◇ Some vegetation may be hard to evaluate. Consequently a default should be used. This may arise because:
i) vegetation is at an intermediate post-fire stage and uncertainty arises (in which case default to good);
ii) there is a paucity of suitable cues (in which case use not-applicable);

iii) the assessor lacks experience and/or confidence (in which case use not-applicable).

◇ *This attribute does not necessarily* reflect a direct relationship between spatial and temporal aspects, although there may be a degree of correspondence.

◇ In practice it is likely that a better assessment of this attribute will result if it is rated at three scales, namely: the 25mx25m quadrat, the 75mx75m array, and the locality immediately adjacent to the array.

◇ *Before proceeding further it is recommended you read the text on key aspects of fire under points F6.1-F6.5 below.*

In the following the main components of any treatment of fire are outlined, though because they interact, not necessarily in isolation. In addition fire has attendant interactions with a range of other factors such as albedo, soil moisture, nutrient cycling, soil formation and erosion.

F.2) RECONNAISSANCE AND FIRE

◇ During reconnaissance pay attention to the state of the target area and vegetation like it in the vicinity.

◇ At this point attempt to locate recently and long-unburnt areas *in the same vegetation type*.

◇ In order to get a feeling for <u>time-since-fire</u>, locate extremes in the vegetation that are, *in the absence of other disturbance*:

- Bare and open – with much exposed soil surface &/or only fine recent litter; *this area is likely to have been recently burnt*.

  It is likely to be about 1 year since fire, and apart from being bare will either feature an ash cover and charred stems, or little volume of woody shrubs, and perhaps early regrowth of perennial grasses, and green shoots or seedlings;

and

- Thick and closed – with little exposed soil surface and good plant cover; *this area is likely to have been long unburnt.*

  It is likely to be some years since fire, and apart from having limited bare ground, there may be patches of well-developped, heavier litter, and even of coarse debris. It is also likely there will be a well-developed understorey (with filled-out crowns and mature leaves) and little or no evidence of charring or fire-scarring on stems.

F.3) INTERPRETING TIME SINCE FIRE

There are basic similarities to the sequence of events that unfold after fire in fire-adapted vegetation. The area will be bare and open following combustion of the flammable component of the vegetation, and remain so until the next rains occur. Fire will have consumed much foliage and fine stem material and there may be evidence of ash and charcoal in this period. If combustion of taller foliage has been incomplete there will be a leaf fall. Then there will be new growth in the form of buds on leaf-blade bases and stems, and seedling emergence. In about 3 to 5 years the vegetation will move from appearing more open to return to a near mature state. After this time there will be a progressive, and noticeable, accumulation of older material within the understorey and as debris and litter, much of it dead. In the absence of fire, some understorey species will reach advanced old age and collapse or even die. If it gets to this point there will be much combustible material and fire, when it occurs, is more likely to be intense.

An outline of the sequence of events that follow fire in banksia woodland, with reference to jarrah forest, is as given in the following table:

	BANKSIA WOODLAND	JARRAH FOREST
YEAR 0	Fire : relatively bare	
	o Litter, and understorey foliage and some stems tend to be consumed. o The effect on the overstorey will depend on the intensity. If it is low much foliage will be retained. If it is high much foliage will be consumed. o Charcoal will be evident on stems (especially understorey) and even on the ground. Charring on overstorey bark. o Dead stems of understorey evident.	
YEAR 1	Regrowth & leaf fall : more open surface than understorey vegetation.	
	o Resprouting of green shoots and leaves from the bases of grasses, sedges and shrubs. o Possible re-sprouting from the bases, stems and limbs of the overstorey. o The presence of seedlings of several species. o It is likely that there will be a thin layer of *fresh* leaf litter as scorched leaves join the usual annual fall. o Charcoal will be evident on stems (especially understorey) and even on the ground. Charring on overstorey bark. o Dead stems of understorey evident.	
YEAR 2	Expansion of the understorey : understorey vegetation beginning to fill out.	
	o Understorey specie's form will be re-emerging and their canopies taking shape. o Dead stems of understorey still evident.	Litter cover 76%; Shrub Height 0.4m; Shrub Cover 18% (McCaw, Neal, & Smith 1996). In medium & high rainfall forest (1K-1.2K mm/year) 90% of all understorey species flowering (Burrows & Friend 1998).
YEAR 3	Expansion of the understorey : understorey vegetation beginning to dominate cover.	
	o Understorey specie's spreading out. More leaves on species that clump, such as sedges. o Freshly germinated seedlings less common. o Charcoal/charring on (dead) understorey stems still present.	Litter fuel building up rapidly (Burrows, Ward, & Robinson 1999). Invertebrate diversity and abundance returning to pre-fire levels (Burrows, Ward, & Robinson 1999). In some places species richness is highest 3-5 years after fire

	o Dead stems of understorey still evident.	and drops slightly as short-lived obligate seed species and herbs decline (Bell & Koch 1980). In other places richness may not change, but some species may become more or less abundant (Christensen & Abbott 1989). In medium & high rainfall forest (1K-1.2K mm/year) 100% of all understorey species flowering (Burrows & Friend 1998). In lower rainfall forest (1K-1.2K mm/year) 100% of all understorey species flowering by year 4 (Burrows & Friend 1998).
YEAR 5		
	o Older litter clearly a greyer colour than recently shed material, especially leaves.	Rate of jarrah litter accumulation decreases (Bell, McCaw & Burrows 1989). After extensive/intensive summer fire it takes 4-6 years for jarrah crowns to recover and for trees to flower (Burrows & Friend 1998). By 5-6 years obligate seeder species along creeks flowering (B&F 1998).
YEAR 9		
		Limited charring still shows on lower tree stems. Litter cover 98%; Shrub Height 1.0m; Shrub Cover 40% (McCaw, Neal, & Smith 1996). Litter fuel about 8t/ha (Burrows, Ward, & Robinson 1999).
MATURE	Understorey mature : one or more strata are obvious in the area	
	o Understorey either woody or with older leaf blades common in clumped grasses and sedges. o Litter a key component and clearly comprised of mixed sources and ages of material. o Remaining charring and scarring from fire mainly confined to patches of bark and exposed wood on overstorey.	At 15 years (fire exclusion) fibrous bark on stems of jarrah & marri increases (and becomes a midstorey fuel factor (McCaw, Neal, & Smith 1996)). At 15 years litter fuel is 10-16t/ha (Burrows, Ward, & Robinson 1999). At 25 years post fire litter accumulation is at equilibrium (Bell, McCaw & Burrows 1989).
LONG UNBURNT	Understorey aging : thick or rank or decaying, little bare ground	
	o Understorey aging and much old and dead material present within the structure. o Litter a key component and clearly comprised of mixed sources, a lot of it old. o Larger debris (>1cm diameter) more evident.	

In order to gain further understanding of time since fire and other fire cues it is advisable to learn more about plants response to fire (see F.6.6 for a basic outline).

◇ Note that:

<u>Time since fire is not itself a condition indicator,</u> but it is one key aspect that helps unlock the concerted components of a "fire regime" that are engendered in the current state of the vegetation.

F.4) SELECTING THE APPROPRIATE BASIC FIRE SCALE

There are two options provided, decide whether fire frequency is increasing or decreasing using the following table. This can also be viewed as the interval between fires contracting or expanding.

Then select the appropriate condition scale to suit the chosen option.

	✪ ►◄ ✪ ►◄ ✪ ►◄ ✪ ►◄ ✪	✪ ◄◄◄◄◄ ◄► ►►►►►✪
FIRE (✪) INTERVAL (►◄)	FREQUENCY INCREASING / INTERVAL CONTRACTING	FREQUENCY DECREASING / INTERVAL EXPANDING
Vegetation, especially understorey is:	Open	Thick, rank
Understorey plants are:	Smaller, greener, &/or immature (perhaps more uniformly so)	Larger, overgrown, woodier, & mature, old or senescent (perhaps more uniformly so)
Relative understorey cover	Possibly low	Possibly high
Fire scars (including blackened stems of understorey):	Obvious, common	Scarce, absent
Sprouting from plant bases &/or limbs:	Obvious, common	Scarce, absent
Seedlings of several species*	(Obvious, common)	(Scarce, absent)
Large debris:	May be absent. (Partly burnt away. Possibly partly charcoal.)	Present & may even be decaying/breaking up. (Little or no charcoal.)
Litter:	Appears young & light in cover.	Appears older (greyer) & heavy in cover. May be incorporating into soil.

(*Under regular fire species which are stimulated by fire and have short life-cycles and rapid seed set, such as 'fire ephemerals', benefit.)

- In both cases it is the move towards the extremes that is contraindicated. Neither a move to the minimum interval nor a move to a state of virtual fire exclusion suit fire-adapted vegetation because they exceed the ability of some resident species to persist. .

F.4.1) NAVIGATING THE MIDDLE GROUND

Although this is presented as two poles on a spectrum there is much middle ground, and in two circumstances it may not be easy to decide which to apply:

A) When vegetation is in an intermediate state; or
B) In the early years following fire in a previously long unburnt area. At this point a long unburnt area that has just been subject to a fire may be hard to tell from an area that has long been repeatedly burnt, and that was also recently burnt.

F.4.2) DEFAULT OPTION FOR SCALE SELECTION

In case of uncertainty as to whether the interval is increasing or decreasing use the frequency increasing scale as a default.

In addition, within that scale the middle (moderate or good) score can be used as the default until a trend becomes obvious.

Note regarding B) immediately above:

In an area that has *recently been burnt*, it may be possible to tell whether its history was of frequent fire or of very infrequent fire.

To do so consider the aspects of the vegetation described in the following table, particularly those highlighted in bold.

<table>
<tr><th>RECENTLY BURNT WITH A HISTORY OF FREQUENT FIRE</th><th>RECENTLY BURNT WITH A HISTORY OF INFREQUENT FIRE</th></tr>
<tr><td>Cues to generally low intensity:
o Tending to a mottled burning pattern of understorey & litter. Likely understorey above-ground parts survive; partial consumption of foliage, few stems consumed.
o Unburnt patches likely present. Including, but not confined to:
    o Limited intrusion into thickets. [Cool & damp burn].
    o Some intrusion into thickets. [Hot & dry burn.]
o Charring of bark on overstorey low (to 1-2m); base of stem/s.
((***scales my be wrong – say high up))
o Fire scarring (breeches of bark) on overstorey low (to 1-2m); base of stem/s.
o Older scars present; eg steadily hollowed-out stems common.
o Limited or no crown effects (in tall woodland or forest).
o Very low intensity - limited or no epicormic sprouting on overstorey. Incidence rises with rising intensity.</td><td>Cues to generally high intensity:
o Tending to a complete burning pattern of understorey & foliage.
Unlikely understorey above-ground parts survive; total consumption of foliage, most stems consumed.
o Few or no unburnt patches. Including, but not confined to:
    o Likely major intrusion into thickets. [Cool & damp burn].
    o Likely complete intrusion into thickets. [Hot & dry burn.]
o Charring of bark on overstorey high (to >2m); full height of stem/s & main limbs.
o Fire scarring (breeches of bark) on overstorey high (to >2m); full height of stem/s & main limbs.
o Older scars uncommon.
o Crown scorching (in tall woodland or forest).
o Much epicormic (stem & branch) sprouting on overstorey. With severe fire - mainly basal (root base) sprouting on overstorey</td></tr>
<tr><td>Immediately after fire – incomplete combustion evidenced by bits of wood and charcoal.
For some time after fire - signs that large logs and stumps burnt incrementally.</td><td>Immediately after fire – complete combustion evidenced by white hot ash.
For some time after fire – signs that large logs and stumps burnt completely away.</td></tr>
<tr><td>((Obligate perennial, woody, slow-maturing, seeder species may decline if fire is very frequent (the interval is very short).))</td><td>((Obligate perennial, woody, slow-maturing, seeder species may be common or prolific after a single large fire.))</td></tr>
<tr><td>Herbaceous or woody, quick maturing, fire-ephemeral species common after fire.</td><td>Herbaceous or woody, quick maturing, fire-ephemeral species response to fire depends on interval. Several decades of fire exclusion may mean they are scarce or absent.
Hard-seeded species - such as Acacias and other pea family species are likely to be more abundant given high temperatures break open the seed coat and hence dormancy.</td></tr>
<tr><td>In the presence of a weed seed source, especially grassy weeds, it is likely weeds are common and have spread through the area (given multiple fires). Road verges near disturbance are a good example.</td><td>In the presence of a weed seed source, it is unlikely weeds have spread through the area (after just one fire).</td></tr>
<tr><td>Potential for sheet-flow of soil during heavy post-fire rain retarded by plant bases and unburnt material if fire was mild and contained.</td><td>Potential for sheet-flow of soil during heavy post-fire rain may be heightened if fire was intense & extensive, as little remains to impede erosion.</td></tr>
<tr><td></td><td>More likelihood of fire trace being of a very large size, or off covering much of a small, isolated, area remnant. When fires eventually occur they are relatively intense, and propagate over much of the area.</td></tr>
</table>

F.5) WORKING WITH THE SELECTED CONDITION SCALE.

((It remains to resolve the issue of fire being cumulative versus a straight linear scale - reconcile this with the patch/uniformity character below.))

FIRE FREQUENCY RISING & INTERVAL CONTRACTING Fires usually of low intensity.	POTENTIALLY 'UNBALANCED' INFLUENCE				'BALANCED' INFLUENCE

How the condition scales are set up for fire.

- The basic polarity behind the scales is as above.
- There are two opposing trends to the scales, only one of which is used for illustration here. Namely "fire frequency rising & interval contracting" & its opposite.
- The scales are arranged with regard to the relative frequency of fire as this is a key facet that has many effects.
- The intervals between fires are treated as either decreasing or increasing. It is not meant to suggest that either state is better or worse. *For this attribute the degraded end of the scale is being used as a means of indicating state & trend more than literal condition as the label "degraded" would imply.*
- This is to address the current interval since fire, and to also look for any indicators as to the pre-existing, and prevailing regime.
- It also makes some allowance for the fact that a spectrum of frequencies and burning regimes is possible. Essentially it represents the early or late stages of maturity and of biomass accumulation in the community.
- Because the two parts attempt to represent halves of a whole spectrum they share the same descriptions within the categories 'very good' or 'excellent'(which attempt to portray the desirable facets of a patchy environment); hence the differences lie in the expressions of frequent or infrequent fire that may alter condition (that is upon the categories from 'good' to 'very degraded').

<u>The fire attributes are explained below, using only the part of the scales that concerns "fire frequency rising & interval contracting" arranged as follows</u>:

	Very degraded	Degraded	Good	Very good	Excellent
FIRE FREQUENCY RISING & INTERVAL CONTRACTING Fires usually of low intensity.	Fire very frequent.	Fire frequent.	Fire becoming frequent.	Fire interval variable.	Fire interval range suits vegetation type/s. (This includes patches within them.)

◇ Fire scars on woody dominants.

	Very degraded	Degraded	Good	Very good	Excellent
Fire scars on woody dominants. (Such as dead branches & hollowed-out stems.)	Most scars recent. Many dominants with scars.	Most scars recent. Several dominants with scars.	Most scars recent. Occasional dominants with scars.	Scars vary in age; old scars still evident. Few scars.	Scars vary in age;

This attribute refers to breaches through the bark, as opposed to recent light fire leaving charring on the bark. Under a high frequency and low intensity fire regime it is likely that: i) a recently burnt bark breach is likely to be relatively small, and limited in extent; and ii) a repeatedly burnt breach is likely to be extensive, much of the stem and branches being affected or consumed. In a 'very degraded' situation the main stem of larger dominants may have been consumed, although it is not possible to tell whether fire was the cause of death.

Jarrah forest trees have become generally more susceptible to fire. In the past undamaged, single-stemmed, trees may have remained uninjured after fires of moderate intensity (<600kWm-1; Bell, McCaw & Burrows 1989). Current factors that pre-dispose trees to damage through the bark (and cambium) include: past wildfires, cutting operations, the fact that many plants now coppice from the base, and the presence of a large number of logs near trees. In dry conditions, even low intensity fires can ignite dry log debris leading to major and recurring damage to the stem.

Such damage, overlaid on timber extraction, can lead to structural change in large areas (Bell, McCaw & Burrows 1989). After a very severe fire, where pole-sized jarrah and marri was killed down to ground level, most trees re-grew as multiple stems from the lignotuber, resulting in a mallee growth form around a central dead spar. Similar consequences have been observed in woodland (Hopkins & Robinson 1981).

◇ Fire-related death of woody plants

	Very degraded	Degraded	Good	Very good	Excellent
Fire-related death of woody plants	Death of many plants from several species.	Death of individuals of one or more species.	Some death may occur.	No deaths.	Mixed: In older patches limited death, in recently burnt patches more.

This attribute refers to the absence of regeneration either by sprouting or germination of some key species in the community. ((This attribute may be more relevant where the interval is increasing and intensity and the risk of death is higher.))

This may be more useful with smooth-barked species? Such as Wandoo, Bullich, Rivergum, Powderbark.

◇ Uniformity and whether the vegetation is more open or closed.

	Very degraded	Degraded	Good	Very good	Excellent
Small-scale uniformity and openness of vegetation (***mainly understorey***).	*Tending uniform.* Uniform - strongly. <> Very open. All lower layers. (Accessible, no thickets). <> Fire & ≥ 1 other disturbance	 Uniform - fairly. <> Open. Most layers. <> Fire & ≥ 1 other disturbance	 Mottled - slightly. <&/OR > Plus 1 patch <> Plus one clump of unburnt, older plants <> Patches Confined <> Open (> denser) 1 or 2 layers. <> Fire & 1 other disturbance	 Mottled - partly. <&/OR > Plus 2 patches <> Plus some clumps of unburnt, older plants. <> Patches spreading <> Open to denser <> Only fire - no other disturbance	*Patches ~ evident.* (*irregular*) Mottled -fully. <&/OR > Plus ≥ 2 patches <> Plus many or big clumps of unburnt, older plants. <> Patches Spread-out <> Denser & open ('long' unburnt & recently burnt). <> Only fire - no other disturbance
Examples of possible balances.		Patch ratio >90:10 (1/10)	Patch ratio 75:25 (1/4)	Patch ratio 60:40 (2/5)	Patch ratio 50:50 (1/2)/or/ ~~33:33:33 /or/ 25:25:25:25~~

This attribute refers to whether patches are present or otherwise.

At the extremes, either frequent fire or the absence of fire can lead to greater uniformity in the vegetation; especially if the fires are extensive. The former will tend to render the vegetation more open, especially the understorey. This is because repeated fire prevents pro-longed build up of biomass and effectively prunes the vegetation. Conversely the latter will tend to make the vegetation more closed (taller &/or denser &/or higher cover) as biomass builds in plants (live & dead parts), litter and debris. In the extreme it may be thick & congested.

On the other hand patches can be thought of as taking place at three different scales. The first is the broadest, and a patch is literally that vegetation within the boundaries of a block of vegetation that was burnt at the same time. The second, conforms to vegetation that tends to burn out of synchrony with that surrounding it, such as thickets along creeks during cool, damp, burns; this often conforms to the vegetation type. The third, is small clumps or pockets of plants within an individual vegetation type that miss the most recent fire due to happenstance (eg fluctuations in wind intensity, or changes in wind direction). The second and third examples can occur within the first.

*To be well described it would ultimately be best to assess patch presence at the level of: i) the quadrat (30m x 30m here); ii) its immediate surrounds in that vegetation type (the 90mx90m array, and perhaps that bordering it); and iii) then the adjacent vegetation.

If mottling of the structure and/or composition, even within a single vegetation type, is lacking or declining it implies that the vegetation is moving more to one state than another. In the case of a contracting fire interval the loss of pockets or patches within or adjacent to the burnt area will affect the persistence of obligate seeder species that take longer than the shortened fire interval to set seed; it may even deplete the reserves of their seed in the soil.

(For example *Lambertia rariflora* is confined to creeklines in the jarrah forest and has a juvenile period of 5-6years. Its habitat protects it from mild spring burns because creekline fuels are too moist at this time of year. A fire may intrude under extreme, hot, dry, conditions, but will not prevent regeneration from seed. Several such fires in short succession (say 5 years) may well exhaust the regenerative capacity of the species at a locality (Burrows & Friend 1998).) The loss of pockets or patches also fails to leave a spectrum of resources for fauna.

At the opposite end of the spectrum the long unburnt areas will tend to be over-mature, rank, with more dead material within the structure, and with little or no evidence of renewed growth and plant resources. In the extreme there may be small pockets where vegetation has deteriorated to the extent that it is now bare.

◇ Presence of epicormic or basal sprouts on trees/woody plants; fire-related

	Very degraded	Degraded	Good	Very good	Excellent
Presence of epicormic or basal sprouts on trees/woody plants; fire-related (not due to other causes eg drought).	Sprouts common.	Sprouts occasional.	Sprouts rare.		In older patches sprouts absent. In recently burnt patches sprouts present.
Understorey regrowth (greener, young & vigorous.)	Much recent regrowth.	Some recent regrowth.	Little recent regrowth.	Foliage generally healthy.	In older patches regrowth absent. In recently burnt patches regrowth present.

This attribute refers to the response of a plant's growing points to fire, and specifically 'resprouting' plants which are not killed outright by fire. These species have dormant growing points that are insulated from fire by bark. Some species sprout from their bases, especially shrubs and mallees. In some cases dominant eucalypt tree species such as jarrah will sprout from their bases if the main stem is killed, and they often tend to coppice after logging. Epicormic sprouting refers to buds that emerge from the bark on the branches and even stems after extensive and intensive fires. Epicormic shoots are often short, fine, and densely crowded.

After fire the regrowth on trees and shrubs will tend to be greener, more supple, and even different in shape, to mature foliage. This is because the nutrients released as ash by fire become available with the advent of subsequent rain.

◇ Biomass stored in vegetation & plant litter.

	Very degraded	Degraded	Good	Very good	Excellent
Biomass stored in vegetation.	Limited biomass.	Low to moderate biomass.	Moderate biomass.	Moderate to high biomass.	In older patches high biomass. In recently burnt patches low biomass.
Plant litter.	Little litter, thin cover. Large logs nearly burnt away. Low humus.		Moderate litter. Moderate debris, including logs. Moderate humus.		In older patches high litter, debris & humus levels. In recently burnt patches low litter, debris & humus levels.

This attribute refers to the material that is likely to combust, which is consumed at the time of fire and is built up again after the last fire. In many situations it is primarily in the understorey, litter and debris. Much of the material that ensures that a fire will take hold and carry is <6mm diameter, and it contrasts with the more resistant and enduring material stored in the stems of key dominants. The amount of biomass that qualifies as fuel and is burnt varies considerably between vegetation types (for example in forest it may be only about 5% of the total standing matter (Bell, McCaw, & Burrows 1989), whereas in spinifex grasslands the combustion is often complete.)

Consequently it is a matter of beginning to appreciate: i) how much of this material has been cleared away by a recent fire; ii) how much has been restored in the interval since fire; iii) and whether the vegetation is aging. Whether it is gathering old material such as dead limbs, old leaves and many leaf falls. Whether termites or fungal decay are breaking down logs. If lichens have become well developed on some surfaces.

◇ Presence of perennial seeder species and presence of senescence.

	Very degraded	Degraded	Good	Very good	Excellent
Presence of perennial seeder species. Presence of senescence.	Many species may no longer be present. (No senescence.)	Few species nearing maturity. (No senescence.)	Many species nearing maturity. (Little sign of senescence.)	Many species are mature & able to reproduce. (Little sign of senescence.)	In older patches most species are mature & able to reproduce. In recently burnt patches fewer species are ready to reproduce. (Likely signs of senescence; in older patches.)

This attribute refers to those woody plant species that only regenerate by seed and which are quite susceptible to repeated fire at intervals less than the time it takes them to mature (eg 3-4 years). In the absence of seed production it is possible for such species to become locally extinct if the adverse conditions persist for longer than it takes for the seed soil reserve to expire.

A secondary associated effect refers to those species that reproduce from underground organs (such as corms, bulbs and tubers). This is because frequent fire at the same time of year, specifically that time of year that leaves and flowers would have developed, not only prevents seed set, but prevents full provision of stores in the parent organ and any new organs that may bud from them.

◇ Presence of fire-ephemeral and ephemeral species.

	Very degraded	Degraded	Good	Very good	Excellent
Presence of fire-ephemeral and ephemeral species. CONUNDRUM – frequent fire suits fire-ephemerals but at expense of other species.	Ephemerals abundant after fire.	Ephemerals becoming common after fire.	Ephemerals occasional after fire. Chance to reproduce increasing.	Ephemerals present after fire. Little patchwork.	Ephemerals present after fire. In older patches ephemerals may be absent or only in the soil seed reserve. In recently burnt patches ephemerals are likely to be present.

Fire ephemeral species are generally short-lived (1-3 (5) years) and exploit the early post-fire conditions with the redistribution of nutrients as ash and reduced competition from perennial species for water and sunlight. They can be a significant part of the vegetation, representing most of the early biomass and the major sink for nutrients immediately after fire.

Some of the key genera that contain species which are obligate or facultative fire ephemerals include: *Codoncarpus, Gyrostemon, Haloragis, Austrostipa* (which are clearly pancontinental); and *Anthocercis, Tersonia, Glichrocaryon, Dysphania, Trachymene,* and *Sida*. The families Haloragaceae and Gyrostemonanceae are strongly represented in this sort of life-strategy.

F.6) KEY ASPECTS OF FIRE

F.6.1) INTENSITY OF FIRE

The intensity of a fire is essentially the product of the fuel load and other influences such as the rate of combustion (Burrows, 1987; Bell, McCaw & Burrows 1989).

The fuel load is that portion of the live and dead vegetation and litter and debris that is in a state, due to its moisture content, particle size and architecture that favours combustion; typically un-compacted understorey and litter material ≤6mm diameter (Burrows & McCaw 1989). In many vegetation types fine fuels in the understorey and litter will be combusted but much biomass will remain after fire in larger material; particularly if it is covered in fire resistant bark or other insulation (eg Macrozamia fibres). Fuel load is closely related to landform and vegetation type (Burrows, McCaw & Maisey 1987).

Other influences are: topography and soils (which affect air-flow, temperature, water movement, and moisture regime); and local weather conditions. Fire is favoured by dry and hot conditions, and is often intensified by wind.

Note that the duration of a fire may play a part in moderating the effects of intensity. When a fire travels up slope or with the wind the intensity will differ from downslope or against the wind with the same fuel. With the former generally more intense as the rate of combustion is greater. Large items such as logs and stumps may heat the soil in their vicinity for longer, and so deeper, than a transient fire (Bell, McCaw & Burrows 1989).

Some features to look out for in order to come to terms with the intensity of the last fire are given in the table.

INTENSE – COMPLETE	MILD - INCOMPLETE
Complete combustion. Little litter, debris, or vegetation left.	Incomplete combustion. Some litter, debris, and small patches of vegetation left.
Logs burnt through.	Logs remain; partially burnt.
White hot ash near logs and stumps.	No white hot ash.
Potentially susceptible understorey killed. Potentially some overstorey killed. (Though even after the most severe fires, with much above-ground death, the dominants can regenerate (McCaw & Burrows 1989).	Little understorey killed. No overstorey killed.
Dry conditions (air, vegetation & soil).	Moist conditions (air, vegetation & soil).
Hot.	Cool.
Windy. (With the wind)	Still. (Or against the wind)
Fast.	Slow.
High up & high degree of scorching (leaves & limbs) & scarring. Usually due to summer fires, and it takes 4-6 years for crowns to recover and trees to flower (Burrows & Friend 1989). Intense fire in 9 year unburnt jarrah caused total crown scorch and bark charring to full stem height and along the main branches (McCaw, Neal & Smith 1996). (Estimated crown scorch of 20m from a high intensity fire in jarrah [summer, early autumn]; Bell, McCaw & Burrows, 1989). (In jarrah severe fire can result in crown death & basal resprouting in 25 - 75% of plants (Peet & Williamson 1968))	Low down & low degree of scorching (leaves & limbs) & scarring. Low intensity, prescribed fires (<350kw/sqm) rarely cause crown damage (Burrows & Friend 1989). Milder fire in 4 year unburnt jarrah caused uniform charring 1-2m above ground level (McCaw, Neal & Smith 1996). (Estimated crown scorch of 8-10m from a low intensity fire in jarrah [cool spring day]; Bell, McCaw & Burrows, 1989).
Large.	Small.
Continuous.	Fragmented / patchwork / residual pockets.
Typically arises with a high fuel load.	Typically arises with a low fuel load.
Ember spotting in front of the fire common.	Ember spotting in front of the fire uncommon.

Intensity has some influence on structure. In the jarrah forest seedling germination and thicket establishment (often by fire-sensitive obligate seeding species) is most successful following moderate intensity fire under dry soil conditions (Shea et al 1979; Christensen 1982; Burrows & Friend 1998).

F.6.2) TIMING OF FIRE – TIME OF DAY AND SEASON

The time of day influences ambient temperature, and to some extent moisture, and it does so throughout the seasons. The coolest times of day are after midnight and around dawn. Often this can correspond to the timing of dew formation in near coastal areas, and also inland under clear sky conditions (Burbidge 1944; Suijendorp 1967).

Fires are less likely to propagate overnight, or to grow in size. Rather there is a better chance they will abate or go out.

Seasonality will depend on the bioregion in question (Gentilli 1972). With hotter and drier weather favouring fire propagation and spread. In the south-west a Mediterranean climate prevails with a wet winter and dry summer. Under these conditions the cooler and moister conditions are (+/- late autumn), winter and early spring, and warm dry conditions are (+/- late spring), summer and early autumn. In large parts of the state under semiarid and arid conditions fire is possible throughout the year in fire-prone vegetation, and only dew, frost or capricious rainfall tend to punctuate this. In the wet-dry and wet tropics seasonality again plays a significant part, with the wet season affecting ambient moisture.

The season of burn can have direct consequences on the biota. For example in the south-west a spring burn or repeated spring burns could impact on the flora as 75% of species flower and set fruit then (Burrows & Friend 1998). The remainder of species flower throughout the year and so some species will be affected at any time of year. The impacts will be greatest on those species that store seed in the canopy and which are consumed by the fire or which rely on the annual sprouting of leaves from underground organs and miss a year’s growth and storage of reserves in their base.

In jarrah forest, in the short term, season of burn had more influence on seedling density than on plant species composition (Burrows & Friend 1998). Fires during the dry soil conditions of summer/autumn resulted in higher levels of seedling germination and survival than fires in spring, probably due to the optimal arrangement of following winter rains that offer the immediate opportunity for establishment. Such dry soil fires favoured tree species and “hard-seeded” understorey species such as legumes. In general fire ephemerals and herbs dominated post-fire germination.

Frequency interacts with timing, and so, just as it is important to vary the interval in order to spread the impacts, it is important to vary the timing in order to give some species a rest from the direct impacts of fire.

F.6.3) FREQUENCY OF FIRE

In order to understand what is meant by the frequency of burning of native vegetation it is important to distinguish between what is possible and what is suitable in terms of conservation and maintenance of biodiversity.

Note that fire frequency and interval are not generally interchangeable and in a sequence of successive fires in the same location it is likely that there will be variation in the interval between fires over time.

It is possible to burn a site repeatedly at the shortest interval it takes for plant re-growth to produce enough fuel for a fire to carry; but it is not necessarily best practice. In general ecosystems will recover from occasional fires at the shortest intervals, but it is likely that sustained burning of the entire landscape (as opposed to patch burning) a the shortest intervals will lead to decline in fire-sensitive taxa and increases in disturbance opportunist such as herbs and grasses (Burrows & Friend 1998).

For instance fuel accumulates rapidly in banksia woodland on the Swan Coastal Plain and it is possible to burn it on a 3-4 year interval (Burrows & McCaw 1989). This is desirable in order to establish buffers between longer unburnt areas with higher fuel loads. However, it is not without potential consequences.

First, the potential for the fire to escape from the buffer area into core longer unburnt areas is greater because of the frequent ignition and the proximity of higher fuel loads in the core area intended for interim protection.

Second, if buffer areas are on the outer periphery of blocks of vegetation, and invasive weeds, especially perennial grasses, and/or disturbance are present, weeds are likely to build in numbers (Gosper, Yates, & Prober 2009; Burrows & Friend 1998).

Third, consistent short intervals are likely to be outside the range of tolerance of some species in the community, especially those that are fire sensitive (Burrows & Friend 1998).

Other examples of short intervals in jarrah forest are less than 6 and less than 8 years in upland forest (high & low rainfall respectively) and less than 12 and less than 16 years in riparian forest (high & low rainfall respectively) (see table ### below; Burrows, Ward, Robinson 1999).

Consequently a suitable fire sequence needs to span many things and to fall within a range set by the tolerances of the biota and previous fire history and long-term climate.

F.6.3.1) THE MINIMUM INTERVAL BETWEEN FIRES

The minimum interval between fires is estimated for two main reasons:

1) for wildfire control.

This is estimated from:

- fuel accumulation.

  Each vegetation type at a locality will have outer limits to the rate of build up and ultimate amount of plant biomass. Such limits are determined by the type of soil, the nutrient cycle, annual rainfall, and latitude which influences day length and seasonality, and hence the temperature and the total hours of sunlight available for photosynthesis.

  The patterns of biomass accumulation are rather like a signature and within vegetation types of similar age in the same bioregion are broadly equivalent (Sneeuwjagt & Peet 1998).

  The amount of biomass that qualifies as fuel and is burnt varies considerably between vegetation types (for example in forest it may be only about 5% of the total standing matter (Bell, McCaw, & Burrows 1989), whereas in spinifex grasslands the combustion is often complete.)

- fire behaviour models and a wildfire threat analysis (see Sneeuwjagt & Peet 1998; McCaw, Neal & Smith 1996).

The consequences of this are:

- Burning rotations in managed forests have been 5-7 years in more productive areas and 8-10 years in the less productive lower rainfall eastern zone where biomass accumulates more slowly (McCaw & Burrows 1989). Broadscale prescribed burning has occurred in the northern jarrah forest since the mid 1960's and on this basis much of it has been burnt between 4 to 8 times, although there is considerable variation around these intervals.
  Burning rotations are at a minimum around habitation. For example, at Dwellingup forest in the township is burnt annually, and that within 3-5km radius on 3 & 4 year rotations (McCaw & Burrows 1989). Similarly the likelihood is high in the metro area that fire frequency in remnants is rising due to controlled burning to protect people and property or due to arson.
-
- Conversely rotational burning has been excluded for select reasons, such as mine rehabilitation, disease management and research (McCaw & Burrows 1989).
- The net result, based on a 5-6 year rotation, was that at least half the northern forest carried fuels less than 3 years old, which greatly enhances the prospects of fire suppression operations (McCaw & Burrows 1989). In general fuels 4 to 8 years old are widespread throughout the whole forest (McCaw, Neal & Smith 1996).

2) to sustain biodiversity:

- Is dependent on the limits of biomass/fuel accumulation as described above (for wildfire control); *and*
- Estimated from:
  - the juvenile period of the slowest maturing vascular plants (especially obligateseeders) plus a margin that allows them to build up seed reserves in the soil.

Evidence suggests that twice the longest juvenile period of the plant species (or 2xLJP) is required for seed bank replenishment (Gill and Nicholls 1989; Kelly and Coates 1995 – Banksias). This means that a very short interval between fires (or high fire frequency) is less than 2xLJP (which automatically includes an interval equal to the LJP; see table ###).

This arrangement is represented as multiples of the Fire Frequency Ratio (FFR) = *the actual* Fire Interval (FI)/ Longest Juvenile Period (LJP) [Burrows & Friend 1998]). When FFR is 2 it represents the basic sustainable interval, and anything below it is unlikely to be sustainable, including an interval equal to the longest juvenile period (FFR=1).

Table ###: The relationship of the sustainable inter-fire interval to the longest juvenile period of the plant community, and where a moderate fire frequency sits amongst other scenarios (Burrows, Ward, Robinson 1999).

Jarrah Forest Type	Rainfall	**Longest juvenile period** [LJP] (yrs) *[FFR=1]*	High fire frequency FFR<2 (yrs)	**Sustainable fire interval** [2xLJP] (yrs) *[FFR=2]*	**Moderate fire frequency** FFR=2-4 (yrs)	Low fire frequency FFR=4-6 (yrs	Very low fire frequency FFR>6 (yrs)
Upland forest	High (>900mm)	3	<6	6	6-12	12-18	>18
Upland forest	Low (<900mm)	4	<8	8	8-16	16-24	>24
Riparian	High (>900mm)	6	<12	12	12-24	24-36	>36
Riparian	Low (<900mm)	8	<16	16	16-32	32-48	>48

Provided most rotation occurs at or above the sustainable fire interval the seed store will be sufficient to ensure adequate regeneration should an occasional fire occur at a shorter interval (Burrows and Friend 1998).

Examples include:

In upland jarrah forest with: i) high rainfall (>900mm annual rainfall) 100% of species were flowering by 3 years, so twice the longest juvenile period returns a minimum of 6 years; and ii) lower rainfall (~750mm) 100% of species were flowering by 4 years, so twice the longest juvenile period returns a minimum of 8 years (Burrows & Friend 1998). Most understorey species in these locations regenerate by re-sprouting (70-75%) (Christensen & Kimber 1975; Bell & Koch 1980; Burrows & Friend 1998).

- the post-fire response patterns of fire sensitive taxa of fauna and flora.

In jarrah forest along creek systems, rock outcrops or moist broad valley floors some obligate seeder species (such as Lambertia rariflora, Melaleuca viminea, & Banksia seminuda) take 6-8 years to flower after fire; hence twice the LJP is 12-16 years. When fire occurs L. rariflora relies on soil-stored seed while the other species rely on canopy-stored seed to regenerate after fire (Burrows, Ward & Robinson 1999). Typically such areas have a high proportion of obligate seeder species (40-60%) especially broad valley floors with thicket forming species (Christensen & Kimber 1975; Christensen & Maisey 1987; Burrows & Friend 1998). The riparian areas have the denser, thicker, understorey within the forest and when it is mature (at least 5-7 years old) it is important habitat for a suite of mammals (Burrows & Friend 1998).

South-coast mallee heath (400mm) it takes 10-15 years for most plants to be at flowering age and the closely connected honey possum numbers to peak (this is a flora & fauna based interval).

In high rainfall Karri forest invertebrates provide a guide as they are susceptible to fire at short intervals and 6 years seems to be a short interval (Burrows & Friend 1998).

The approach based on the LJP may also provide an indication of the longest interval between fires, however, other information on the biota is also important to help inform this.

F.6.3.2) THE MAXIMUM INTERVAL BETWEEN FIRES

Maximum interval between fires is largely estimated in order to sustain biodiversity:

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- Estimated from plant species richness with time since fire,
- seed bank quantity and durability (shelf life)
  - maxima may be derived from extrapolation of the longest juvenile period by six times and may reflect senescence for some species. This tends to be corroborated by fauna observations. Compare an estimate of 36 to 48 year intervals in riparian jarrah forest (high & low rainfall respectively) with the decline in quokka & tammar numbers at about 25 to 30 years (Burrows and Friend 1998; Burrows, Ward and Robinson 1999).
- vegetation/habitat biomass increment and structural changes with time,
  - Biomass increment is outlined above under minimum interval fuel accumulation;
  - In order to regenerate thickets, and the fauna habitat they provide, moderate intensity fire is required (at about 20-30 year intervals) (Christensen 1977, 1982).
- post-fire response patterns and habitat requirements of key fauna. For example (Burrows and Friend 1998; Burrows, Ward and Robinson 1999):
  - In south-coast mallee heath (400mm annual rainfall) it is around 40 years after fire that ash-grey mouse numbers appear to drop. It prefers the abundant herbs, grasses & seed found in the early post-fire period (this is a fauna based interval).

- The decline of quokka and tammar numbers in riparian jarrah forest appears to occur about 25 to 30 years after fire.

F.6.3.3) MELDING MAXIMA AND MINIMA

Once they are melded, a local community's pool of minima and maxima can be used to establish the outer limits of community tolerance to fire at either end of a representative spectrum.

Devising a way to have fire intervals fall within the community's range of tolerance requires a careful blend of known limits and an adaptive cycle of burning.

Consequently development of a patch work of burnt and unburnt vegetation on the local scale is also a fitting *temporal solution to contrasting aspects of the population dynamics* of the fauna. Habitat requirements vary for each jarrah forest mammal species (table***; Burrows, Ward, Robinson 1999); some prefer low, open, vegetation associated with drier upland sites, and *with early post-fire conditions*, and others prefer tall, dense, mature vegetation, associated with riparian zone thickets in broad valley floors, and *with later post-fire conditions* (Burrows, Ward, Robinson 1999). This has the contrasting requirements of more frequent and extensive burning in upland situations (which suits more mobile species) and infrequent, partial, and intense burning of thickets to promote regeneration when they age and become rank (which suits less mobile species; whose numbers decline after 3 decades as the vegetation ages).

Preferred habitat type	Flamability	Animal
Tall, dense vegetation in creeks, swamps and valleys.	Low - winter & spring, Extreme - in summer & autumn.	Quokka. Mardo. Quenda. Honey Possum. Pygmy possum. Bush rat.
Low, open, understorey vegetation, ridges, midslopes and broad valleys.	Low – winter. Moderate – spring. High - summer & autumn.	Numbat. Ring-tail possum. Echidna. Chuditch. Brush-tailed possum. Brush wallaby. Western Grey Kangaroo. Woylie.
Tall, dense thickets with grassy ground cover along broad valley floors.	Very low - winter & spring. High - summer & autumn	Tammar
Wide range of habitat types including ridges, midslopes, creek lines and swamps.	Variable.	Brush-tailed phascogale. Red-tailed phascogale. Fat-tailed dunnart. Dunnart.

Devising a suitable, flexible, regime requires two adjustments to fire timing and to interval. The timing of burning can be set to encourage patch work with even large areas because of the inherent differences in vegetation dryness and soil moisture, and so in flammability at certain times of year (for example spring burns tend to mean that valley thickets don't burn). Similarly, fire rotation at near the sustainable interval keeps most fuel loads at low to moderate levels. If most regular burning happens in a preferred season and at a sustainable interval, it becomes possible to occasionally change season and increase the interval. This not only changes the intensity and extent of regeneration after the burn, it also gives all species a longer interval between fires, and potentially changes the state of patchiness in the burnt area.

It is possible to incorporate such values into a condition score array for each vegetation type as shown in the appendix ***, with an emphasis on either rising or falling fire frequency from a starting point of a sustainable minimum frequency and assuming a degree of patch burning.

F.6.4) SCALE OF FIRE

This component is perhaps best assessed last because delimiting the extent of a fire depends on an understanding of the characteristics of the other components that were uncovered.

Fires can be quite small and confined to just an isolated patch or extensive and cover a whole landscape. In general the former will be much less intense than the latter, and tend to do less harm. Also the latter generally happen when fuel or biomass has built up to high levels and conditions are very dry (and even windy). The latter have become more common in inland areas with extensive vegetation and low population density (Burrows, Burbidge & Fuller 2000). The areas that have been burnt tend to be smaller closer to habitation (McCaw & Burrows 1989; McCaw, Neal & Smith 1996).

Evidence of former burning practices in a large area of the Western Desert in 1953 shows a strong patch work of small burns. The mean was 64ha, and 75% or ¾ of all burns were less than 32ha, and in an area of 241000ha (49km x 49km) very, very, few approached or exceeded 2000ha in size (Burrows, Burbidge & Fuller 2000). The area burnt by most fires has grown many multiples since then.

Compared to the above forest fires are relatively large. In the northern jarrah forest blocks of several kilometres width are generally burnt (eg 4km x 4km=1600ha; McCaw & Burrows 1989). A maximum workable size for hazard reduction is given as 2000ha (4.5km x 4.5km). Large scale is considered >3000ha (>5.5km x 5.5km), and it tends to burn the whole landscape (Burrows & Friend 1998).

Grazing interacts strongly with fire in most regions. Grazing impacts from large and mobile macropods are most intense when they congregate after fire, and in order to mitigate this it is best to ensure the total area burnt exceeds 500ha (2.2km x 2.2km as one block, larger in extent if patchy) (Christensen and Kimber 1975; Christensen cited in Burrows, Ward & Robinson 1999). Note this does not mean that there will not or cannot be a smaller patchwork within the overall burnt area.

Fauna are generally impacted by large and intense fires which result in near complete combustion of vegetation over the landscape. To some degree short-range, local species are better suited if fires are patchy and relatively small, as recolonisation from adjacent unburnt patches is quicker. This is true for Honey Possums (*Tarsipes rostratus*) (Richarson & Wolller 1991; Burrows & Friend 1998), birds (Christensen et al 1985); and lizards (Burrows & Friend 1998).

F.6.5) PATTERN OF FIRE

When all the fire traces of different ages in a landscape are viewed collectively it can be seen that they tend to fit together like a jigsaw or a mosaic. With time the mosaic changes as biomass once again builds and new fire traces tend to gradually overlay the older ones.

It is within the topic of pattern that the concept of a fire trace as one form of “patch” becomes relevant.

The term patch generally:

i) applies at a local, small, scale;
ii) implies that it will affect only a part of each vegetation type that it reaches.

If a network of small patches is established in an area it creates a fragmented fuel matrix and tends to ensure that:

i) there is less chance that large, intense, and inherently more disruptive fires will occur because more recently burnt patches, with lower fuel loads, dot the landscape;
ii) there is less chance that all higher fuel patches will burn because they are separated by one or more lower fuel patches. Hence those higher fuel load patches that persist will still have fauna sheltering in the thicker vegetation and debris. From such patches fauna can then reinvade adjacent recently burnt areas as regeneration occurs and resources return.
iii) in the medium term there is a mix of resources for the biota. This is because within close proximity there are younger and older patches and a contrasting and complementary range of resources. For animals shelter may be found in the thicker, longer, unburnt vegetation and also more nutritious regrowth, and more abundant flowers, seeds and fruit, in the more recently burnt vegetation. In many respects this may also apply to plants (for example orchids depend on pollinators and fungal symbionts that may require a range of resources in the vicinity).
There needs to be an element of balance in this in terms of the size and number of patches of refuge versus those of forage. The pressure can be intense in a small area of refreshed resources; especially when mobile species from the surrounds, such as kangaroos, invade and concentrate their grazing in one patch.

Consequently development of a patch work of burnt and unburnt vegetation on the local scale is also a fitting *spatial solution to contrasting aspects of the population dynamics* of the fauna. Habitat requirements vary for each jarrah forest mammal species (table***); some prefer low, open, vegetation associated with drier upland sites, and *with early post-fire conditions*, and others prefer tall, dense, mature vegetation, associated with riparian zone thickets in broad valley floors, and *with later post-fire conditions* (Burrows, Ward, Robinson 1999). This has the contrasting requirements of more frequent and extensive burning in upland situations (which suits more mobile species) and infrequent, partial, and intense burning of thickets in order to stimulate regeneration when they age and become rank (which suits less mobile species; whose numbers decline after 3 decades as the vegetation ages).

The role of fire in providing plants with cues and opportunities for germination is significant, and so a patchwork also ensures fire-adapted communities are re-invigorated. For example, in the jarrah forest few seedlings germinate in the absence of fire, and so the diversity and abundance of species declines with time since fire; there ~22 to 24 species/m^2 after fire compared to 4 species/m^2 in the absence of fire for 18 years (Burrows and Friend 1998).

<u>Trap Door Spiders and a Patchwork of Resources in Space and Time</u>

Trap door spider species (Myglamorphs) are Gondwanic Relictual elements of the fauna with particular habitat requirements. In the wheatbelt much of their range is now fragmented and they are present in isolated remnants.

They require a diversity of resources in space and time, and a patchwork is a suitable way to achieve this. Specific requirements depend on the species. However, there are select requirements at various stages of life. For instance: i) some species need bare areas of soft sand when young in order to commence burrowing, and too much litter creates a barrier. In areas where litter is thick they will commonly be found near the edge of litter on open soil where they can both commence burrowing and later collect litter; ii) however, intense fire that removes all litter will remove material for burrow construction and affect the population or immigration; as opposed to moderate intensity where scorched leaves will rain down and form a fresh resource 1-2 years after fire; iii) spiders are vulnerable to fire and could become locally depleted for a period of time (Main 1987). After fire the spiders are likely to be re-established in less than 15 years (M. Davis pers. com.); iv) a long fire-free interval (>30 years) will limit resources for the population in two ways. Burrows are often near plants that are a food source for ants, and near ant trails in particular. Ant numbers dwindle as their food plants age, and so fire that regenerates ant's food plants also renews prey for the spiders. Fire may also provide more litter of the right size for the spiders to use in construction (M. Davis pers. com. - i), ii) & iv)).

F.6.6) PLANT RESPONSE TO FIRE

A basic division of plant response to fire, in reproductively mature individuals with 100% leaf scorch, is:

i) those which die (or re-seeder species); and
ii) those which survive (or re-sprouter species) (Gill 1981b).

The former survive via their seeds and either have seed protected either by structures on the plant and/or buried in the soil. These species are favoured in habitat with longer intervals between fire.

The latter survive via the mature individual and tend to have buds on the stem and limbs (epicormic buds) and/or that are buried beneath the soil (basal buds). These species are favoured in habitat with longer intervals between fire (Keeley & Zedler 1978). They can also reproduce by seed, but the rate and amount of such reproduction is often less than species which are solely dependent on seed production to survive.

In jarrah dominated forest (largely upland and dryland areas) 69% of species could regenerate by epicormic buds or basal sprouts or both (Bell & Koch 1980; Christensen & Kimber 1975). In northern sandplain heaths 66% were re-sprouter species. In jarrah forest the majority of the understorey, and the major canopy species (eg jarrah, marri and sheoak) are epicormic re-sprouters (though after very intense fires jarrah will re-sprout from the base). Subcanopy species (eg *Banksia grandis*, *Persoonia elliptica*, and *P. longifolia*) also tend to epicormic sprouting, but can resprout from the base after intense fire. Resprouting woody unerstorey species (eg *Grevillea wilsonii, Hibbertia hypericoides*, and *Hakea amplexicaulis*) tend to be basal stem sprouters. Resprouting herbaceous perennial species tend to have subterranean buds or vegetative reproductive organs (eg *Xanthorrhoea gracilis, Lomandra sonderi*, and *Anigozanthos humilis*).

In jarrah forest 16% of woody shrub species are killed by scorch and re-establish by seed. Of this 10% store seed in protective woody structures and 6% rely on 'hard' seed which accumulates in the soil (Christensen & Kimber 1975). Such species include *Acacia pulchella*, *Bossiaea aquifolium* and *Trymalium ledifolium* (these have been referred to as fireweeds). The former two are pea family or legumes and they tend to require high soil temperatures for the seed to germinate (this is a product of the hard seed coat and their deep burial by ants - >2-3cm; Shea *et al* 1979). Conversely low intensity fires in spring tend to favour the germination of other species as legumes lie dormant.

Such effects of fire intensity on germination mean that the community composition can be influenced by fire (Shea 1984). For example intense fire in jarrah forest can have these effects: i) favour Acacia pulchella which in turn may suppress dieback fruiting progress, increase nutrition and health of plants via nitrogen fixation, and provide fauna habitat; & ii) decrease Banksia grandis density and so reduce the preferred fruiting habitat for dieback.

Many species are stimulated to flower by fire, so seed is released into the early post-fire environment. For example the cycad (*Macrozamia reidlei*) produces cones after fire and these mature over the two following seasons. In jarrah forest this includes members of the grass tree family (*X. preissii*, *X. gracilis*, *Kingia australis*, *Lomandra sonderi*, *L. preissi;* Bell, McCaw & Burrows 1989). Certain orchids flower particularly well after fire (*Lyperanthus nigricans*, *Leporella fimbriata*, *Eriochilus scabra*, and *Prasophyllum elatum*; Hoffman & Brown 1984). Some species require certain types of fire; hot summer burns are required for some sundews to flower (eg *Drosera erythrorhiza*, and *D. zonaria*; Dixon & Pate 1978).

Some species benefit from enhanced seed production and root-stock regeneration (eg *Anigozanthos humilis*, *Adenanthos barbigera* and *Clematis pubescens*; Bell & Koch 1980).

Tolerance of the overstorey to fire is directly related to the likelihood of periodic fire occurring; this reflects likely minimum fire frequencies as outlined above (Bell, McCaw & Burrows 1989). In jarrah forest the trees that best tolerate fire are those of the lateritic uplands and fertile valley sites (*E. marginata*, *E. calophylla*, & *E. patens*). These areas have rapid fuel accumulation, regular seasonal drought, and often steeper topography, and likely variable fire intensity. In contrast, lower fire tolerance is typical of trees found on sites where fire occurrence is less common, such as constantly moist areas (*E. rudis, E. megacarpa*), areas with slow fuel buildup (*E. wandoo*), or areas with barriers to fire spreading, such as large rock outcrops on the scarp (*E. laeliae*). Note that the former trees have thick bark and the latter have smooth bark.

F7) FIRE-RELATED TERMINOLOGY

Fire interval (or fire-return interval or fire-free interval or inter-fire interval):
Interval in years between two successive fires in a designated area of given size (Mcpherson et al 1990).
Usually indicates composite fire interval, but may indicate point fire interval.

> Point fire interval:
> A composite fire interval over a relatively small area that is taken to be a point (for example, 1 or 2 ha). May refer to number of years between fire scars on a single tree. Since a fire can burn through a small area without scarring any trees, the point fire interval may underestimate fire frequency (Patton 2007, Taylor 2000).
>
> Composite fire interval:
> Number of years between fires that scarred one or more trees within a given area (Dieterich 1980). Often indicates the number of years between fires that scarred at least one tree in the area (e.g., Heyerdahl et al 2001), but may describe number of years between fires that scarred a certain proportion of trees in the area (e.g., Stephens et al 2003). This criterion (single tree, two or more, 10% or more, etc.) Must be specified. The composite fire interval is estimated from a pool of trees within an area, and is intended to account for the likelihood that not every tree will be scarred by every fire that occurs in the area (Patton 2007).

Fire frequency = fire occurrence:
Number of fires per unit time in a specified area of given size (Mcpherson et al 1990). The (mean) return interval of fire over a specific time in a given area.

FIRE CYCLE:
Length of time for an area equal to the entire area of interest to burn; size of the area of interest must be clearly specified (McPherson et al 1990).

FIRE DURATION:
The length of time that combustion occurs at a given point (McPherson et al 1990). Fire duration relates closely to downward heating and fire effects below the fuel surface as well as heating of tree boles above the surface.

FIRE EXCLUSION:
The policy of suppressing all wildland fires in an area (Smith 2000).

FIRE INTENSITY:
A general term relating to the heat energy released in a fire (Keeley 2009, McPherson et al 1990). Wherever possible, FEIS uses more specific terms to describe rate of heat release. See fireline intensity below.

FIRELINE INTENSITY:

The rate of heat release per unit time per unit length of fire front. Numerically, the product of the heat of combustion, quantity of fuel consumed per unit area in the fire front, and the rate of spread of a fire, expressed in kW/m (McPherson et al 1990). Not synonymous with FIRE SEVERITY, which refers to the degree of environmental change caused by fire.

FIRE REGIME:
Describes the patterns of fire occurrence, size, and severity—and sometimes, vegetation and fire effects as well—in a given area or ecosystem (Agee 1994, Mutch 1992, Johnson and Van Wagner 1985). A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured. The fire regime on a particular kind of site or in a particular ecosystem is not cyclic in a deterministic sense; it is, rather, a story about climate, human use, other disturbance, and species dispersion as they have all changed and interacted to affect an ecosystem, both suddenly and subtly, over millennia. The concept of fire regime as story lets us think about the future in that type or ecosystem as a question, perhaps a choice, rather than a destiny. According to Agee (1994), "A fire regime is a generalized way of integrating various fire characteristics. The organization may be according to the characteristics of the disturbance..., dominant or potential (climax) vegetation on the site..., or fire severity, the magnitude of effects on dominant vegetation...." According to Mutch (1992), "A natural fire regime is the total pattern of fires over time that is characteristic of a natural region or ecosystem. The classification of fire regimes includes variations in ignition, fire intensity and behavior, typical fire size, fire return intervals, and ecological effects." According to Johnson and Van Wagner (1985), "... fire regime is a multivariate system characterized by (i) the fire history measured in fire frequency or fire return period, (ii) fire intensity measured in kW/m, and (iii) depth of burn (duff removed) measured in kg/m, or percent...."

FIRE-RESISTANT SPECIES (FIRE TOLERANT):
Species with morphological characteristics that give it a lower probability of being injured or killed by fire than a FIRE-SENSITIVE species, which has a "relatively high" probability of being injured or killed by fire (McPherson et al 1990). Implies that the organism does not get injured by things that would seem able to injure it (Johnson and Van Wagner 1985). Rowe (1983) uses a more restrictive definition of resistance - relating it only to plants with aboveground parts that survive fire.) According to Levitt (1980), there are two kinds of RESISTANCE: (1) TOLERANCE, which describes species that mitigate dangerous, often lethal conditions. In regard to fire, TOLERANCE means that living cells are severely heated but survive anyway—such traits are rare. (2) AVOIDANCE, which describes ways of preventing cells from heating to lethal temperatures. Most plant cells that survive fire do so through AVOIDANCE—because of insulating tissues, for example, or because of an insulated microenvironment. Since Rowe (1983) uses AVOIDANCE with a meaning different from this one, FEIS usually uses RESISTANCE to indicate both FIRE TOLERANCE and AVOIDANCE.

FIRE ROTATION INTERVAL:
The time required to burn the equivalent of a specified area (Bond and Keeley 2005).

FIRE SEVERITY:
Fire severity is defined and measured in several different ways. FEIS uses the term to indicate the degree of environmental change caused by fire (following NWCG 1996). Another definition with similar meaning is: the effect of a fire on ecosystem properties, usually defined by the degree of soil heating or mortality of vegetation (Scott and Reinhardt 2007). Other definitions of fire severity include the product of fire intensity and residence time (McPherson et al 1990, Agee 1994, Rowe 1983) and aboveground and belowground organic matter consumption from fire (Keeley 2009). Because “fire severity” is not used consistently in the literature, Jain et al (2004) recommend that it be defined and the measurement method explained whenever it is used quantitatively.

MEAN FIRE INTERVAL:
Arithmetic average of all fire intervals determined, in years, for a designated area during a specified time period; the size of the area and the time period must be specified (McPherson and others 1990).

EPICORMIC BRANCHING OR SPROUTING:
A shoot arising spontaneously from an adventitious or dormant bud on the stem or branch of a woody plant, often following exposure to increased light levels or fire (Helms 1998).

GRASS/FIRE CYCLE:
An altered fire regime that may result when nonnative invasive grass species dominate the herbaceous layer in a plant community. The process occurs in this way: the nonnative grass colonizes an area and provides a continuous fine fuel that is readily ignited and facilitates fire spread. Larger and possibly more severe fires then occur more frequently in the invaded area than in similar, uninvaded communities. Following these grass-fueled fires, nonnative grasses typically recover more rapidly than native species, further increasing the probability of fire and the possibility of greater fire size and severity and decline of native species (adapted from D'Antonio and Vitousek 1992

DRMW) RESILIENCE

This is a potential attribute.

This attribute may have its place at the end of the assessment procedure, when the evidence gathered from the site can be combined and *assessed in a consistent and less subjective manner*. It is not recommended that this attribute is assessed at the start as it may pre-empt the overall pattern that emerges from the collective attributes

It is included at this stage for two reasons, namely that it illustrates how: i) a short review of key attributes; and/or ii) a dichotomous or decision tree approach to rating might be included in the scales. In terms of i) the key attributes implied to reflect resilience by Connell (1995) were disturbance, weeds, and recruitment; though it seems likely that this collective attribute is also subject to most other attributes/ecological processes or adverse trends. Note that neither Connell (1995) and Thackway & Leslie (2006) indicate the aspects that are the basis of a decision about the state of resilience; this is shown in the table. Note that on the Connell (1995) scale ~NO RESILIENCE means no likelihood that richness & structure will be self-sustaining, and HIGH RESILIENCE means richness is self-sustaining.

RESILIENCE	LOW RESILIENCE	LOW TO MOD. RESILIENCE	MODERATE RESILIENCE	MOD. TO HIGH RESILIENCE	HIGH RESILIENCE
Adapted alignment from Connell 1995: Likelihood of being self-sustaining.	Low likelihood that richness & structure will be self-sustaining	Moderate to low likelihood that richness & structure will be self-sustaining	Moderate likelihood that richness & structure will be self-sustaining	Moderate to high likelihood that richness & structure will be self-sustaining	High likelihood that richness & structure will be self-sustaining
Adapted alignment from VAST (Thackway & Leslie 2006): Regenerative capacity	Capacity limited. Capacity degraded by past & current land use practices (since 1750). (Disturbance likely extensive, and/or significant and/or recurrent.)	Capacity becoming limited. Capacity at risk from past & current land use practices (since 1750). (Disturbance likely significant and/or recurrent.)	Capacity persists in tandem with changed land use practices (since 1750). (Disturbance limited, diffuse, well-removed, and intermittent.)	Capacity persists. Change in land-use/management commencing.	Capacity intact. Unmodified.

To assess resilience via:
i) a short review of key attributes use the following table.
Work from left to right. If any one of the listed attributes is “very degraded” then the resilience is low. If this is not the case and any three attributes are “degraded” then the resilience is low to moderate. If this is not the case and any five attributes are “good” then the resilience is moderate.
Note that ~NO RESILIENCE and HIGH RESILIENCE equate to ALIENATED and PRISTINE respectively.

RESILIENCE LEVEL >	LOW RESILIENCE	LOW TO MOD. RESILIENCE	MODERATE RESILIENCE	MOD. TO HIGH RESILIENCE	HIGH RESILIENCE
	Any 1 of these attributes in this state	Any 3 of these attributes in this state	Any 5 of these attributes in this state		
CONDITION SCALE >	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT
SITE ATTRIBUTES					
Composition	X	X	X		
Disturbance (all forms of disturbance to soil, the surface & vegetation)	X	X	X		
+ Weeds	X	X	X		
Surface stability	X	X	X		
Water-logging	X	X	X		
Salinity	X	X	X		
Grazing	X	X	X		
(+/- recruitment?)					
FRAGMENTATION ATTRIBUTES					
Isolation, small size, inbreeding	X	X	X		

ii) a dichotomous or decision tree approach use the following table (version 2). Decide on the state of clearing and then whether the area is unfragmented or fragmented and then select a row. Within the row select a category that best matches the combination of state of the soil and composition of the plants and rate accordingly. (Altered refers to the soil having been moved or disrupted in some way by the mode of disturbance, even if it is only surface disturbance. The table begins with and undisturbed state, then essentially reflects the escalating effects of isolated disturbance to the surface and biota, then repeated disturbance, and then repeated disturbance combined with fragmentation.)

TABLE : Version 1 of an approach that relates resilience to disturbance and the state of soil and plant species.

RESILIENCE (*after Perkins 2002; cultivated includes pasture that has been improved)	Very low resilience	Low resilience	Low to mod. resilience	Moderate resilience	Mod. to high resilience	High resilience	High resilience
• NOT CLEARED *AREA UNFRAGMENTED &/or FRAGMENTED*	*Soils stripped/replaced*			**Soils unmodified; uncultivated** + Exotic dominated	**Soils unmodified; uncultivated** + *Mix of exotics & natives*	**Soils unmodified; uncultivated** + **Native dominated**	*Not applicable – no impacts*
• CLEARED ONLY ONCE &/OR RECENTLY (<2YEARS)* *AREA UNFRAGMENTED &/or FRAGMENTED*		Soils modified; cultivated; imported material. + Exotic dominated (Normally)	*Soils partly modified; Some imported material.?* + Exotic dominated	**Soils unmodified; uncultivated** + Exotic dominated	**Soils unmodified; uncultivated** + *Mix of exotics & natives*	**Soils unmodified; uncultivated** + **Native dominated**	
• CLEARING REPEATED *AREA UNFRAGMENTED* *Hence re-invasion from all surrounds possible.*		*Soils partly modified; Some imported material?* + Exotic dominated (Normally)	**Soils unmodified; uncultivated** + Exotic dominated	**Soils unmodified; uncultivated** + *Mix of exotics & natives*	**Soils unmodified; uncultivated** + **Native dominated**		
• CLEARING REPEATED OR CONSOLIDATED/ LONGSTANDING* *AREA FRAGMENTED*	Soils modified; cultivated; imported material. + Exotic dominated (Normally)	**Soils unmodified; uncultivated** + Exotic dominated	**Soils unmodified; uncultivated** + *Mix of exotics & natives*	**Soils unmodified; uncultivated** + **Native dominated**	*Unlikely given history*	*Unlikely given history*	

TABLE : Version 2 of an approach that relates resilience to disturbance and the state of soil and plant species.

RESILIENCE (*after Perkins 2002; cultivated includes improved pasture) (Weeds = exotics)	~NO RESILIENCE	LOW RESILIENCE	LOW TO MOD. RESILIENCE	MODERATE RESILIENCE	MOD. TO HIGH RESILIENCE	HIGH RESILIENCE	HIGH RESILIENCE
• NOT CLEARED *AREA UNFRAGMENTED &/or FRAGMENTED*	*Soils stripped/replaced*	**SOILS UNMODIFIED; UNCULTIVATED** + *WEED DOMINATED*	**SOILS UNMODIFIED; UNCULTIVATED** + *WEEDS, MAINLY*	**SOILS UNMODIFIED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS COMMON*	**SOILS UNMODIFIED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS FEW*	**SOILS UNMODIFIED; UNCULTIVATED** + *NATIVE DOMINATED*	*Not applicable – no impacts*
• CLEARED ONLY ONCE &/OR RECENTLY (<2YEARS)* *AREA UNFRAGMENTED &/or FRAGMENTED*		Soils altered; +/-cultivated; +/- imported material. + *WEED DOMINATED*	SOILS ~ALTERED; UNCULTIVATED + *WEEDS, MAINLY*	**SOILS UNMODIFIED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS COMMON*	**SOILS UNMODIFIED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS FEW*	**SOILS UNMODIFIED; UNCULTIVATED** + ***NATIVE DOMINATED***	
• CLEARING REPEATED *AREA UNFRAGMENTED Hence re-invasion from all surrounds possible.*	Soils altered; +/- cultivated; +/- imported material. + *WEED DOMINATED*	SOILS ~ALTERED; UNCULTIVATED + *WEEDS, MAINLY*	**SOILS ~ALTERED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS COMMON*	**SOILS ~ALTERED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS FEW*	**SOILS ~ALTERED; UNCULTIVATED** + ***NATIVE DOMINATED***		
• CLEARING REPEATED OR CONSOLIDATED/ LONGSTANDING* *AREA FRAGMENTED Hence re-invasion from the surrounds unlikely.*	Soils altered; +/- cultivated; +/- imported material. + *WEEDS, MAINLY/ DOMINATED*	**SOILS ~ALTERED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS COMMON*	**SOILS ~ALTERED; UNCULTIVATED** + *NATIVES, MAINLY WEEDS FEW*	**SOILS ~ALTERED; UNCULTIVATED** + ***NATIVE DOMINATED***			

To complete this process combine the two scores from i) and ii) and incorporate them into a single site attribute entitled "RESILIENCE" on the field sheet.

5.6.3) BALANCING LANDSCAPE CONTEXT & VEGETATION CONDITION ATTRIBUTES

In this treatment the division of attributes adopted by Oliver et al (2007) is used to align the respective schemes from Victoria (Habitat Hectares), Tasmania (TasVeg), New South Wales (Biometric), and South Australia (Bushland Condition Monitoring – Manual for the Southern Mount Lofty Ranges).

Under Landscape Context are attributes for Patch (remnant: size; shape; km from water; km to a <10ha patch; km to a >100ha patch; km to caves or tunnels; & years since isolation) and for Matrix (remnant connectivity; structural contrast; surrounding land use; invasive species adjacent; & IBRA region vegetation cover).

Under Vegetation Condition are Focal Taxa; Native Richness; & Exotic Cover (all 'Compositional'); then Abiotic Cover; Biotic Cover; & Heterogeneity (all 'Structural'); and then Flows; Threats – Current; & Threats – Past (all 'Functional'). These are further subdivided (see Table ***).

There are two estimates of the relative weighting that may be given to 'landscape context' versus 'vegetation condition' attributes. A ratio based on the consensus of 31 ecologists places the relative weighting at 0.36 Landscape Context : 0.64 Vegetation Condition (Oliver et al 2007). In Victoria Habitat Hectares employs a ratio of 0.25 : 0.75 (Parkes et al 2003). There does not appear to be any empirical evidence for these ratios.

It is also assumed that in intact (extensive or variegated) landscapes that attributes within 'landscape context' are of low importance, whereas, in fragmented (or relictual) landscapes they may be key factors behind the state of species-level biodiversity.

An intensive large scale study in New Zealand tends to support the latter assumption (Overton & Lehmann 2003). Essentially the study shows very strong buffering of condition within un-fragmented areas except for specific instances of change in land-use. In fragmented areas there were very strong effects on condition of land cover category (which encompasses extent of alienation and/or remnant size) and then disturbance in the near vicinity. Relative distance from extensive conservation areas explained very little of the variation in condition. This is compatible with findings in the wheatbelt that show key invertebrate species respond strongly to remnant size but not to remnant shape or degree of isolation (Abensperg-Traun and Smith 2004).

5.6.3.1) CONDITION SCALES - ADDING LANDSCAPE ATTRIBUTES

NOTES:
The following attributes are yet to be adapted to fit the scale from excellent to very degraded. The sources of the scales are:
S- Southern Mt Lofty Ranges scheme; BC - BioCondition scheme; H - Habitat Hectares scheme; BM - BioMetric scheme.

Patch size, (and nature) (key to Oliver et al 2007) (Adapted from S then BC & H)

Size refers to the combined continuous remnant vegetation in the immediate vicinity, of which the vegetation type or zone of interest is located and is a part. Scoring is weighted towards larger vegetation patches because these are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller patches (McIntyre et al (2000); Lindenmayer et al (1999).

SHOULD NON-REMNANT VEGETATION OR REGROWTH BE INCLUDED?

A) Record the size of the remnant or patch.

The remnant includes adjoining bushland regardless of tenure, management, assessment status, or regional ecosystem category. The remnant ends where there is:

- a substantial artificial barrier greater than 10m wide (eg a paved or consolidated road, railway line, concrete drain, row of houses etc.(S));
- connection to larger areas by narrow corridors (<200m in width) within 1 km radius of the site. (BC).

(The integration of the patch into local vegetation then depends on the definition of connectivity given later (namely a gap of less than 100m or a corridor of vegetation >30m in width between the patch and other vegetation that is in moderate or better condition and of > 1 ha in size).

B) Decide if there is evidence of disturbance that obviously affects features such as understorey species and soil and how far this extends into the remnant.

C) Use the area, and if applicable, disturbance to determine a score from the table.

		Extent to which disturbance intrudes into remnant.		
Size of Remnant (including any adjoining bushland)	With no regard to disturbance.	Extends 10m into scrub interior.	Extends 50m into scrub interior.	Extends 100m into scrub interior.
______________ha				
< 2ha	1	-1	-2	-3
2 - < 5ha	2	0	-1	-2
5 – 10 ha	4	1	0	-1
10 -20 ha	6	2	1	0
20 – 100 ha	8	3	2	1
100 – 500 ha	10	4	3	2
> 500 ha	12	5	4	3
	(H)	(S)	(S)	(S)

Patch Shape (from S)

The score is determined from the following table.
The remnant includes adjoining bushland regardless of tenure, management, assessment status, or regional ecosystem category. The remnant ends where there is:

- a substantial artificial barrier greater than 10m wide (eg a paved or consolidated road, railway line, concrete drain, row of houses etc.(S));
- connection to larger areas by narrow corridors (<200m in width***) within 1 km radius of the site. (BC).

Shape	**Score**
Circular or compact (eg square)	2
Oval, oblong or triangular	1
Irregular with many indentations	0
Long and thin	-1
	(S)

Distance from Patch to Nearest Large Patch. (> 100 ha?) (key to Oliver et al 2007)

Equivalent to Distance to Core Area (H).
A core area is any patch of native vegetation >50ha regardless of type, quality or tenure. Where the habitat zone in question is part of a remnant patch greater than 50ha, the distance to the core area is taken to be “continguous”. The distance is the shortest path from the edge of the habitat zone in question to the edge of the nearest core zone (and this determines the category in the table, along with the presence of disturbance).
Table : Criteria and scoring relating to the distance to core area.

Distance	Core Area not significantly disturbed.	Core Area significantly disturbed *.
> 5km	0	0
1 to 5 km	2	1
< 1 km	4	3
Contiguous	5	4
* defined as per RFA ‘Old Growth’ analyses.		
(H)		

Matrix Connectivity (key to Oliver et al 2007) (adapted from BC & BM)

BC:
This attribute addresses the degree of connection between the patch being assessed and adjacent native vegetation. Connectivity influences the opportunities for species to disperse between habitat patches in the landscape, and therefore has important implications for species persistence

(With 2004). A landscape with high connectivity is one in which a given fauna species can readily move between suitable areas of habitat. A landscape with low connectivity means populations become largely isolated (Bennett et al.al. 2000). Immigration by a species into a single patch of habitat is related to connectivity at the landscape scale. However, other aspects such as the size of the patch and the amount of habitat in the landscape, as well as the dispersal behaviour of species, contribute to the strength of the relationship (Tischendorf and Fahrig, 2000).

Criteria for assessing connectivity value apply to the patch of vegetation containing the assessment site (adapted from BioMetric & BioCondition).The most important criteria are the extent of connection and the dispersion of links to native vegetation. The other criteria can assist in making a decision. Where the locale includes multiple types of vegetation, choose the highest connectivity value that pertains to vegetation within the locale. Any gap >100m within a proposal means that the vegetation is not linked. Vegetation is linked to surrounding native vegetation if it is ≤100m from native vegetation that is, in turn, linked to native vegetation not in low condition and ≥1ha. Native vegetation of any description is in low condition if <50% of vegetation in the ground layer is indigenous species or >90% has been regularly ploughed or remains fallow (BioMetric).

(THIS HAS TO DO WITH MOSAICS. Notes: Only patches of vegetation >0.25ha (ie 50x50m) are assessed separately (as distinct zones) from surrounding vegetation in BioMetric.)

Table * Criteria for assessing connectivity value.**

BioC	BioC	BioC	BioMetric	BioMetric	BioMetric	BioMetric	
Category	Score	Extent of connection.	Dispersion. Number of compass quarters with links to native vegetation.	Dispersion. Number of compass quarters with links to exotic vegetation.	Mean width (of links)	Condition	Off-set. Connections to adjacent vegetation.
None	0	The patch is not connected in the ways described below.	0	(0)	--	--	
Low	1	The patch;– • adjoins remnant vegetation along <5% of its border	--	> 1 OR*> (*only 1 applies)	5 – 30m <OR*>	Low <OR*	At least 1 low connectivity link is maintained or created on more than one compass quarter.
Medium	2	The patch;– • adjoins remnant vegetation along >5% to < 50% of its border OR • adjoins remnant vegetation along <5% of its border AND • adjoins <u>non-remnant native vegetation</u> > 25% of its border	>1		> 30m - <100m	(Not low)	At least 1 moderate connectivity link is maintained or created on more than one compass quarter.

High	4	The patch;– • adjoins remnant vegetation along 50% to 75% of its border	>1		> 100m	(Not low)	At least 1 high connectivity link is maintained or created on more than one compass quarter.
Very High	5	The patch;– • adjoins remnant vegetation along > 75% of its border	>1		(>>100m)	(Not low)	

Matrix Surrounding Landuse (adapted from S)

• Bushland degradation risk - surrounding land use (S);

Select the description that best fits the majority of land use surrounding the remnant.

Surrounding Bushland and other land	Score
Highly degraded bushland with dense, weedy growth, and/or partially cleared, highly weedy land under little or no active management.	-2
Pasture cropping land and/or urban development and/or roads	-1
Adjoining small remnants of bush in reasonable condition and/or partially cleared areas	0
A mix of undisturbed bush in mostly non-weedy condition and cleared, non-weedy areas	1
Relatively undisturbed bush on most sides in non-weedy condition	2
	(S)

• Neighbourhood (H) and the % Native Vegetation Cover In The Landscape (BM).

This measure reflects the amount and, to some extent, the configuration of native vegetation in proximity to the remnant in question. A progressive picture of the neighbourhood surrounding the remnant can be built from a series of nested circles that originate from the centre point of the remnant. The assessor then estimates the proportion of the area within each of the circles that is made up of native vegetation. Native vegetation is lumped, regardless of the vegetation types that comprise it, their quality or the land tenure. Native vegetation is considered to include wetlands and all water-bodies with the exception of the oceans. Care may have to be taken with general mapping that shows the extent of native vegetation in the vicinity; as this may not take account of certain types of vegetation that do not stand out well in remote imagery. It may be necessary to carefully interpret remote images for the area based on the experience gained on the ground, especially mapping that shows the extent of remnant vegetation, as some types of vegetation may not have been picked up by a broad-scale vegetation mapping exercise.

> This exercise can be conducted by drawing three/four***? concentric circles from the centrepoint, then estimating the cover by rounding to the nearest 20% (ie 0, 20, 40, 60, 80 & 100%) for each of the radii (then in HH multiplying by the weighting).

Radius m	Radius Km	scale of ha	actual ha	Highlights coverage of	Comments	Source	(Weighting Hab. Hec.)
100	0.10	1	3.1	Patch		Habitat Hectares	0.03
200	0.20	10	12.6	patch +/- neighbours		BioMetric	
550	0.55	100	95.0	patch and immediate neighbours	crosses several small-scale vegetation units	Biometric	0.04 (1000m)
1750	1.75	1000	961.6	vegetation at the locality		BioMetric	
5000	5.00	10000	7850.0	vegetation in the catchment	crosses one to several broad-scale vegetation units	Habitat Hectares	0.03

• total adjacent remnant area (BM)

"This measure is meant to encourage the establishment of offsets adjacent to, or as part of, remnants that are of equivalent size or larger than the remnant in which clearing is proposed to occur. This reflects findings that vegetation that is adjoining, and therefore part of, larger remnants is generally of more value to biota than vegetation that is adjoining, and therefore part of, smaller remnants (e.g. Platt 2002). Record the total remnant area of which the proposal is a part as one of four levels: very large, large, medium or small. Very large, large, medium or small remnants are defined differently according to the extent to which the vegetation unit in question has been cleared."

Table: Criteria used for assessing total adjacent remnant area (example). Adjacent remnant area refers to the area (in ha) of native vegetation that is not in low condition and is linked (by gaps ≤100m) to the proposal area.

Level for total adjacent remnant area	% native vegetation cleared in the vegetation type in which most of the proposal occurs			
	<30%	30-70%	71-90%	>90%
Very large	>500	>100	>50	>20
Large	201-500	51-100	21-50	11-20
Medium	101-200	21-50	11-20	1-10
Small	<100	<20	<10	<1

<u>Joint function of % of vegetation type remaining and its local extent</u> (BM).

(BM) "Regional value is based on the relationship between the % cleared of the vegetation types on the site relative to their pre-colonisation extent. In BioMetric a value is derived from a joint function of % cleared and a generic species area curve (Rosenzweig 1995)."

((Remnant in association score {ie the % remaining of type} (S)))

Determine the vegetation type in which the remnant occurs and the percent of native vegetation that remains in the association. This figure can be used to assign a score.

% of Remnant Vegetation in Environmental Association	Score

<5%	-2
5 – 10 %	-1
11 – 20%	0
21 – 50 %	1
50 – 75%	2
>75%	3
	(S)

Other things that might be adapted to also appear as attributes at landscape scale.

Examples include:

- Weeds versus vegetated area size - fragmentation
- Feral animal incursion distance (m) - fragmentation
- Fire regime as influenced by fragmentation

There would appear to be limited benefit in singling out certain attributes to set in context against fragmentation. Rather, it is better to employ landscape attributes in tandem with site specific attributes. In addition parts of the feral incursion attribute is covered by the provisional attribute infrastructure corridors as invasion routes.

5.6.4) CONDITION SCALES - ADDING & ADJUSTING ATTRIBUTES

Rationale and pointers for constructing an attribute scale

Take time and take care.

Iterate an attribute more than twice before consolidating a scale.

Aim to limit most scoring to the range between the “VERY DEGRADED” to “EXCELLENT” categories and to preserve “ALIENATED” and “PRISTINE” as the outer boundaries. As a general rule the breadth of any particular attribute will span these inner categories; it is preferable to attempt to quarantine “PRISTINE” from general use as the degree to which this now truly applies is highly variable even in the most isolated areas. It is available where a scorer feels strongly that a particular attribute is of outstanding quality or it proves particularly difficult to contrive a fit of a substantiated pattern to the overall category scale.

A key tipping point is at “GOOD”. Many trends are likely to be accelerated and non-linear ‘below’ “GOOD” – that is towards “ALIENATED”.

No extra weighting is implied by the presence of more sub-categories within one attribute compared to another. They only reflect more evident aspects that can be examined in a quasi-methodical way under that attribute.

Attributes are by and large viewed as independent (unless clearly shown to be otherwise). This is more conducive to rating subcategories in a quasi-methodical way.

Regarding the consistent use of words and of phrases when filling out attributes. Give first preference to using the categories low, low/moderate, moderate, moderate/high, and high.

Two alternative percent scales are shown below. The simple conceptual scale has limited application (to such factors disturbance where conceptually intact is 100% and degradation can proceed from there). Most attributes seem to be inherently better suited to a sliding scale (an accelerated, non-linear, scale. This is because of themes such as biotic factors and compounding interactions.

	ALIENATED Engineered or dedicated to exotic species.	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE State close to pre-1750
Simple conceptual scale – less common in practice.							
Intact process		0 20	20 40	40 60	60 80	80 100	
Adverse process		100 80	80 60	60 40	40 20	20 0	
More typical accelerated non-linear scale							
NATIVE FAUNA SIGNS &/OR LIKELY HABITAT		Absent.	0-5% of area	>5-15% of area	>15-50% of area	>50-90% of area	
FERAL ACTIVITY – EXTENT & IMPACT		High impact 90->50% of area	High to moderate impact 50->15% of area	Moderate impact 15 ->5% of area	Moderate to low impact 5-0% of area	None	

It may also be possible to put numerical category boundaries on the attributes if this is considered a necessary adaptation.

6) PLANT DIVERSITY

As has already been stated, condition assessment is supplementary and complementary to plant diversity assessment; it is not put forward as a substitute for the former.

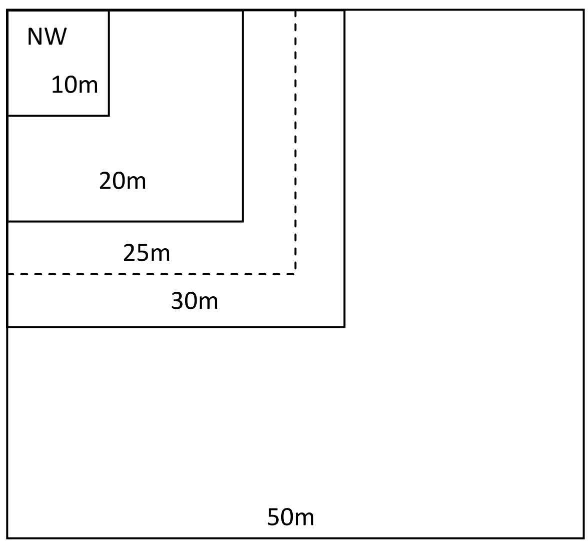
The main requirements for an assessment of the total number of plant species present at a site are regard for the timing of sampling (see 5.6.2.3), and the application of the appropriate bioregional quadrat size. Further details on these matters are to be found in the Environmental Protection Authority Guidance on survey for vegetation and flora. A guide to the whole assessment procedure is provided in Keighery (1994) and the associated field sheets are included in an appendix here or available at the Perth Biodiversity Project website.

6.1) COORDINATION OF PLANT DIVERSITY & CONDITION

The key point of coordination between condition assessment and plant diversity is the overlaying of quadrats, which is referred to as 'nesting'.

The condition quadrat at 25mx25m is the fixed ingredient, and it is then a matter of aligning a variable range of bioregional quadrats with it; this is simply achieved by ensuring the north-west corners (or closest equivalent) align and overlap. This is illustrated using 10, 20, 30 & 50m quadrats in the following diagram. In the south-west 10 & 20m quadrats have been widely used, in semi-arid and arid areas it is the larger sizes. See 7) for how this relates to a remote sensing array. Where this has been overlaid on a quadrat of another size one condition quadrat should suffice for comparison in most cases. However, if it is overlaid on a 50mx50m or larger quadrat and there is variation in condition, the installation of another condition quadrat may be justified in order to reflect the variation in condition. Above 50mx50m it is likely to be mandatory, such as with 100mx100m.

In some cases this may be based on existing plant diversity quadrats and this will determine the orientation in which case nest the former into the corner that most closely corresponds to the north-west corner.



The standardisation of much work to set quadrats has advantages as it renders different assessments more comparable. Common quadrat sizes that have been used in major biogeographic survey in W.A. are:

- South-west area (excluding the wheatbelt): 10x10m quadrats (many hundreds of sites; Gibson et al 1994; Markey 1997; Havel and Mattiske 2000).
- Wheatbelt : a 20x20m quadrat for over-storey with a nested 10x10m quadrat for all other vascular plant species (circa 1500 sites; Gibson et al 2004).
- Coolgardie bioregion: 20x20m (circa 250 sites; Gibson et al 1997; Gibson and Lyons 1998 a & b, 2001a & b).
- Semi-arid and arid areas: a variety of quadrat sizes have been applied (including informal releves). They tend to be larger than the preceding because of lower plant density. One of the more common options that has been applied to large-scale biogeographic work is 50x50m (Trudgen, M., 2002; Trudgen, M., and Griffin, E. A., 2001).

The format could address a limitation to standardised quadrats, namely that each represents a quite restricted sub-sample of a vegetation type. Under a nested arrangement an intensive search for every plant species can be extended beyond the basic plant diversity quadrat in a known area - either where the condition quadrat is larger or a virtual remote sensing array is deployed (see 7). This may be useful with species that are scarce.

If required the plot size that captures most of the plant diversity in a given area can be determined by plotting the species area curve. Pilot work can graph the cumulative number of species found as the area sampled increases (that is as either the quadrat size or number is increased) The number of species found should start to plateau when the area covered by sampling is sufficient to represent a selected unit of vegetation (See also the SOP for quadrats for an approach to this matter.)

7) CONTEMPORARY REMOTE-SENSING ARRAY

7.1) RATIONALE - REMOTE SENSING PIXEL SIZE & ALIGNMENT

The size of the condition assessment quadrat is tied to the pixel size of the national mapping grid, and although other sizes might have relevance, this is a common unit and it is likely to remain stable through time even though the characteristics of remote sensors may change.

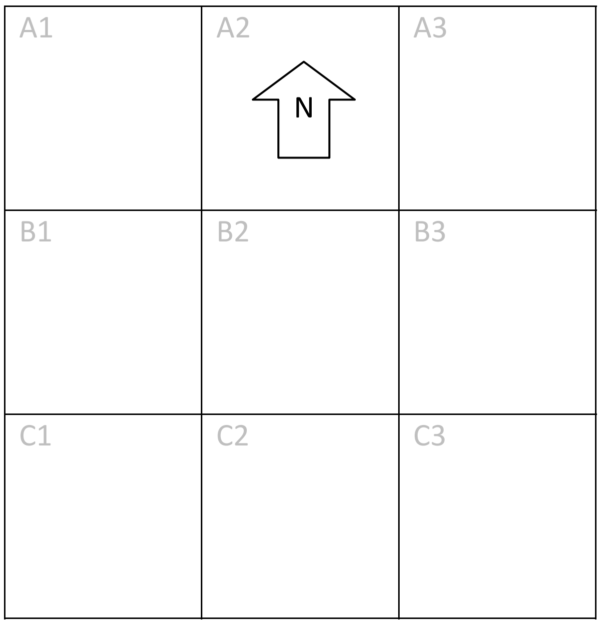
The pilot version of vegetation assessment used a quadrat size of 30mx30m (equivalent to Landsat pixels before rectification, and a reasonable approximation for several of the other remote “platforms” in operation) which in turn were combined into a block of 9 (ie 3x3) that then equated to an outer edge of 90m x 90m. Hence a swath width between 30 to 90m was covered; although the primary intent was to cover a margin for error of +/- quadrat around the central 30m x 30m quadrat. They had a north-south orientation.

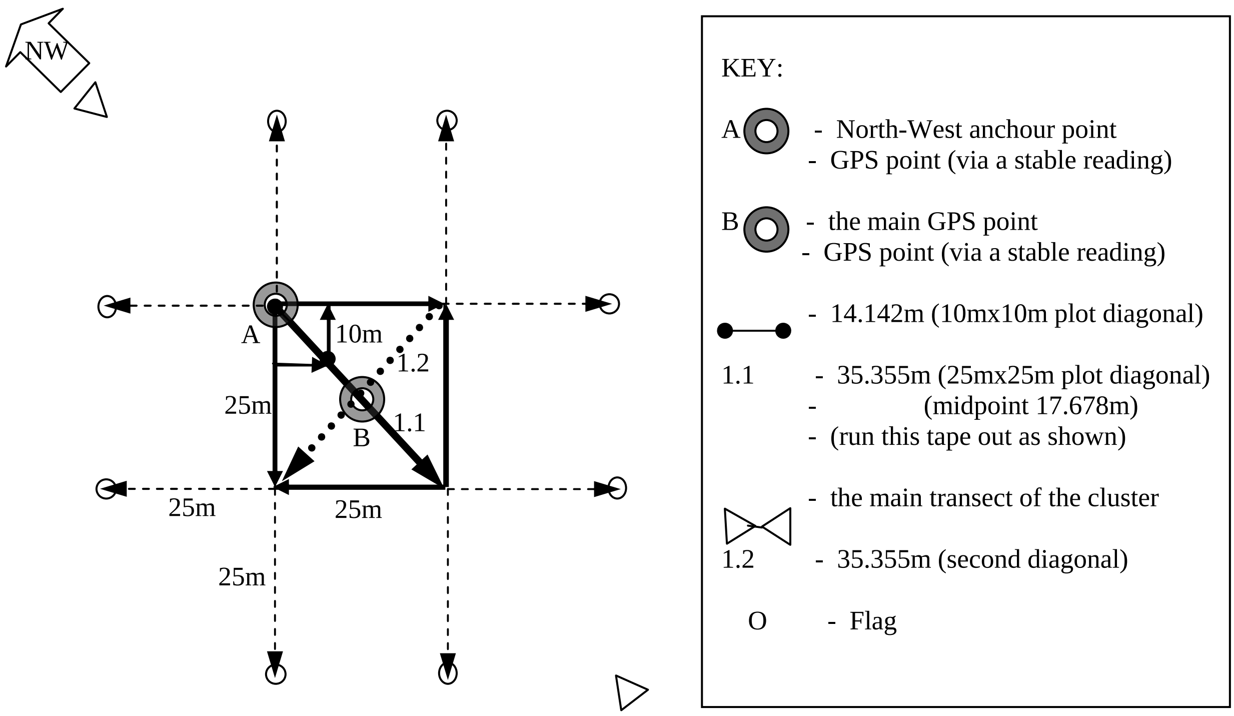
However, DEC GIS section have adopted the standard Australian approach to remotely sensed data based on the Office of Climate Change specifications both in terms of size and rectification (other standards also exist). Hence Landsat data with a raw 30m pixel is re-sampled to 25m to fit standard mapping grids and measurements (Graeme Behn pers. com.). In the process a north-south orientation is imposed and parts of more than one raw pixel may be combined to create a virtual pixel. This obviously affects the signature of each virtual pixel as it incorporates varying degrees of neighbouring raw pixels (Paul Rampant pers. com.).

This re-sampling and rectification overcomes variation due to:
i) differences in the area covered by the sensor’s of satellites (for example Landsat has a raw pixel width of 30m and NOAA has raw pixels of 1km (vertical centre of path/swath) and 6km (oblique outer part of the path/swath; the path itself is 850km wide for NOAA). Landsat is effectively the standard in terms of the extent of coverage, in addition it has a reference catalogue of imagery that stretches back for over two decades;
ii) differences in the flight path of satellites and so image orientation (image collection is not in a consistent direction such as north-south);
iii) drift in the flight path of any one satellite with time, the passes are rarely exactly repeated;
iv) distortion of pixels that are farthest from the centre of the sensor’s view (largely due to an oblique angle of view; in the raw state these pixels are more rectangular).
(Paul Rampant pers. com.)

7.2) SITE LAYOUT

The remote sensing array is also based on 25mx25m units which are arranged as a 3x3 grid; that is a block of 9. A standard grid reference has been adopted commencing with the north-west quadrat. Each 25mx25m quadrat may be divided with one or two diagonal transects with a length of 35.355m; these are optional depending on the purpose. This is shown in the following diagram.





The array is based around the central condition quadrat (B2) and so it is *important* that this is located in the target vegetation type and *desirable* that the whole array also fits in this type to the extent that it is possible.

[*Ideally* it may help to align quadrat B2 exactly with the national grid.]

For the purposes of condition assessment the central quadrat (B2) is the only part of the array that *needs* to be permanently marked and geo-referenced. This is provided the surrounding 25m quadrats are carefully delineated by reference back to the central quadrat and use of a compass to mark the corners with flagging tape. If 50m tapes are used it is a simple matter to run each tape out straight and so extend each side by 25m, and by default demarcate the whole array. Virtual setup saves time and resources and presents less logistical problems; the error associated with this is likely circa 1-2%. Use of different coloured flagging to differentiate the east (yellow) and west (pink) sides of the quadrat/cluster may help with orientation.

For other purposes, such as plant species diversity or quantitative measures requiring replicate samples, it is essential that the relevant quadrats in which they occur in the array are marked.

7.3) BASIC PROTOCOL FOR MEASURES

This is an outline of the steps involved in making a basic assessment of an array; more detail and a guide to further measures follows in the next section.

In order:
I) map zones onto a grid of the array (zones include vegetation types, naturally bare areas and disturbance). Make sure that the zones are labelled and briefly explained;
II) it is efficient to simultaneously estimate cover per quadrat (in the core categories: overstorey (preferably split into main dominants); understorey; litter; bare; disturbed). Ideally this would be repeated for the heights of the main strata. (When estimating percent cover of understorey, litter, bare, and disturbed, it may help to assess these in several small squares placed at random throughout each half of the quadrat.)
III) use the scale at the bottom of the first quadrat sheet to group like vegetation types or zones as shown below. (In the example quadrats A1 to A3 group together as being similar and B1 to C3 form a different group.)

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*	A1	A1	A1	B2	B2	B2	B2	B2	B2
GROUP LIKE QUADS BY STATE	B2	B2	B2	B2	B2	B2	B2	B2	B2

This activity can be underpinned by use of a suitable version of Table 8.2.2.D, such as the following from Caraban trial sites.

MEASURE\/ / QUADRAT >	A1	A2	A3	B1	B2	B3	C1	C2	C3
OVER ALL	B2	B2	C3	B2	B2	C3	B2	C3	C3
NATIVE PLANTS TOTAL COVER *Adenanthos* (1)	B2	B2	C3	B2	B2	C3	B2	C3	C3
DISTURBANCE (2)	A1	A1	A1	A1	B2	B2	A1	A1	A1
TOPOGRAPHY (3)	MID	LOW	LOW	HIGH	MID	LOW	HIGH	MID	MID

It is not essential that all rows in the table are filled out, but it is important that the most predominant features are recorded and placed in order of relative bearing upon the type/identity or the state of the site. For instance, at the Caraban trial sites, in terms of:
i) type - all arrays were situated in mixed *Banksia* woodland but some could be further subdivided on the basis of the presence of understorey thickets of *Adenanthos* - so this is the most prominent feature affecting subdivision at the site based on type; and
ii) state - the next most prominent feature was disturbance and this could be used to group quadrats by state (taking precedence over topography).

IV) conduct a condition assessment on quadrat B2 using a range of attributes.
V) conduct a condition assessment using the same range of attributes *on each of the other quadrats that clearly diverge from B2 in state*. If most attributes are in the same state throughout the array and it is only a matter of a couple of attributes that differ between quadrats, it may prove simplest to use the same recording sheet to note the exceptions.
VI) if short of time, and in need of an alternative to V), or to finish the expanded condition process, fill out the row “group by like state” in the same way as illustrated under III). (In the example all quadrats are in a similar state to B2.)
VII) optional procedures for a range of quantitative or statistical or remote sensing purposes can be carried out at this point (see the following section). For instance, work with high resolution imagery for specific issues, may require individual GPS coordinates and/or mapping using the array as means of grid-referencing the locations.

8) ADDING OTHER FORMS OF ASSESSMENT

8.1) THREE WAYS OF ASSESSING EACH QUADRAT

The following table outlines the three main ways of utilizing each quadrat within the array.

8.1.1) WHOLE QUADRAT MEASURES (A)

There are four ways whole quadrats may be used; to:
a) create an index like ‘heterogeneity’ (8.2 below) using condition attributes or their combined value and correlating each of these with pixels from remote sensing;
b) create an index like ‘heterogeneity’ (8.2 below) using % cover and layers correlating each of these with pixels from remote sensing;
c) create an index like ‘heterogeneity’ (8.2 below) using any other quadrat-based measure and correlating each of these with pixels from remote sensing;
d) assess full plant diversity as outlined above in part 6.

8.1.2) 1 *OR* 2 DIAGONAL TRANSECTS (B)

The use of diagonal transects is a way of sub-sampling part of the quadrat.

These transects begin at the default NW & optional NE corners and rely on samples along each length. This is an effective way of sampling across the quadrats and of returning to the same place on successive visits; given that transects are pegged at their ends.

If point intercepts are recorded a basic idea of cover can be estimated and may be matched with visual estimates of percent based on the whole quadrat (though this may require conversion factors for canopy to foliage as the two forms of cover estimate may tend to emphasize one more than the other). If a link to remote sensing is intended the ratio of bark to foliage may be required to be calculated). The point samples need to fall into categories based on the strata in the vegetation, and other desired categories. (Strictly speaking this can be done with a vertically marked touch pole (Burrows & McCaw 1990), though this has its complications in terms of access, damage to thick undergrowth, and expediency.)

It is possible to assess the point intercept transect for whatever feature is required. For example grazer’s scats, grazed plants, animal disturbance such as digging and pathways, dead plants, stressed and diseased plants, etc.

Such point measurements may be suited to non-parametric or parametric statistical analysis if they are broken down into subsections that may be treated as sub-samples (eg every 5m). The sample number or the number of points available can be raised simply by shortening the interval between points (eg 25cm rather every 50cm).

The sample number available can also be raised by adding subplots – either along the diagonal transects or by nesting in the corners and center of the quadrat. Such multiple subplots allow statistics such as ANOVA to be used.

If subplots are required in order to get replication within the 25mx25m quadrat, then these can be placed along the transects at the intervals shown. Small bounded quadrats or virtual unbounded plots (often circular) can be placed at set intervals along the tape. For example 1mx1m may help refine sampling of understorey which is usually occurs at a higher density than overstorey, or a plot 1m in radius can be used for point assessment of the presence or absence of disease such as dieback and which can be matched with high resolution remote imagery if the coordinates are also recorded.

8.1.3) NESTED SUBPLOTS (C)

The use of nested subplots is a way of sub-sampling part of the quadrat.

This is done by placing sub-plots in each of the corners and at the centre of the 25mx25m is another way of getting coverage across the quadrat and achieving replication. (Multiple subplots allow statistics such as ANOVA to be used).

The size of the subplots will depend on the purpose. Subplots are typically a scale of magnitude less than the 25mx25m condition plot.

TABLE : Three main ways of utilizing each quadrat within the array based on: A) the whole quadrat; B) 1 *or* 2 diagonals; & C) nested subplots.

[* - includes strata (at least overstorey & understorey), litter, bare ground, and disturbance (age of disturbance will matter); ~ - point is an all or nothing judgement (a weakness of this is that straw-like articles can qualify as a contact point when their surface cover is in fact minute a means of adjusting for this is required); NW - begin at this corner; NE - begin at his corner; # n=3 or more suits statistics such as ANOVA.]

USE WITH 25MX25M QUADRAT (optional)	USE WITH 75MX75M ARRAY (optional)	LOCATION IN 25MX25M QUADRAT	METHOD	MEASURE/METRIC	PURPOSE	QUALIFICATION	APPLICATION TO QUANTITATIVE & STATISTICAL ANALYSIS	APPLICATION TO REMOTE SENSING	SAMPLE NUMBER *PER 25m QUADRAT* #
X	X (each quadrat)	A) Whole 25m quadrat	a) Condition assessment b) Visual estimation of % cover (by categories*) c) Other 1 quadrat = 1 pixel methods	a) Overall condition index *or* individual attributes. b) % cover c) Examples: heterogeneity index, disturbance index.			(low, insufficient subsamples per quadrat; better suited to an index of variation over the whole array)	X	n=1
(X)	(X)(central quadrat - as a check on this, unlikely for others)	B) 1 Diagonal transect (central quadrat NW)	Point intercept ~	% cover	Check on agglomerative quadrat estimate	conversion required of canopy to foliage	(possible depending on how points are subdivided)	X	n=68 (if point is every 50cm; n=136 if every 25cm)
(X)	(X) (central quadrat & *others in array only where features clearly differ*)			% cover	To establish strata & the degree to which they overlap (possible R-S application;)	Calculation is very *time consuming* & requires automating (needs ratios: canopy/foliage & bark/foliage)	N/A	X	n=68 (if point is every 50cm; n=136 if every 25cm)
(X)	(X) (central quadrat & *others in array only where features clearly differ*)		Circular subplots (eg 1m radius at 3m spacing along tape)	Observation of: presence/absence; cover; frequency; intensity. (If a quadrat is substituted then add density.)			X	X	n=10 (if subplot every 3m on transect)
(X)	(X)(central quadrat - as a check on this, unlikely for others)	B) 2 Diagonal transects of (central quadrat NW&NE)	Point intercept ~	% cover	Check on agglomerative quadrat estimate	conversion required of canopy to foliage	(possible depending on how points are subdivided)	X	n=136 (if point is every 50cm; n=272 if every 25cm)
(X)	(X) (central quadrat & *others in array only where features clearly differ*)			% cover	To establish strata & the degree to which they overlap (possible R-S application)	Calculation is very *time consuming* & requires automating (needs ratios: canopy/foliage & bark/foliage)	N/A	X	n=136 (if point is every 50cm; n=272 if every 25cm)
(X)	(X) (central quadrat & *others in array only where features clearly differ*)		Circular subplots (eg 1m radius at 3m spacing along tape)	Observation of: presence/absence; cover; frequency; intensity. (If a quadrat is substituted then add density.)			X	X	n=20 (if subplot every 3m on transect)
(X)	(X) (central quadrat & *others in array only where features clearly differ*)	C) Subplots nested in the corners & centre.	Square quadrats (eg 2mx2m or 4mx4m)	Plant counts/area = density. Any other measures required.			X	X	n = 5 (nested in the corners & centre)

8.1.4) TRENDS AND STATISTICAL ANALYSES OF TIME SERIES

If samples have been well replicated and the sample number is adequate statistical analyses may be required for the time series and the factors that may be exerting an effect on the vegetation.

Experiments looking at trends in factors are likely to use a Before-After-Control-Impact design (BACI; Stewart-Oaten et al. 1986). The BACI ANOVA (Analysis of Variance) was applied to a trial that included time (before fire, 6 months after fire), fire treatment (burnt, unburnt) and grazing treatment (grazed, ungrazed) (Reaveley et al 2009). Interaction terms for fire*grazing and time*fire*grazing were also included to test for a significant interaction between fire, grazing and time. A 3-way Analysis of Variance (ANOVA) was used. If a significant interaction was detected, results were interpreted using means and 95% confidence intervals and displayed graphically. All variables were examined for normality and heteroscedasticity using box plots, Q-Q plots and residual plots. Counts (vegetation structure) and litter depth were square-root transformed to meet assumptions of ANOVA. Variables recording percentage cover (vegetation cover, soil cover, litter cover, canopy cover), were adjusted by arcsine square-root transformation (Zar 1999).

The former approach uses parametric statistics which require the data to meet a range of assumptions; it is worth considering non-parametric alternatives such as the Friedman test (Zar 1999).

8.2) LINKING AN ARRAY TO REMOTE ASSESSMENT (INCL. CONDITION)

Much existing remote sensing work observes change - either in spatial pattern or with time at any given location on a pixel by pixel basis; a weakness of some of this work (especially change with time) is that it is either very coarsely linked to ground features or not linked at all.

There is a clear and present need to add more verification and meaning to spectral information in a consistent manner, that is to fill in the middle ground between ground work and remote sensing work on the same area, *and establish real links*.

The array has potential in this regard because a quadrat taken in isolation may not supply the appropriate information. For example, some parameters are particular to the identity of a given vegetation type (eg cover and height) and so data from one quadrat are not readily translated to condition assessment without the use of conversion weightings that are specific to a reference state of the vegetation type. However, quadrats within an array can be used collectively to establish contrasts, where data from each quadrat is compared with all the others, and correlated with remote sensing data.

<u>There are three main ways that an array may be employed in ground work to help make links to remote sensing they are to: A) recognise change; B) establish a sense of pattern; and C) recognise the identity of the vegetation</u>.

Observe that once B) & C) are established they too can be assessed for change.

8.2.1) RECOGNISING CHANGE

Much remote sensing work looks at the change in spectral images with time at the same location. This can show something is happening but in the absence of a ground link is not very “meaningful”. The meaningfulness of any link will depend on the characteristics that are selected and their intended application, and the degree to which they are related to the pattern and identity in the vegetation.

**The common remote-sensing indices should be incorporated here*.

8.2.2) ESTABLISHING A SENSE OF PATTERN

A general means of establishing a sense of pattern on the ground is to use a heterogeneity index; which is reliant on the use of an array.

This has the potential to be an adaptable, approach, suited to plugging in more than one meaningful and consistent measure collected on the ground *provided* it is drawn from a plot that is pixel-sized. *Essentially it is a technique that relies on the contrast of opposites. It can be used to pick up patchiness or the lack of it* overlaid on the background pattern in the vegetation/land unit/landscape element.

Within the current context this would employ:

- A 25mx25m condition quadrat as equivalent to a pixel *and* the collective information from an array of 9 such quadrats.
- Each of the quadrats in an array is scored for selected features and this in turn is used to make an index of diversity in the selected features (literally the number of *different* values per feature found across the array). The selected features may include:
  - The overall condition score. Note that this is not necessarily the best approach as it is relatively “fuzzy” due to it merging symptoms of separate attributes; which means underlying causes are being viewed “third-hand” rather than “second-hand” or directly.
  - Any pertinent individual condition attribute.
  - Any other pertinent individual metric.
  - Any combination of measures combined in a meaningful way. A potential range of measures is given in the following table***. A pertinent condition-based index might be the sum of the different plant diversity, structure, and soil stability scores (as outlined below; D = Sp + Sst + Sss; condition would need to be rated for the whole 9 quadrats per array);
- At the same location the equivalent array of pixels is given a coefficient of variance based on the spectral reflectance collected around the same time and under similar conditions to ground work.

Working with the array is more intensive than working with one quadrat. This is because it requires replication of sites and of measures. The replication is required at a site (the array requires 9 quadrats, rather than 1) and also, *preferably*, per vegetation type/target area (that is more than one array per vegetation type/target area). The degree of effort will also depend on the number of measures that are involved. *The whole exercise is likely to improve as the number of arrays installed in a given target area increases.*

Note that the heterogeneity approach is indirect matching because it matches and attempts to correlate the variation in an array of pixels with the variation in an array of quadrat. So a direct match of pixel to quadrat might return better correlations provided that pixels and quadrats can be accurately aligned.

An example of this sort of approach is provided by Fabricius et al (2002). They used a version of an array to link ground work and remote sensing in order to compare intact vegetated areas and alienated/fragmented areas (20mx20m quadrats in groups of 12). There were 10 such arrays at each location in vegetated and fragmented areas, and this paired arrangement was repeated 3 times. The geographic coordinates were recorded. The ground measures taken were: mean % cover of trees and shrubs in 5 categories; mean height of trees and shrubs in 5 categories; and the presence and type of a range of forms of disturbance.
The ground measures were put into a simple diversity coefficient
D=Sc+Sh+Sd;
Sc = the number of *different* vegetation cover classes in the array;
Sh = the number of *different* vegetation height classes in the array;
Sd = the number of *different* disturbance features in the array.
The reflectance spectra from each quadrat were put into a coefficient of variation for an array.
They found good correlation between the two measures.

The table presents some ground measures that *could* be taken at each quadrat in an array of 9 quadrats. Any of these might be used alone or in combination to create a simple diversity coefficient to compare to the coefficient of variation (CV) of reflectance for an array (**after Fabricius et al 2002**). This might be attempted in the original form or adapted by adding an understorey versus overstorey split (more unwieldy) and/or basic measures of pattern and of connection of the vegetation.

Table 8.2.2.A): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

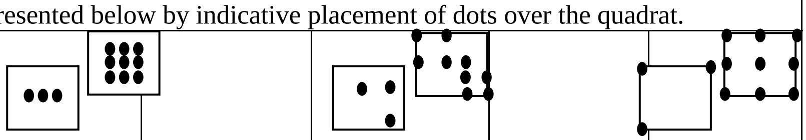
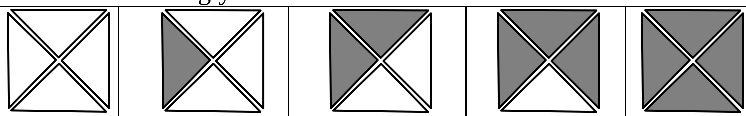
PATTERN - is there obvious clumping or is there very even distribution throughout? Default to intermediate if unsure. Basic pattern matching is represented below by indicative placement of dots over the quadrat.						
						
		Clumped	Converging	Intermediate	Separating	Dispersed
	Overstorey					
	Understorey (may be further split)					
CONNECTING - is there continuity between foliage in each of the quarters formed by the diagonals? Can climbing animals move through the canopy or midstorey interrupted by only small gaps (@10-30cm)? Count the number of quarters with a presence and score accordingly.						
						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey					
	Understorey (may be further split)					
THICKETS - does close proximity of growth forms create merged entities that provide refuge and continuous cover? Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey					
	Understorey					
ECOTONES - are there distinct interfaces between vegetation types in any of the quarters? Thicket/open interfaces are also relevant. Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey					
	Understorey					

Table 8.2.2.B): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

COVER (%) - record the cover category for each feature						
		1-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)					
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)					
	Bare					
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Disturbance3					
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0

TABLE 8.2.2.C): An example of a data sheet for a whole array that captures some of this sort of information.

	% cover	% cover		% cover	% cover		% cover	% cover
	A1 Live	A1 Dead		A2 Live	A2 Dead		A1 Live	A2 Dead
OS sp 1								
OS sp 2								
OS sp 3								
US								
Litter								
Bare								
Trunk								
	B1 Live	B1 Dead		B2 Live	B2 Dead		B1 Live	B2 Dead
OS sp 1								
OS sp 2								
OS sp 3								
US								
Litter								
Bare								
Trunk								
	C1 Live	C1 Dead		C2 Live	C2 Dead		C1 Live	C2 Dead
OS sp 1								
OS sp 2								
OS sp 3								
US								
Litter								
Bare								
Trunk								

TABLE 8.2.2.D): A way of recording which quadrats are alike for select factors in an array.

MEASURE\/ / QUADRAT >	A1	A2	A3	B1	B2	B3	C1	C2	C3
OVER ALL									
NATIVE PLANTS TOTAL COVER									
NATIVE PLANTS COMPOSITION									
NATIVE PLANTS DENSITY									
NATIVE PLANTS STRATA									
NATIVE PLANTS HEALTH									
WEED TOTAL COVER									
WEED COMPOSITION									
WEED STRATA									
DISTURBANCE (2)									
PROCESSES									
THREATS									
SOIL									
TOPOGRAPHY (3)									
ALTITUDE									
WATER GAINING AREAS									
SOIL GAINING AREAS									
RIPARIAN									
WETLAND									

Since it is not necessarily feasible to assess every quadrat for all attributes, a means of rapidly marking out which quadrats differ and in what respects is required, and such an arrangement is shown in the table above. It is intended that this complement full condition assessment (and preferably plant diversity) in at least the two most divergent quadrats in the array. More factors may need to be added to such a table and/or be made more explicit.

This sort of approach has the potential to address aspects of provision of "habitat" or a sense of architecture that is not readily covered by condition scales (see 5.6.2.3).

There are various other generic indices that are applied to vegetation assessment, and these need to be collated, tabulated and appendicised, as an aid to systematic development in this area.

8.2.3) RECOGNISING IDENTITY OF VEGETATION

The recognition of the identity of vegetation ought to be possible, by two means, namely by using high resolution spectral images or identifying spectral signatures.

High resolution images (for objects about 2m or less in diameter) are able to be interpreted by eye in the same manner as high resolution aerial photographs. This is suited to quite specific work at a site or locality scale (such as micro-lensing of dieback or identifying individual tree death due to drought). It may be best used as an interpretative tool to supplement work at a coarser resolution that is meant to be applied at a broad, landscape, scale.

Spectral work looks at the signatures of the main components of a vegetation type and is in an area of remote sensing referred to as "spectral un-mixing". *Systematic application of such an approach is likely to place strong demands on resources and be best suited to incremental implementation*.

The sort of information that might be acquired on the ground that might help this process includes:

- Establishing the actual composition of the vegetation in terms of cover of the most abundant and common species (which may reflect the proportion of a pixel with a given signature and aid correlation of ground and remote spectra);
- The use of a field spectrophotometer (such as the Fieldspec Pro) to establish the signature of key species.

This might be implemented incrementally for areas that are well understood by getting the spectral signatures of key dominants (such as jarrah, marri, blackbutt, bullich, wandoo and *Banksia grandis* and *B. littoralis* in the jarrah forest; and *B. menziesii*, *B. attenuata*, *B. ilicifolia* and *Eucalyptus todtiana* on the coastal plain). This would require considerations such as: several readings per plant (such as from the canopy at four compass points and the centre), separation of leaf and bark and live and dead, the signature of the ground surface, sampling at 4 times of year and 3 times of day, the interpretation of cyclic effects such as fire and drought, possibly the use of a cherry picker, and validation by testing the recognition of types outside the area of calibration.

9) GENERAL CONSIDERATIONS ON MONITORING & SAMPLE NUMBERS

The following is a general account of elements to consider when sampling in space and time.

9.1) CONSIDERATIONS THAT AFFECT THE NUMBER & LAYOUT OF SAMPLING SITES

There are a number of risks and limitations inherent in a monitoring scheme. There is a risk a monitoring scheme will not be placed in the exact location or set at the appropriate time that the symptoms of change manifest themselves. It is essential to employ the correct means of measuring change so accurate and relevant data is recorded. These risks can be reduced by increasing the intensity of sampling in space and time (greater site density and sampling frequency) and by employing every conceivable measure to ensure the change is recorded.

This is counterbalanced by the real constraints that exist on time and other resources. In the end there may have to be a simple call - in many cases it may be better to have some indication of change rather than none at all, and to clearly recognize the limitations.

The number of sites required will depend on:
A) the choice of monitoring options and whether it is a basic and limited approach, or a more a comprehensive approach.
B) the number of vegetation units being sampled and the level of plot replication required.

9.1.1) CHOICE OF MONITORING OPTION

Monitoring is taken to be the repeated assessment of the same measures at the same sites at different times.

A basic and limited approach refers to plots that were not set up with monitoring as the primary purpose. Most existing vegetation survey sites fall into this category. It is possible to follow trends through time at a single one of these sites by revisiting it. It may be that there are limits to the setup and measures that have been taken (as monitoring was not the primary purpose). It is also likely there is limited replication, with only one plot per vegetation type.

Basic sites will reveal a trend through time but it may be difficult to interpret what the change means with restricted measures and context.

A more comprehensive approach will have an initial design that is dedicated to repeated visits to sites and the revelation of trends. Sites are specifically dedicated to monitoring. These sites may have been carefully selected so that many peripheral issues that may have confounded monitoring have been excluded. These sets of sites should reflect similar conditions and share reasonable proximity (and so similar rainfall and climate), similar topography, geology, soil, hydrology, species, history (of fire and other disturbance), and any other processes and factors.

It is essential to maintain consistency throughout the monitoring process. This reduces the influence of controllable factors, improves clarity, and keeps the focus on change in environmental factors.

Factors that are controllable and can be held constant ideally include: the observers, return to the exact location, sampling methods, forms and record keeping. If a decision is made to change the way data are analysed and/or the rationale behind the analysis changes, the only way to ensure consistency is to re-analyse from the earliest point.

A comprehensive approach can be tailored to follow the consequences of disturbance or intervention in ecosystem processes, and it is likely to take the form of a trial or case study. This involves the application of sites with different purposes, namely reference, controls and test sites, and may require replication (to improve coverage).

Benchmark

A benchmark is a vegetation unit that describes the state of the vegetation unit prior to European settlement. This description is generated from existing standardised floristic and habitat data collected from reference sites, and/or elicited from experts with knowledge on vegetation units. A benchmark is usually taken as the desired end state for study areas. A benchmark may also be ‘virtual’ i.e. based on the median derived from the assessment of a vegetation unit over a period of years.

Reference site

A reference is the best-on-offer (BOO) representation of a benchmark. BOO areas usually lack more recent pressures by virtue of their isolation, remoteness or a form of active exclusion of factors such heavy grazing.

Control site

The control is the matching pair to the test site; a comparative site where no intervention will take place. Such sites are deemed to show the changes that would occur without intervention. They are not necessarily as removed from ‘adverse’ change as a benchmark. A control can be considered a barometer of background patterns such as prevalent climatic cycles and hydrology.

In some situations an ethical dilemma may arise about the use of a control. It is conceivable that there is too little of an area remaining and/or the potential for further harm is too great to allow any further deterioration of a trial area by simply doing nothing. In such circumstances the precautionary principle invites intervention.

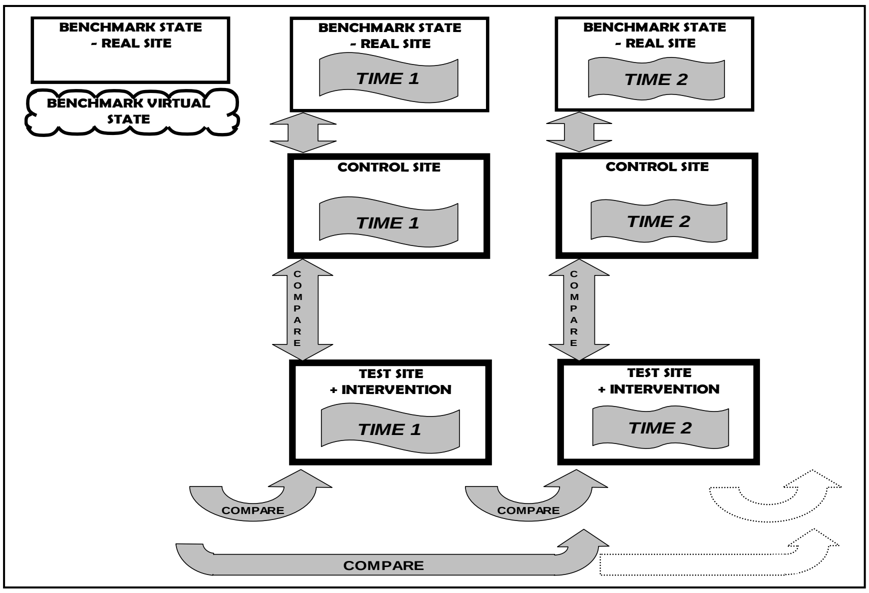
Test site

A test site is the matching pair to the control site; the site where the intervention or 'treatment' will take place. Such intervention usually takes the form of the application or removal of pressure.

In practice more than one environmental intervention may be required to address more than one factor. Consequently the trial format and analysis can get more complicated and analysis may require more complex statistical analysis. In many ecological settings, and given finite resources, such design is unlikely to prove practicable.

The basic paired arrangement of a control and test can be applied with two plots, two transects or two lines of plots arrayed along a landscape gradient. (In the increasingly unlikely situation where a reference state exists in a suitable range of situations then the pairing would be the reference-control and test.)

Figure 1: The comparative roles of test and control sites, and their relationship with a reference benchmark



9.1.2) NUMBER OF VEGETATION UNITS BEING SAMPLED

The number of vegetation units being sampled is a guide to the minimum number of sites required. A basic approach will employ one site per unit, so if there are 2 units there will be 2 sites. A comprehensive approach will employ the paired arrangement of a control and test site in much the same way, so in the case of 2 vegetation units there will be 2 test and 2 control sites, or 2 test-control pairings.

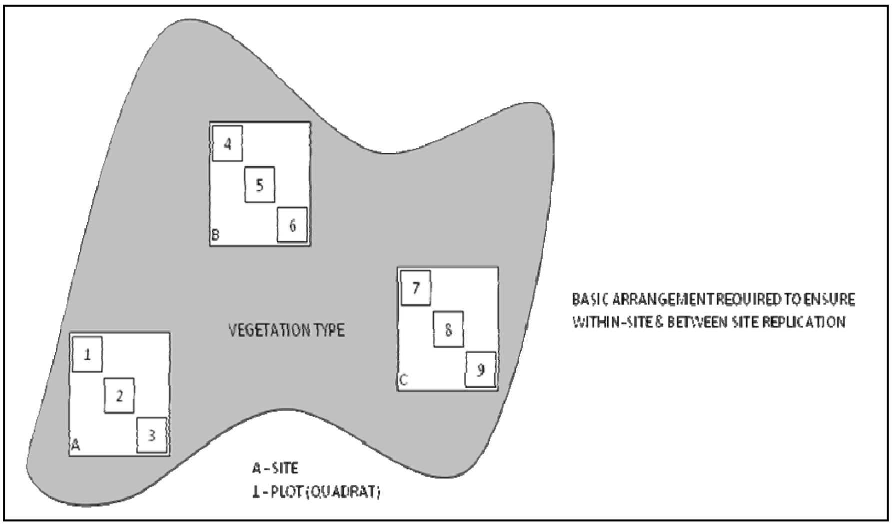
9.1.3) THE LEVEL OF PLOT REPLICATION REQUIRED

Wherever possible it is desirable to build on the basic one plot per vegetation unit and to raise the number to improve coverage within the unit.

There is of course a tradeoff, the broader the coverage of area required the harder it will be to incorporate a high level of replication.

Replication also becomes increasingly important as an element of manipulation is introduced, such as managed intervention in ecosystem processes. Replication applies between-sites and within-sites. Increasing the number of sites in a vegetation unit is an example of increasing between site replication. Installing subplots is a means of having within site replication. In an optimum arrangement both will be taken into account. A basic arrangement that takes into account between and within site replication is given in the table and figure.

Desirable basic number of:	CONTROL	TEST
Samples per species per site	n = 3 (minimum) [preferred n ≥ 30]	n = 3 (minimum) [preferred n ≥ 30]
Plots within 1 site	n = 3 (minimum) [preferred n ≥ 30]	n = 3 (minimum) [preferred n ≥ 30]
Sites within a vegetation type	n = 3 (minimum) [preferred n ≥ 30]	n = 3 (minimum) [preferred n ≥ 30]



Note that a high number of replicates within a site without replication of whole sites within a vegetation unit is called “pseudo-replication” and can be a fundamental error.

The following is an example of the total number of sites required for each choice of monitoring option based on two vegetation units, and with basic replication of 3 sites* (assuming time and resources allow this).

	Basic	Comprehensive
Vegetation units	2	2
Monitoring site options	1	1 benchmark / unit 1 control / site 1 test / site
Replication per unit (# control + test sites)	1 (no replication)	3*
Total # of sites	2	[2xbenchmark] + {([2xcontrol] + [2xtest])x3} = 14

9.2) TIMING OF SAMPLING

The timing of sampling needs to be:

i) relatively simultaneously for every set of linked sites; essentially within the same season and preferably the same bracket of rainfall and other short-term climatic conditions.

ii) within a relatively close interval for all the sites in a particular trial for the same reasons.

iii) repeated at the same time of year; usually with regard to the season/s that deliver/s the regional rainfall. This is particularly important as the intervals increase between sampling periods; that is to a number of years as the scheme matures. (In the early stages it may be prudent to begin with quarterly sampling. In some situations it is desirable to sample more than once in a season because not all species are necessarily emergent, flowering or reproducing at the same time. Several visits are warranted in areas with sequential flora such as the claypans of the Swan Coastal Plain or on other heavy soils such as cracking clays in other areas.)

iv) able to accommodate seasonal factors that affect both plant species and remote sensing opportunities. The coordination of both on-the-ground measures and remote measures may mean that fieldwork will occur at more than one time of year. This is outlined in the following table.

	Ground Truth - Vascular Plant Diversity	Remote sensing & matching Ground Truth during growing season	Remote sensing & matching Ground Truth during dry season (max plant stress)
Southwest	Spring	Winter/Spring	Summer
Semi-arid to arid areas south of summer rainfall line	Capricious – 1 to 2 months after major rainfall (trending winter)	Capricious – 1 to 2 months after major rainfall (trending winter)	End of dry season/Summer (before period most likely to produce any summer rain)
Semi-arid to arid areas north of summer rainfall line	Capricious – 1 to 2 months after major rainfall (trending summer)	Capricious – 1 to 2 months after major rainfall (trending summer)	End of dry season/Summer (before period most likely to produce any summer rain)
Kimberley – wet-dry tropics	Near the end of the Wet Season & Multi-season 1 to 2 months after capricious rain	Near the end of the Wet Season & Multi-season 1 to 2 months after capricious rain	End of the dry

Resolution of both groundwork and remote work may improve if the influence of the local climatic cycle is better understood. For instance being able to recognize divergence from average rainfall, a clear idea of what constitutes a significant rainfall event for plant growth and/or flowering, and remote sensing near the end of drought. Key considerations for remote sensing are likely to include the times of year that are least likely to have cloud cover, smoke, and other air-borne particulate matter such as dust.

9.3) FREQUENCY OF SAMPLING

The sampling interval that is set will depend very much on the purpose. If work is for the purposes of basic vegetation condition assessment sampling in the correct season for the vascular plants at a spacing of 5 year intervals may be sufficient. If it is in order to conduct comprehensive work so as to capture most of the detail in plant species diversity (such as the early phases of calibration of the approach) it will require sampling in the optimum season/s and this is best achieved by quarterly sampling in the first year, biennial sampling in the second, once a year up to the fifth year, and then longer intervals after that (say every 5 years, or as seems appropriate given early results).

A workable compromise may be to conduct detailed work only intermittently at a site and to rely on basic measure for most of the intervening time. For instance sample comprehensively in the first year, including condition assessment. Then make a condition and photographic assessment in the next three years. Then sample intensively again in the fifth year.

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APPENDIX 1: LIST OF ATTRIBUTES FOR A SHORT ASSESSMENT

1	NATIVE PLANT SPECIES COMPOSITION	
2	STRUCTURE OF VEGETATION	
3	RECRUITMENT	
3	HEALTH	
3	DEATH	
4	STABILITY	
4	LITTER	
4	BIOTURBATION	
5	WEEDS	
6	OVERALL DISTURBANCE	
6		EROSION/DEPOSITION
6		CORRIDORS
6		CLEARING
6		RESOURCE EXTRACTION
6		OTHER SURFACE DISTURBANCE
6	A) WATERLOGGING OR B) DROUGHT	
6	SALINITY - SECONDARY	
6	HARVESTING	
6	FERAL ANIMALS	
6	TOTAL GRAZING	
7	FIRE	

IN THE FOLLOWING A MINIMUM SET IS INDICATED BY ◊ AND THE DATA SHEETS CAN BE FOUND IN SECTION 5.2.

THIS FORMAT MAY BE SUITED TO A FLIP-CHART FOR FIELD USE.

How the Keighery scale aligns with the current scales (this is an aid to consistent format for comparison & storage).

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Keighery Condition Scale (Keighery 1994)	**Completely Degraded** *[completely # is better here & such a split improves alignment]*	**Degraded II** The structure of the vegetation is no longer intact and the area is *[completely #]* or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.	**Degraded I** Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; &grazing.	**Good** Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; & grazing.	**Very good** Vegetation structure altered; obvious signs of disturbance For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; & grazing.	**Excellent** Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species	**Pristine** Pristine or nearly so, no obvious signs of disturbance.

Short scale for quick assessment (this is recommended for consistency with this document).

Order of priority (Semi-sequential & independent)	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Structure of vegetation	Complete absence of native plant species and either loss of the soil or long-standing barriers to recruitment from seed.	Widespread loss of layers.	One or more layers missing or frequently & repeatedly removed.	All layers present, but some may be sparse or discontinuous.	All layers present, with minor modification.	All layers present.	Complete absence of any measure of influence from post-settlement activities.
Plant composition.		Many species missing.	Several species diminished/missing.	One or more species diminished	At least one species diminished.	Full range of native species present.	
Disturbance &/or weeds (Converse is soil seed bank integrity)		High level <> Extensive area (consolidated) <> Repeated/ongoing (frequent)	Mod/high level <> Growing area (melding) <> Intermittent (sporadic)	Moderate level <> Limited area (scattered) <> Single incidence (infrequent)	Mod/low level <> Minor area (isolated) <> Single incidence (infrequent)	Low level	
Recruitment		No seedlings <> No saplings	Scarce or no seedlings <> Scarce or no saplings	A few species have isolated seedlings <> A few species have isolated saplings	Several species have few seedlings <> Several species have a few saplings	Several species have several seedlings <> Several saplings	

CONDITION SCALES - COLOUR CODE FOR DISPLAY

The set of five categories is readily graded into a grey-scale or colour spectrum for the purposes of display. It may require the categories alienated and pristine to be defined in a complementary and contrasting way to provide full context.

Standard colour code for the 5 central categories for GIS (greyscale - colour blind friendly).

		VERY DEGRADED **0%**	**DEGRADED** **25%**	**GOOD** **50%**	**VERY GOOD** **75%**	**EXCELLENT** **100%**	

Standard colour code for the 5 central categories for GIS (colour - colour blind friendly).

		VERY DEGRADED	**DEGRADED**	**GOOD**	**VERY GOOD**	**EXCELLENT**	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
◊							
Native plant species composition (Note: 1) record if fire happened recently & composition is un-interpretable; use n/a.)	Native species depleted <> 0% native plant composition	Few remaining native species <> Typical dominants & faithful species scarce. <> >0-20% native plant composition.	Less than half of the original complement of native species present <> <> >20-40% native plant composition.	Around half the original complement of native species present <> Some typical dominants or faithful species declining or scarce. <> >40-60% native plant composition	More than half of the original complement of native species present <> <> >60-80% native plant composition	Native species at full complement, minor evidence of impacts) <> Typical dominants & faithful species common. <> >80-100% native plant composition	Native species at full complement, (abundance and vigour). <> <> 100% native plant composition
Native plant species composition form VAST		<> Dominant structuring species present. Many other species missing.	<> Dominant structuring species present. Several species diminished/missing.	<> Dominant structuring species present. One or more species diminished.	<> Dominant structuring species present. At least one species diminished.	<> Dominant structuring species present. Full range of native species present.	
◊							
Structure of vegetation *(VAST shown in italics)* (Note: 1) layers may also be taken as growth-forms & age classes of species; 2) if change is subtle & it is unclear if natural patchiness or impacts are the cause default to "very good"; 3) record the cause if the state is due to "natural" cyclic & random events; 4) record if fire happened recently & structure is un-interpretable; use n/a.	Structure depleted. Loss of diverse layers.	Structure greatly altered. Widespread loss of layers. (loss of: i) several layers in a multilayer unit or ii) near loss of the main layer in a one layer unit.) <> *Several layers frequently & repeatedly removed.* <> Dominant structuring species likely to be affected.	Structure partially altered. One or more layers missing. (Community may lack shrub & ground cover species) <> *At least one layer frequently & repeatedly removed.* <> Dominant structuring species may be affected.	Structure basically intact, impacts evident. All layers present, but may be sparse. <> *At least one layer thin or discontinuous.* <> Dominant structuring species unlikely to be affected.	Structure intact, early signs of impacts. All layers present, with minor modification. <> *At least one layer somewhat diminished.* <> Dominant structuring species unaffected.	Structure intact, verging on pristine. All layers present.	Structure pristine
Extent of disturbance at site.		Disturbance high.		Disturbance moderate.		Disturbance minimal.	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
◊							
Recruitment Consider: Seedlings; Saplings; Balance in the population age/stage arrangement: Whether cohorts of plants that have not yet set seed are present. Note: Senescence chiefly in woody species.		Low to no recruitment <&/or > No seedlings. <> No saplings. <> Most species appear senescent. <> Extensive soil disturbance (pervasive &/or repeated) or loss. Probable soil seed reserve is depleted. <> (high weed presence)	Mod to low recruitment (scarce) <&/or > Scarce or no seedlings. <> Scarce or no saplings <> Several populations / species appear senescent. <> Growing soil disturbance. <> (mod weed presence)	Moderate recruitment (localized) <&/or > A few species have isolated seedlings. <> A few species have isolated saplings <> Populations of some species *may* be senescent. <> Limited soil disturbance. Soil seed reserve may be intermittently replenished. <> (low weed presence)	Mod to high recruitment. (common) <&/or > Several species have a few seedlings. <> Several species have a few saplings. <> Limited senescence & reproductively mature. <> Minor soil disturbance. <> (low / no weed presence)	High recruitment (widespread). <&/or > Several species have several seedlings. <> Several species have several saplings. <> Limited senescence & reproductively mature. <> Soil intact. Soil seed reserve is likely to be steadily replenished. <> (weeds absent)	Regeneration occurring in the appropriate timeframe. <&/or > Likely a varied range of ages/stages throughout the localized area (incl. mature). <> Limited senescence & reproductively mature. <> Soil & soil formation intact. The soil seed reserve is likely to be being steadily replenished.
◊							
Health - General Of key species (esp. mature individuals). % plants with significant health problems (foliage loss, canopy decline, stem lesions, etc). Cause of stress, if known Trees/ mallees Symptoms __________ Cause _____________ Shrubs Symptoms __________ Cause _____________		High impact. (Severe stress.) <> State of species. Most individuals - of - Most prone species <> State of individuals - Many severely damaged, dying or dead.	High to moderate impact (Advanced signs of stress) <> State of species. Many individuals - of - Several species. <> State of individuals - Extensive damage incl: Most leaves damaged (or few left). Crown fragmented. Many canopy branches dead; One or more dead stems; Resprouting from damaged parts.	Moderate impact (Signs of stress.) <> State of species. Several individuals - of - Few species. <> State of individuals - Minor/moderate damage. Some leaves dead/dying. Minor branches damaged. Crown intact. Main limbs intact.	Low impact (Early signs of stress.) <> State of species. Isolated individuals - of - Few species. <> State of individuals - Minor damage. Some leaves damaged. Minor branches ~intact. Crown intact. Main limbs intact.	Majority healthy (Background levels) <> State of individuals - No obvious leaf or woody damage. *(or minority of each leaf 's surface affected*)	Majority healthy
◊							
Death of key species (especially of mature individuals).		High incidence. <> Most individuals - of - Most species.	Mod/high incidence. <> Many individuals - of - Several species.	Moderate incidence. <> Several individuals - of - Few species	Low incidence. <> Isolated individuals - of - Few species.	Limited death <> Deaths scarce, uncommon.	Deaths scarce, uncommon.

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Surface stability Contributing factors to a consolidated soil surface such as root mats (surface roots); fibre; humus; cryptogams; blue-green bacteria; oxide crusts. (Exclude naturally bare areas; eg outcrops, sand, dunes, riverbeds.) (Disturbance includes: earth movement; trampling; erosion & weeds)	None	Heavy disturbance to structure. _______ Low content	Moderate to heavy disturbance _______ Low to moderate content of surface roots & stems. <> Low to moderate organic matter present <> Low to moderate development of upper crust	Moderate disturbance to structure. _______ Moderate content	Moderate to low disturbance _______ Moderate to high content of surface roots & stems. <> Moderate to high organic matter present. <> Moderate to high development of upper crust	Surface seems stable. Little evidence of disturbance to structure. _______ High content	
Litter (May be rated as not applicable to naturally bare areas; eg outcrops, sand, dunes, riverbeds.) NB: b) *Diverse components are a mix of bark, leaves, twigs, branches (+/- debris-* larger material such as logs of >10cm) c) Exotic cover is often mostly from ephemeral, herbaceous, weeds.	a) stability b) *fauna habitat* c) exotic contribution d) *fire* e) presence of fungal hyphae (diverse invertebrates)	Generally: Litter loosely strewn on surface. Light. (Recent fall) <&/or> Litter not stabilizing the surface <> No contribution of debris to cover <> Tending to dry out in soil surface <> *Few components from few plant layers & species* *(plant layers lost)* <> Total cover by exotic litter; even smothering. <> *After fire litter is uniformly removed.* <> no fungal hyphae a single species of invertebrate profuse	*After fire litter persists in patches(few, little area).*	At least in places: Litter accumulation in pockets. (Intermediate age) <&/or> Litter partially stabilizing the surface. <> Some contribution of debris to cover <> Some parts are protected from drying. <> *Range of components from a range of plant layers & species (plant layers +/- diminished)* <> Moderate cover of exotic litter (+/- thick patches) <> *After fire litter persists in patches(several, moderate area).*	*After fire litter persists in patches (several, moderate to high area).*	At least in places.: Litter firmly integrated into top layer. Thick. (Long-standing buildup) <&/or> Litter stabilizing the surface <> Debris firmly part of cover & decaying <> Tending to retain moisture in soil surface <> *Diverse components from diverse plant layers & species* *(plant layers intact)* <> Little cover of exotic litter (sparse) <> *After fire litter persists in patches (many, much of area)* <> fungal hyphae in litter several invertebrate species in litter	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Bioturbation (Observe the nature, complexity, & processes) Backup to surface stability. Focuses on: a) primarily ants, then termites, (then other soil invertebrates); & b) vertebrates. [a) & b) may need to be split.]	a) soil invertebrates	Only one species of ant predominant and likely exotic <> Termites present (may be 1 species) <> No other soil invertebrates present (after intensive searching) or one species predominant & likely exotic		2 species of ant observed <> Termites present (1 or more species) <> 1 or more soil invertebrates present		2 to several species of ants observed (look for differences in nests & in worker size & shape) <> Termites present (2 or more species) <> Several groups of other soil invertebrates present	
	b) vertebrates	Vertebrate activity may include ferals. +/- FERAL SPECIES <> Activity intense, &/or large in area. <> Heavy disturbance to surface / sub-surface / roots High density of faeces		Activity of one to two vertebrate species NOT FERAL SPECIES <> Activity moderate &/or moderate in area. <> Moderate disturbance		Activity of several vertebrate species NOT FERAL SPECIES <> Activity low/diffuse &/or small in area. <> Little disturbance to surface / sub-surface / roots Low density of faeces	
Weeds	Completely disturbed Complete weed cover / dominance	Weeds common in area, replacing native species <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <90-60%	Balance tipping to weeds <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <60-30%	Weed presence building, under equity (+/- spot occurrences) <&/or> Many individuals, (few to several species). <&/or> Cover/abundance of weeds <30-15%	Weed presence low <&/or> Several individuals, (few to several species). <&/or> Cover/abundance of weeds <15-2%	Weeds scarce, uncommon (or absent) <&/or> Few individuals, (1 (to 2) species) - only in disturbed pockets <&/or> Cover/abundance of weeds <1%	Weeds absent Cover/abundance of weeds 0%
Overall disturbance (to the soil surface.) (This opposes soil seed bank integrity)		High level <> Extensive area (consolidated) <> Repeated/ongoing (frequent)	Mod/high level <> Growing area (melding) <> Intermittent (sporadic)	Moderate level <> Limited area (scattered) <> Single incidence (infrequent)	Mod/low level <> Minor area (isolated) <> Single incidence (infrequent)	Low level	.

THIS ATTRIBUTE IS AN ALTERNATIVE TO THE NEXT TWO PAGES

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Erosion/deposition due to disturbance / changed land use a) Erosion of soil Overtaken by wind (eg blowout) or water (gullying & sheet) erosion. <&/or> b) Depostition of sediment Overtaken by wind (eg dune-like) or water (sediment) deposition. State which __a_or_b__		Severe Extensive (consolidated) <> (eg >50% of site)	Moderate to severe Growing (melding) <> (eg >15-50% of site)	Moderate Limited (scattered) <> (eg >5-15% of site)	Minimal Minor (isolated) <> (eg 0-5% of site)	Low to none	
Infrastructure disturbance corridors - characteristics FORMAL: Roads, Service corridors (rail, power – gas & electric) surface drainage & sub-surface drainage fencing & walls INFORMAL: Tracks; Off-road vehicle disturbance; Paths & recreation Note which points apply: a) b) c) d)	a) b) c) d)	Density high <&/or> Strong barrier – wide &/or heavy traffic <> Substantial foundations & compaction Surface hydrology disrupted Soil movement /formation disrupted <> Very regularly renewed & maintained	Density mod to high <&/or> Mod to strong barrier – either wide or heavy traffic <> Some foundations & compaction Surface hydrology altered Soil movement/formation altered. <> Regularly maintained	Density moderate <&/or> Moderate barrier – mod width &/or mod traffic <> Some foundations & compaction Surface hydrology intact Soil movement/formation intact <> Rarely maintained	Density low <&/or> Weak barrier – narrow &/or low traffic <> No foundations & Little compaction Surface hydrology intact Soil movement/formation intact <> No recurrent disturbance		
Clearing (The focus here is on clearing of vegetation rather than soil.)	Totally cleared	*Heavy clearing*. <> Longstanding <> Repeated/ongoing (frequent) <> (eg >50%)	Partial (*to heavy*) clearing. <> Intermediate in age (or a mix of old and new) <> Intermittent (sporadic) <> (eg >15-50%)	Partial clearing. <> Recent (≤2 years) <> Single incidence (infrequent) <> (eg >5-15%)	*Little clearing*. <> Recent (≤2 years) <> Single incidence (infrequent) <> (eg 0-5%)	*Little or no clearing*	*No clearing*.

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
Resource extraction (Soil surface generally cleared) Mining______________ Construction__________ Material ______________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________	Dominant <&/or> Removed to C horizon Landscape processes may be disrupted	High impact Extensive (consolidated) <&/or> A horizon removed <> (B horizon removed) <> (C horizon removed) <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <&/or> A horizon removed in part <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <&/or> A horizon disturbed <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction	
Other surface disturbance (Due to stock, feral animals, or machinery)	Dominant	High impact Extensive (consolidated) <> A horizon disturbed repeatedly/frequently <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <> A horizon disturbed intermittently <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <> A horizon disturbed infrequently <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
◊							
a) Waterlogging (usually seasonal) or b) Drought Record if a) or b).	Most of site affected	>50% of site affected a) Waterlogging - swamp tolerant plants have replaced original species. <or> b) Drought - Graveyard death of overstorey (and perhaps some deep-rooted understorey)	10-50% of site affected Waterlogging Pockets of dead local plants, swamp tolerant plants replacing original species. <or> Drought - Whole patches with dead overstorey (and perhaps some deep-rooted understorey).	<10% of site affected Waterlogging Scattered individual plants stressed or dying <or> Drought - Scattered individual overstorey plants stressed or dying.	Site little affected Isolated individual plants may be stressed.	Site unaffected	
◊							
Salinity - secondary P/A ________________ *Proximity of (secondary) salt outbreak to drainage line* FRAGMENTED CHARACTER	*(Proximity) Riparian* <&/or> (Secondary) Salt outbreaks at site – severity high [‘S3’] Heavily impacted. Invasive salt tolerant plants have replaced original species.	*(Proximity) <200m* <&/or> (Secondary) Salt outbreaks at site – severity moderate [‘S2’] Moderately impacted. (May be) Salt tolerant plants replacing original species.	*(Proximity) <500m* <&/or> (Secondary) Salt outbreaks at site – severity low [‘S1’]	*(Proximity) <1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity high [‘S3’]	*(Proximity) >1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity moderate [‘S2’]	*Distant (or only primary-with intact diversity)* [+] <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity low [‘S1’]	*Absent (or only primary with intact diversity)* [+] <&/or> No (secondary) salt outbreaks
◊							
Harvesting of biomass a) Logging b) Firewood, fencepost & craft wood removal c) (Wildflower		Heavy ________________ Ongoing logging. <> Several rounds of logging evident. <> Mix of small, medium & larger older stumps, may be evident. <> Most trees of small diameter. (+/- young) <> Multi-stemmed coppicing from stumps common. <AND/OR>_______ Area denuded. Likely recent & regular (sawdust & cuts). <AND/OR>_______ Uniform and heavy	Moderate to heavy ________________ Ongoing logging. <> More than one round of logging evident. <> Mix of small, medium & larger older stumps, evident. <> Most trees of small diameter. (+/- young) (eg ≤15cm) <> Multi-stemmed coppicing from stumps common <AND/OR>_______ <AND/OR>_______	Moderate ________________ Logging relatively recent, and may be ongoing. <> More than one round of logging evident. <> Mainly medium stumps (/logs). <> Mix includes trees of medium diameter. (eg 30-40cm) <> Multi-stemmed coppicing from stumps evident. <AND/OR>_______ Select sizes and patches of logs & stumps removed <AND/OR>_______ Patches harvested	Limited to moderate ________________ Some time since logging occurred. <> More than one round of logging evident. <> Mix of medium & old & large stumps. <> Scarce trees of larger diameter. (eg ≥50cm) <> Scattered multi-stemmed coppicing from stumps <AND/OR>_______ <AND/OR>_______	Limited. ________________ Long-past logging. <> Only one round of logging evident. <> Mainly scattered old & large stumps. <> A few trees of larger diameter (+/- mature) <> Trees generally single stemmed. Little multi-stemmed coppicing from stumps. <AND/OR>_______ Logs, stumps, & debris present. Likely old & irregular. <AND/OR>_______ Scattered light	Likely no history of harvest ________________ No logging. <> Some trees of larger diameter. Mature or maturing trees are present in the population. ________________ ________________

harvesting)		harvesting				harvesting	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
◊							
Feral vertebrate animals present. Indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens/warrens.		Recent ≥ old activity <&/or> Present throughout <> High intensity <> Several species Several signs/species <> (eg>50% cover)	Recent & old activity <&/or> Activity across the site <> Moderate to high intensity <> Several species Few signs/species <> (eg >15-50% cover)	Old & recent activity <&/or> Activity scattered <> Moderate intensity <> 1 (to 2) species 1 (to 2) signs/species or 1 species several signs <> (eg >5-15% cover)	Very old activity <&/or> Activity isolated <> Moderate to low intensity <> 1 species Few signs <> (eg 0-5% cover)	No activity	Absent - no history of feral intrusion.
◊							
Total Grazing Note overgrazing from all sources (stock, feral & native) ___________ (If stock or feral animals are present italics may apply).		Grazing heavy. <> Most species grazed. (Mainly unpalatable species grazed) <> Individual plants heavily pruned. <> Regeneration from seed little or none. <> Most of area damaged (eg >50%); intense. <> *Soil surface highly disturbed.*	Grazing moderate to heavy. <> Many species grazed. Regeneration from seed little or none. <> Much of area damaged (eg >15-50%); intense. <> *Soil surface moderately disturbed.*	Grazing moderate. <> Several species grazed. (Some unpalatable species grazed) <> Individual plants moderately pruned <> Generally seedlings affected. <> Little of area damaged (eg >5-15%). <> *Soil surface slightly disturbed.*	Grazing low to moderate. <> Several species grazed. Some seedlings affected. <> Minor area of damage (eg 5-0%). <> (*Soil surface little disturbed*)	Grazing at appropriate levels. <> Select species grazed (Mainly palatable species grazed) <> Individual plants lightly pruned <> Few seedlings affected. <> Grazing spread evenly / less evident. <> (*Soil surface intact*)	Grazing at appropriate levels. Even spread permits vegetative and seedling regeneration. <> Grazing spread evenly.

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
FIRE FREQUENCY RISING & INTERVAL CONTRACTING Fires usually of low intensity.		Fire very frequent.	Fire frequent.	Fire becoming frequent.	Fire interval variable.	Fire interval range suits vegetation type/s. (This includes patches within them.)	
Fire scars on woody dominants. (Such as dead branches & hollowed-out stems.)		Most scars recent. Many dominants with scars.	Most scars recent. Several dominants with scars.	Most scars recent. Occasional dominants with scars.	Scars vary in age; old scars still evident. Few scars.	Scars vary in age;	
Fire-related death of woody plants		Death of many plants from several species.	Death of individuals of one or more species.	Some death may occur.	No deaths.	Mixed: In older patches limited death, in recently burnt patches more.	
Small-scale uniformity and openness of vegetation (***<u>mainly understorey</u>***).		*Tending uniform.* Uniform - strongly. <> Very open. All lower layers. (Accessible, no thickets). <> Fire & ≥ 1 other disturbance	Uniform - fairly. <> Open. Most layers. <> Fire & ≥ 1 other disturbance	Mottled - slightly. <&/OR > Plus 1 patch <> Plus one clump of unburnt, older plants <> Patches Confined <> Open (> denser) 1 or 2 layers. <> Fire & 1 other disturbance	Mottled - partly. <&/OR > Plus 2 patches <> Plus some clumps of unburnt, older plants. <> Patches spreading <> Open to denser <> Only fire - no other disturbance	*Patches ~ evident.* (*irregular*) Mottled -fully. <&/OR > Plus ≥ 2 patches <> Plus many or big clumps of unburnt, older plants. <> Patches Spread-out <> Denser & open ('long' unburnt & recently burnt). <> Only fire - no other disturbance	
Presence of epicormic or basal sprouts on trees/woody plants; fire-related (not due to other causes eg drought). Understorey regrowth (greener, young & vigorous.)		Sprouts common. Much recent regrowth.	Sprouts occasional. Some recent regrowth.	Sprouts rare. Little recent regrowth.	Foliage generally healthy.	In older patches sprouts absent. In recently burnt patches sprouts present. In older patches regrowth absent. In recently burnt patches regrowth present.	
Biomass stored in vegetation. Plant litter.		Limited biomass. Little litter, thin cover. Large logs nearly burnt away. Low humus.	Low to moderate biomass.	Moderate biomass. Moderate litter. Moderate debris, including logs. Moderate humus.	Moderate to high biomass.	In older patches high biomass. In recently burnt patches low biomass. In older patches high litter, debris & humus levels. In recently burnt patches low litter, debris	

						& humus levels.	
Presence of perennial seeder species. Presence of senescence.		Many species may no longer be present. (No senescence.)	Few species nearing maturity. (No senescence.)	Many species nearing maturity. (Little sign of senescence.)	Many species are mature & able to reproduce. (Little sign of senescence.)	In older patches most species are mature & able to reproduce. In recently burnt patches fewer species are ready to reproduce. (Likely signs of senescence; in older patches.)	
Presence of fire-ephemeral and ephemeral species. CONUNDRUM – frequent fire suits fire-ephemerals but at expense of other species.		Ephemerals abundant after fire.	Ephemerals becoming common after fire.	Ephemerals occasional after fire. Chance to reproduce increasing.	Ephemerals present after fire. Little patchwork.	Ephemerals present after fire. In older patches ephemerals may be absent or only in the soil seed reserve. In recently burnt patches ephemerals are likely to be present.	

	ALIENATED	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	PRISTINE
FIRE FREQUENCY DECLINING & INTERVAL EXPANDING Fires usually of high intensity.		Fire very infrequent.	Fire infrequent.	Fire becoming infrequent.	Fire interval variable.	Fire interval range suits vegetation type/s. (This includes patches within them.)	
Fire scars on woody dominants. (Such as dead branches & hollowed-out stems.)		Scars very old. or Scars absent.	Most scars old. Very few scars.	Most scars aging. Occasional scars.	Scars vary in age. Few scars.	Scars vary in age. (Balance of recent & older burning).	
Fire-related death of woody plants		No death.	Little or no death.	Some death may occur.	No deaths.	Mixed: In older patches limited death, in recently burnt patches more.	
Small-scale uniformity and openness of vegetation. (***<u>mainly understorey</u>***).		*Tending uniform.* Uniform - strongly. <> Very dense. All lower layers. (Inaccessible thickets. Possible senescence.) <> Fire & ≥ 1 other disturbance	Uniform - fairly. <> Dense. Most layers. <> Fire & ≥ 1 other disturbance	Mottled - slightly. <&/OR > Plus 1 patch <> Plus one clump of burnt, younger plants <> Patches Confined <> Dense (>open) 1 or 2 layers. <> Fire & 1 other disturbance	Mottled - partly. <&/OR > Plus 2 patches <> Plus some clumps of burnt, younger plants. <> Patches spreading <> Dense to open <> Only fire - no other disturbance	*Patches ~ evident.* (*irregular*) Mottled -fully. <&/OR > Plus ≥ 2 patches <> Plus many or big clumps of burnt, younger plants. <> Patches Spread-out <> Open & dense (recently burnt & long unburnt). <> Only fire - no other disturbance	
Presence of epicormic or basal sprouts on trees/woody plants; fire-related (not due to other causes eg drought). Understorey regrowth (greener, young & vigorous.)		Sprouts absent. No recent regrowth.	Sprouts rare. Little recent regrowth.	Sprouts occasional. Some recent regrowth.	 Foliage generally healthy.	In older patches sprouts absent. In recently burnt patches sprouts present. In older patches regrowth absent. In recently burnt patches regrowth present.	
Biomass stored in vegetation. Biomass includes *combustible* live & dead matter, old plants, understorey thickets, & foliage. Plant litter.		High biomass. High litter; thick cover. High debris, including logs.	Moderate to high biomass	Moderate biomass. Moderate litter. Moderate debris, including logs.	Moderate to high biomass.	In older patches high biomass. In recently burnt patches low biomass. In older patches high litter, debris & humus levels. In recently burnt patches low litter, debris & humus levels.	

		High humus.		Moderate humus.			
Presence of perennial seeder species. Presence of senescence.		Many species aged. Many perennial seeder species senescent. (Little recruitment.)	Many species aging. Few to many perennial seeder species becoming senescent.	Many species nearing maturity. (Little sign of senescence.)	Many species are mature & able to reproduce. (Little sign of senescence.)	In older patches most species are mature & able to reproduce. In recently burnt patches fewer species are ready to reproduce. (Likely signs of senescence; in older patches.)	
Presence of fire-ephemeral and ephemeral species.		Ephemerals absent (or confined to the soil seed reserve which may be declining).	Ephemerals scarce after fire. Opportunities to reproduce declining.	Ephemeral species occasional after fire. Opportunities to reproduce declining.	Ephemerals present after fire. Little patchwork.	Ephemerals present after fire. In older patches ephemerals may be absent or only in the soil seed reserve. In recently burnt patches ephemerals are likely to be present.	

APPENDIX 2: AN EXTENDED LIST OF ATTRIBUTES (SOME MAY NOT APPLY, OTHERS ARE RUDIMENTARY OR INDICATIVE)

SPECIES COMPOSITION / STRUCTURE / HETEROGENEITY

Native plant species composition (Note: 1) record if fire happened recently & composition is un-interpretable; use n/a.)	Native species depleted <> 0% native plant composition	Few remaining native species <> Typical dominants & faithful species scarce. <> >0-20% native plant composition.	Less than half of the original complement of native species present <> <> >20-40% native plant composition.	Around half the original complement of native species present <> Some typical dominants or faithful species declining or scarce. <> >40-60% native plant composition	More than half of the original complement of native species present <> <> >60-80% native plant composition	Native species at full complement, minor evidence of impacts) <> Typical dominants & faithful species common. <> >80-100% native plant composition	Native species at full complement, (abundance and vigour). <> <> 100% native plant composition
Native plant species composition form VAST		<> Dominant structuring species present. Many other species missing.	<> Dominant structuring species present. Several species diminished/missing.	<> Dominant structuring species present. One or more species diminished.	<> Dominant structuring species present. At least one species diminished.	<> Dominant structuring species present. Full range of native species present.	
Additional cues (Either: compared to a reference area or state, or due to disturbance at site).		Soil disturbance consolidated & extensive. Topsoil widely removed &/or repeatedly disturbed and it is likely the soil seed reserve is also depleted. <> Weed dominance, replacing natives. <> Heavy grazing, of most species. <> Heavy harvesting. <> Any of above <90-60%	Soil disturbance melding & growing <> Balance tipping to weeds. <> <> <> Any of above <60-30%	Soil disturbance Scattered & limited, not repeated. <> Weed presence building, under equity. <> Moderate grazing, of several species. <> Moderate harvesting. <> Any of above <30-15%	(Soil disturbance little) <> Weed presence low. <> <> <> Any of above <15%	(Soil disturbance little or none) Topsoil intact and may contain a soil seed reserve. <> Weeds scarce. <> Limited grazing. <> No harvesting. <> Any of above none	

Structure of vegetation *(VAST shown in italics)* (Note: 1) layers may also be taken as growth-forms & age classes of species; 2) if change is subtle & it is unclear if natural patchiness or impacts are the cause default to "very good"; 3) record the cause if the state is due to "natural"	Structure depleted. Loss of diverse layers.	Structure greatly altered. Widespread loss of layers. (loss of: i) several layers in a multilayer unit or ii) near loss of the main layer in a one layer unit.) <> *Several layers frequently & repeatedly removed.*	Structure partially altered. One or more layers missing. (Community may lack shrub & ground cover species) <> *At least one layer frequently & repeatedly removed.*	Structure basically intact, impacts evident. All layers present, but may be sparse. <> *At least one layer thin or discontinuous.*	Structure intact, early signs of impacts. All layers present, with minor modification. <> *At least one layer somewhat diminished.*	Structure intact, verging on pristine. All layers present.	Structure pristine

cyclic & random events; 4) record if fire happened recently & structure is un-interpretable; use n/a.		<> Dominant structuring species likely to be affected.	<> Dominant structuring species may be affected.	<> Dominant structuring species unlikely to be affected.	<> Dominant structuring species unaffected.		
Extent of disturbance at site.		Disturbance high.		Disturbance moderate.		Disturbance minimal.	

SEMI-PATCH COMPATIBLE \/

Tree habitat. Hollow size above DBH is: i) small >3-15cm; ii) medium >15-30cm; iii) large >30cm (for mallees: >3-9cm; >9-15cm; >15cm).	(a) No trees &/or (b) No tree hollows. (c) No logs	All young trees or no live trees. <&/or> Near absence of hollows. <> Near absence of logs. All small. <> Mainly in dead trees	Mainly young trees. <&/or> Few hollows (scattered & isolated). <> Few logs. All small. <>	Mix of young & maturing trees. <&/or> Some hollows. (eg 1-2 trees) <> Some logs. Small & medium sizes. <> Mix in live & dead trees	Mix of young & maturing trees. <&/or> Frequent hollows. <> Frequent logs. Small & medium sizes. <>	Range of young to mature trees. <&/or> Hollows common. (eg 3-6 trees) <> Logs common. Small, medium & large. <> Mainly in mature trees	Range of young to mature trees. <&/or> Hollows common. <> Logs common Small, medium & large.

/\ Pair ?\/ (NOT PATCH COMPATIBLE?\/) NOT APPLICABLE AT QUADRAT LEVEL

Interconnecting overstorey / midstorey canopy offering continous foraging (and nesting) habitat for fauna.		All young trees or no live trees. Low level/absence of interconnecting canopy	Mainly young trees.	Mix of young & maturing trees. Medium level of interconnecting canopy	Mix of young & maturing trees.	Range of young to mature trees. High level of interconnecting canopy	Range of young to mature trees.

PATCH COMPATIBLE IF TAKEN IN TANDEM \/ NO! THEY CANCEL OUT IF TAKEN IN TANDEM AT THE SAME SITE!!!

Thickets or refuge areas. [Works if independent of open areas but in tandem] ((Added can apply to subgroups such as old growth & fire-exclusion areas)) Includes: grass hummocks, grass tussocks/bases; dense understorey of all sorts.	(a) Absent. &/or (b)	Absent. No shrub /understorey cover.	Poorly-developed, limited in extent, or disrupted. At best a tiny occurrence. Generally sparse. Low Shrub/understorey cover 0-15%.	Moderately developed. Rudimentary or scattered thickening of the undergrowth . Moderate Shrub/understorey cover >15-30%.	Moderately to well developed. Consolidated thickets in parts of the area. Much thickening of the undergrowth. Moderate/high Shrub/understorey cover >30-60%.	Well developed. Through much of the area or adjacent areas (within 100 to 200m). In bands. High Shrub/understorey cover >60-100%.	Well developed. Through much of the area or adjacent areas (within 100 to 200m). In bands.

Open areas. [Works if independent of thickets but in tandem] Presence of areas of young re-growth (especially after fire).	Absent.	Absent.	Poorly-developed, limited in extent, or disrupted. At best a tiny occurrence. Generally sparse.	Moderately developed. Rudimentary or scattered re-growth.	Moderately to well developed. Consolidated re-growth in parts of the area. Much thickening of the undergrowth	Well developed. Through much of the area or adjacent areas (within 100 to 200m). In bands.	Well developed. Through much of the area or adjacent areas (within 100 to 200m). In bands.
Ecotones and a mosaic of patches. At site and adjacent to it.		Relatively uniform. Ecotones scarce or absent. Patches scarce. Small interface	Ecotones scarce to moderately developed.	Parts of the area heterogeneous in terms of age &/or structure &/or type of vegetation. Ecotones moderately developed. Some patches present. Moderate interface	Ecotones moderately developed to common.	Relatively heterogeneous. Ecotones common. Patches common. Strong interface	Heterogeneous/mosaic/mixture of ages &/or structure &/or types of vegetation.

Surface stability Contributing factors to a consolidated soil surface such as root mats (surface roots); fibre; humus; cryptogams; blue-green bacteria; oxide crusts. (Exclude naturally bare areas; eg outcrops, sand, dunes, riverbeds.) (Disturbance includes: earth movement; trampling; erosion & weeds)	None	Heavy disturbance to structure. _______ Low content	Moderate to heavy disturbance _______ Low to moderate content of surface roots & stems. <> Low to moderate organic matter present <> Low to moderate development of upper crust	Moderate disturbance to structure. _______ Moderate content	Moderate to low disturbance _______ Moderate to high content of surface roots & stems. <> Moderate to high organic matter present. <> Moderate to high development of upper crust	Surface seems stable. Little evidence of disturbance to structure. _______ High content	

Litter is better part split and put into thickets and patches in terms of faunal habitat and a basic absent or low to high

Litter (May be rated as not applicable to naturally bare areas; eg outcrops, sand, dunes, riverbeds.) NB: b) *Diverse components are a mix of bark, leaves, twigs, branches (+/- debris-* larger material	a) stability b) *fauna habitat*	Generally: Litter loosely strewn on surface. Light. (Recent fall) <&/or> Litter not stabilizing the surface <> No contribution of debris to cover <> Tending to dry out in soil surface <> *Few components from few plant layers & species* *(plant layers lost)*		At least in places: Litter accumulation in pockets. (Intermediate age) <&/or> Litter partially stabilizing the surface. <> Some contribution of debris to cover <> Some parts are protected from drying. <> *Range of components from a range of plant layers & species(plant layers +/- diminished)*		At least in places.: Litter firmly integrated into top layer. Thick. (Long-standing buildup) <&/or> Litter stabilizing the surface <> Debris firmly part of cover & decaying <> Tending to retain moisture in soil surface <> *Diverse components from diverse plant layers & species* *(plant layers intact)*	

such as logs of >10cm) c) Exotic cover is often mostly from ephemeral, herbaceous, weeds.	c) exotic contribution d) *fire* e) presence of fungal hyphae (diverse invertebrates)	<> Total cover by exotic litter; even smothering. <> *After fire litter is uniformly removed.* <> no fungal hyphae a single species of invertebrate profuse	*After fire litter persists in patches(few, little area).*	<> Moderate cover of exotic litter (+/- thick patches) <> *After fire litter persists in patches(several, moderate area).*	*After fire litter persists in patches (several, moderate to high area).*	<> Little cover of exotic litter (sparse) <> *After fire litter persists in patches (many, much of area)* <> fungal hyphae in litter several invertebrate species in litter	
Bioturbation (Observe the nature, complexity, & processes) Backup to surface stability. Focuses on: a) primarily ants, then termites, (then other soil invertebrates); & b) vertebrates. [a) & b) may need to be split.]	a) soil invertebrates _____________ b) vertebrates	Only one species of ant predominant and likely exotic <> Termites present (may be 1 species) <> No other soil invertebrates present (after intensive searching) or one species predominant & likely exotic _____________ Vertebrate activity may include ferals. +/- FERAL SPECIES <> Activity intense, &/or large in area. <> Heavy disturbance to surface / sub-surface / roots High density of faeces	_____________	2 species of ant observed <> Termites present (1 or more species) <> 1 or more soil invertebrates present _____________ Activity of one to two vertebrate species NOT FERAL SPECIES <> Activity moderate &/or moderate in area. <> Moderate disturbance	_____________	2 to several species of ants observed (look for differences in nests & in worker size & shape) <> Termites present (2 or more species) <> Several groups of other soil invertebrates present _____________ Activity of several vertebrate species NOT FERAL SPECIES <> Activity low/diffuse &/or small in area. <> Little disturbance to surface / sub-surface / roots Low density of faeces	
Native fungi. Presence.	Absent	Low incidence No species evident 1 or more pathogenic species present	Few individuals. One species. &/or Isolated incidences	Moderate incidence Few individuals. Few species. &/or Tending to be confined	Few individuals. Several species. &/or Scattered through area.	High incidence Several individuals. Several species. &/or Spread through the area.	Present throughout

Nutrient cycling Near background levels of inputs & outputs Faunal – faeces & urine Plant cycling – most – N Plant – N fixation Mineralization		High input High density of faunal activity trampling, digging, grazing, faeces High density of weeds either binding up nutrients Or grass weeds in remnants releasing nutrients in fire Input from soil or water flow from horticulture, agriculture, plantations, industry, or drainage Combination of harvesting, cation removal, an acid front and a fluctuating watertable.				Low/sustained input	

Erosion/deposition due to disturbance Erosion of soil or Depostition of sediment Soil and substrate movement due to changed land use State which __________	a) Overtaken by wind (eg blowout) or water (gullying & sheet) erosion. <&/or> b) Overtaken by wind (eg dune-like) or water (sediment) deposition.	Severe Extensive (consolidated) <> (eg >50% of site)	Moderate to severe Growing (melding) <> (eg >15-50% of site)	Moderate Limited (scattered) <> (eg >5-15% of site)	Minimal Minor (isolated) <> (eg 0-5% of site)	Low to none	

Infrastructure disturbance corridors - characteristics FORMAL: Roads, Service corridors (rail, power – gas & electric) surface drainage & sub-surface drainage fencing & walls INFORMAL: Tracks; Off-road vehicle disturbance; Paths & recreation Note which points apply: a) b) c) d)	a) b) c) d)	Density high <&/or> Strong barrier – wide &/or heavy traffic <> Substantial foundations & compaction Surface hydrology disrupted Soil movement /formation disrupted <> Very regularly renewed & maintained	Density mod to high <&/or> Mod to strong barrier – either wide or heavy traffic <> Some foundations & compaction Surface hydrology altered Soil movement/formation altered. <> Regularly maintained	Density moderate <&/or> Moderate barrier – mod width &/or mod traffic <> Some foundations & compaction Surface hydrology intact Soil movement/formation intact <> Rarely maintained	Density low <&/or> Weak barrier – narrow &/or low traffic <> No foundations & Little compaction Surface hydrology intact Soil movement/formation intact <> No recurrent disturbance		

Infrastructure disturbance corridors - invasion route	a) b)	Exotics predominant along corridor <&/or> Disease predominant along corridor	Exotics prolific along corridor. <&/or> Disease prolific along corridor	Exotics frequent along corridor. <&/or> Disease frequent along corridor.	Exotics scattered along corridor. <&/or> Disease scattered along corridor.	Exotics scarce to absent (along corridor) <&/or> Disease absent (along corridor)	

Clearing (The focus here is on clearing of vegetation rather than soil.)	Totally cleared	*Heavy clearing.* <> Longstanding <> Repeated/ongoing (frequent) <> (eg >50%)	Partial (*to heavy*) clearing. <> Intermediate in age (or a mix of old and new) <> Intermittent (sporadic) <> (eg >15-50%)	Partial clearing. <> Recent (≤2 years) <> Single incidence (infrequent) <> (eg >5-15%)	*Little clearing.* <> Recent (≤2 years) <> Single incidence (infrequent) <> (eg 0-5%)	*Little or no clearing*	*No clearing.*

Resource extraction (Soil surface generally cleared) Mining______________ Construction__________ Material ____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________		High impact Extensive (consolidated) <&/or> A horizon removed <> (B horizon removed) <> (C horizon removed) <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <&/or> A horizon removed in part <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <&/or> A horizon disturbed <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction	

Other surface disturbance (Due to stock, feral animals, or machinery)		High impact Extensive (consolidated) <> A horizon disturbed repeatedly/frequently <> (Most of area) (eg >50%)	Mod/high impact Growing (melding) <> A horizon disturbed intermittently <> Much of area (eg >15-50%)	Moderate impact Limited (scattered) <> A horizon disturbed infrequently <> Part of area (eg >5-15%)	Low impact Very minor disturbance to A horizon <> Tiny area (eg 0-5%)	No extraction	

a) Waterlogging (usually seasonal) or b) Drought		>50% of site affected a) Waterlogging - swamp tolerant plants have replaced original species. <or> b) Drought - Graveyard death of	10-50% of site affected Waterlogging Pockets of dead local plants, swamp tolerant plants replacing original species. <or> Drought - Whole patches with dead overstorey (and	<10% of site affected Waterlogging Scattered individual plants stressed or dying <or> Drought - Scattered individual overstorey	Site little affected Isolated individual plants may be stressed.	Site unaffected	

Record if a) or b).		overstorey (and perhaps some deep-rooted understorey)	perhaps some deep-rooted understorey).	plants stressed or dying.			
Waterlogging Or Drought History if known		Long-standing (decades or more)	Of moderate duration (several years)	Recent			

Salinity - secondary P/A ________________ *Proximity of (secondary) salt outbreak to drainage line* FRAGMENTED CHARACTER	*(Proximity) Riparian* <&/or> (Secondary) Salt outbreaks at site – severity high [‘S3’] Heavily impacted. Invasive salt tolerant plants have replaced original species.	*(Proximity) <200m* <&/or> (Secondary) Salt outbreaks at site – severity moderate [‘S2’] Moderately impacted. (May be) Salt tolerant plants replacing original species.	*(Proximity) <500m* <&/or> (Secondary) Salt outbreaks at site – severity low [‘S1’]	*(Proximity) <1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity high [‘S3’]	*(Proximity) >1000m* <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity moderate [‘S2’]	*Distant (or only primary-with intact diversity)* [+] <&/or> (Secondary) Salt outbreaks, not at site, in local landscape – severity low [‘S1’]	*Absent (or only primary with intact diversity)* [+] <&/or> No (secondary) salt outbreaks
Salinity - secondary; history if known		Long-standing (decades or longer)	Of moderate duration (several years)	Recent (1-2 years)			
[OPTIONAL] Salinity - secondary; remedial action - salt affected		Directing drains & saline flows into reserves.	Redirecting saline flows away from reserves (incl. deep drainage). Planting salt-tolerant non-local species in saline areas. Mechanically lowering the watertable. Fencing saline areas to exclude stock &/or pests. Letting the first flows of the season flush through.	Planting deep-rooted local species higher in the profile. Planting salt tolerant local species in saline areas.			

Wetland eutrophication Degree Extent		Algae dominant &/or Typha predominant Benthos algal/detrital 90->60% of site	Algae common &/or Typha common Benthos algal/detrital 60->30% of site	Occasional algal blooms &/or Typha present 30->15% of site	Native rushes common (except Typha) 15-0%	Native rushes dominant (except Typha)	

Pollutants -external input of nutrients & other chemicals. From anthropogenic sources: habitation, horticulture, agriculture, plantations, industry, (including: rubbish dumps, mine waste & tailings, sewerage, and all urban, rural, mine & industrial drainage and sumps). Type of pollution ___________________ a) Waterborne - surface water, seepage, or the watertable b) Airborne - aerosols, gaseous emissions, and particulates. c) Animal excreta		Major waterborne At site In contact with sources <&/or> Receives urban or industrial drainage <> Sustained contact with a contaminated watertable <> Mass decline and death of all plant species on contact with contaminated water or watertable. Major airborne Major impacts of particulates. Thick film. Consolidated/Most of area. High cover. <> Sustained contact with a plume <> Mass decline and death of all plant species on contact with a plume. High frequency of droppings/activity	Moderate waterborne Near site <200m Surrounded by sources <&/or> Presence of urban or industrial drainage <> Regular episodic contact with a contaminated watertable <> A front of decline and even death is evident through part of the site from a source. Moderate airborne Moderate impacts of particulates. Medium film. Melding/Part of the area. Moderate cover. <> Regular episodic contact with a plume <> A front of decline and even death is evident through part of the site from a source. Moderate to high frequency of droppings/activity	Low waterborne Locality >200m - <1000m Down gradient of adjacent sources <&/or> Down gradient of urban or industrial drainage <> Intermittent contact with a contaminated watertable <> Scattered pockets & low cover. Some decline and even isolated death may be evident near the source. Low airborne Low impacts of particulates. Thin film. Scattered. Low cover. <> Intermittent contact with a plume <> Scattered pockets & low cover. Some decline and even isolated death may be evident near the source. Moderate frequency of droppings/activity.	Minor waterborne Distant sources. Up gradient of any sources <&/or> Up gradient of any drainage <> Watertable not contaminated / landform not in direct contact with watertable. <> Minor decline and negligible death. Minor airborne Negligible effects of particulates. Low frequency of droppings/activity.	<<a) Waterborne <<b) Airborne << c) Animal excreta	

Rubbish dumping Material _____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________		Consolidated High cover Thick depth 90->50%	Melding Moderate cover Moderate depth 50->15%	Scattered Low cover Thin depth 15-0%	Isolated Negligible cover		

SIVICULTURAL MANAGEMENT

Sivicultural management of forests regeneration & lifecycles influenced by practices such as stocking rates,	Infrequent Sporadic Intermittent Occasional Rare Uncommon	High intervention - of numerous forms. Recent & repeated.	Moderate intervention - of several forms. Medium age & moderate repetition	Low intervention - of one or more forms. Long-standing & low repetition.	Limited intervention (mainly fire regime). Otherwise infrequent.	Limited intervention (mainly fire regime). Otherwise uncommon.	Structure and composition determined by natural cycles in processes

harvesting & associated disturbance, and fire regimes		High age/class selection. (Mainly small stems & a range of stump sizes) Age/class uniformity (seed or habitat trees excepted). Form and genetic composition selected High cover/density: - harvester movement; - extraction tracks; - log landings Highly Compacted surface Churned top & subsoil Disrupted soil structure High intensity Post- harvest fire High intensity Understorey rolling Scattering of debris High use of chemicals eg phosphite	Moderate age/class selection. Moderate cover/density: - harvester movement; - extraction tracks; - log landings Moderately Compacted surface Churned top & subsoil Disrupted soil structure Moderate intensity Post- harvest fire Moderate intensity Understorey rolling Scattering of debris Moderate use of chemicals eg phosphite	Low age/class selection. (Mainly medium stems & medium or large stumps) Low cover/density: - harvester movement; - extraction tracks; - log landings Low incidence Compacted surface Churned top & subsoil Disrupted soil structure Low intensity Post- harvest fire Low intensity Understorey rolling Scattering of debris Low use of chemicals eg phosphite	Limited age/class selection. Age/class largely heterogenous (selective removal) Limited cover/density: - harvester movement; - extraction tracks; - log landings Limited Compacted surface Churned top & subsoil Disrupted soil structure Limited intensity Post-harvest fire Limited intensity Understorey rolling Scattering of debris Limited use of chemicals eg phosphate	Age/class self-regulating (Some large stems & scarce very large stumps) Age/class heterogeneity	

HARVESTING

Harvesting of biomass a) Logging b) Firewood, fencepost &		Heavy Ongoing logging. <> Several rounds of logging evident. <> Mix of small, medium & larger older stumps, may be evident. <> Most trees of small diameter. (+/- young) <> Multi-stemmed coppicing from stumps common. <AND/OR> Area denuded.	Moderate to heavy Ongoing logging. <> More than one round of logging evident. <> Mix of small, medium & larger older stumps, evident. <> Most trees of small diameter. (+/- young) (eg ≤15cm) <> Multi-stemmed coppicing from stumps common <AND/OR>	Moderate Logging relatively recent, and may be ongoing. <> More than one round of logging evident. <> Mainly medium stumps (/logs). <> Mix includes trees of medium diameter. (eg 30-40cm) <> Multi-stemmed coppicing from stumps evident. <AND/OR>	Limited to moderate Some time since logging occurred. <> More than one round of logging evident. <> Mix of medium & old & large stumps. <> Scarce trees of larger diameter. (eg ≥50cm) <> Scattered multi-stemmed coppicing from stumps <AND/OR>	Limited. Long-past logging. <> Only one round of logging evident. <> Mainly scattered old & large stumps. <> A few trees of larger diameter (+/- mature) <> Trees generally single stemmed. Little multi-stemmed coppicing from stumps. <AND/OR> Logs, stumps, & debris	Likely no history of harvest No logging. <> Some trees of larger diameter. Mature or maturing trees are present in the population.

craft wood removal c) (Wildflower harvesting)		Likely recent & regular (sawdust & cuts). <AND/OR> Uniform and heavy harvesting	<AND/OR>	Select sizes and patches of logs & stumps removed <AND/OR> Patches harvested	<AND/OR>	present. Likely old & irregular. <AND/OR> Scattered light harvesting	
Acidity buildup Most likely in clay-free, un-buffered, soils		Heavy logging. Repeated harvesting & cation export – high likelihood of acidity buildup	Moderate to heavy logging	Moderate logging Moderate harvesting & cation export – moderate likelihood of acidity buildup	Limited to moderate logging	Limited. Limited harvesting & cation export – low likelihood of acidity buildup	
Nutrient export		Heavy logging. Repeated harvesting & export – high likelihood of loss	Moderate to heavy logging	Moderate logging Moderate harvesting & export – moderate likelihood of loss	Limited to moderate logging	Limited. Limited harvesting & export – low likelihood of loss	

WEEDS

Enrichment planting / sowing Non-local plants versus Local native plants – <u>that is very local, locality, seed stock</u> Default to good if uncertain.		Planting extensive – Only non-local plants	Planting or sowing extensive – Only local stock	Mix of self-regeneration & planting or sowing (local stock).	Mainly self-regeneration (mostly undisturbed) and some (infill) planting with local plants.	Only self-regeneration (undisturbed soil surface, and community).	

Weeds associated with disturbance (Disturbance opportunists)	Completely disturbed Complete weed cover / dominance	Weeds common in area, replacing native species <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <90-60%	Balance tipping to weeds <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <60-30%	Weed presence building, under equity (+/- spot occurrences) <&/or> Many individuals, (few to several species). <&/or> Cover/abundance of weeds <30-15%	Weed presence low <&/or> Several individuals, (few to several species). <&/or> Cover/abundance of weeds <15-2%	Weeds scarce, uncommon (or absent) <&/or> Few individuals, (1 (to 2) species) - only in disturbed pockets <&/or> Cover/abundance of weeds <1%	Weeds absent

Weeds not associated with disturbance (Relatively aggressive or invasive species) (Requires reference work – so n/a is appropriate if unconfident)	Completely disturbed Complete weed cover / dominance	Weeds common in area, replacing native species <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <90-60%	Balance tipping to weeds <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <60-30%	Weed presence building, under equity (+/- spot occurrences) <&/or> Many individuals, (few to several species). <&/or> Cover/abundance of weeds <30-15%	Weed presence low <&/or> Several individuals, (few to several species). <&/or> Cover/abundance of weeds <15-2%	Weeds scarce, uncommon (or absent) <&/or> Few individuals, (1 (to 2) species) - only in disturbed pockets <&/or> Cover/abundance of weeds <1%	Weeds absent

Weeds not associated with disturbance (relatively aggressive or invasive species) (REQUIRES REFERENCE WORK – SO N/A MAY BE APPROPRIATE WHERE NOT CONFIDENT)	Completely disturbed Complete weed cover / dominance	Weeds common in area, replacing native species <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <90-60%	Balance tipping to weeds <&/or> Prolific individuals, (few to many species). <&/or> Cover/abundance of weeds <60-30%	Weed presence building, under equity (+/- spot occurrences) <&/or> Many individuals, (few to several species). <&/or> Cover/abundance of weeds <30-15%	Weed presence low <&/or> Several individuals, (few to several species). <&/or> Cover/abundance of weeds <15-2%	Weeds scarce, uncommon (or absent) <&/or> Few individuals, (1 (to 2) species) - only in disturbed pockets <&/or> Cover/abundance of weeds <1%	Weeds absent

Weeds versus vegetated area size (this addresses 'remnant' size in fragmented areas (gaps >100m) & edge effects in fragmented & extensive areas) A large area is ≥1500ha and a small area ≤200ha (~3.9km & ~1.4km square; Safstrom 1999). (*Shape not considered – drop a category -1 if long and thin; more compact shapes do as is).		Small vegetated areas faster penetration from large perimeters brimming with weed sources. (Weeds a major component.) <&/or> Weeds intrude more than 100m into remnant	Weeds intrude 50-100m into remnant	Medium vegetated areas Intermediate penetration from boundaries. (Weeds a sub to main component.) <&/or> Weeds intrude 20-50m into the remnant	Weeds intrude 10-20m into remnant	Large vegetated areas slow penetration from boundaries and nucleation by seeds (esp. via animal vectors). (Weeds a subcomponent.) <&/or> Weeds intrude less than 10m into remnant	

>>>ALIENATION BELONGS HERE

Recruitment (<u>State if stages present & their % cover</u>) Seedlings: Saplings: Population age/stage balanced: (Consider if cohorts of plants that have not yet set seed are present.) Note: Senescence chiefly in woody species.		Low to no recruitment <&/or > No seedlings. <> No saplings. <> Most species appear senescent. <> Extensive soil disturbance (pervasive &/or repeated) or loss. Probable soil seed reserve is depleted. <> (high weed presence)	Mod to low recruitment (scarce) <&/or > Scarce or no seedlings. <> Scarce or no saplings <> Several populations / species appear senescent. <> Growing soil disturbance. <> (mod weed presence)	Moderate recruitment (localized) <&/or > A few species have isolated seedlings. <> A few species have isolated saplings <> Populations of some species *may* be senescent. <> Limited soil disturbance. Soil seed reserve may be intermittently replenished. <> (low weed presence)	Mod to high recruitment. (common) <&/or > Several species have a few seedlings. <> Several species have a few saplings. <> Limited senescence & reproductively mature. <> Minor soil disturbance. <> (low / no weed presence)	High recruitment (widespread). <&/or > Several species have several seedlings. <> Several species have several saplings. <> Limited senescence & reproductively mature. <> Soil intact. Soil seed reserve is likely to be steadily replenished. <> (weeds absent)	Regeneration occurring in the appropriate timeframe. <&/or > Likely a varied range of ages/stages throughout the localized area (incl. mature). <> Limited senescence & reproductively mature. <> Soil & soil formation intact. The soil seed reserve is likely to be being steadily replenished.

Input required to promote regeneration		Major resources required to promote regeneration. (eg alter processes & nearby land use; such as falling or rising watertable; secondary salinity; major erosion or deposition; major clearing; major resource extraction; harvesting long-standing and recurrent; dominated by weeds).	Significant resources required to promote regeneration (eg the surface soil & the soil profile may need to be restored in places, and plant species may need to be planted or sown.)	Strategic resources may promote regeneration, rather than decline. (eg limit access or activities)	Scarcely any resources required to promote regeneration.	No resources required to promote regeneration.	

Health - General Of key species (esp. mature individuals). % plants with significant health problems (foliage loss, canopy decline, stem lesions, etc). Cause of stress, if known Trees/ mallees Symptoms __________ Cause _____________ Shrubs Symptoms __________ Cause _____________		High impact. (Severe stress.) <> State of species. Most individuals - of - Most prone species <> State of individuals - Many severely damaged, dying or dead.	High to moderate impact (Advanced signs of stress) <> State of species. Many individuals - of - Several species. <> State of individuals - Extensive damage incl: Most leaves damaged (or few left). Crown fragmented. Many canopy branches dead; One or more dead stems; Resprouting from damaged parts.	Moderate impact (Signs of stress.) <> State of species. Several individuals - of - Few species. <> State of individuals - Minor/moderate damage. Some leaves dead/dying. Minor branches damaged. Crown intact. Main limbs intact.	Low impact (Early signs of stress.) <> State of species. Isolated individuals - of - Few species. <> State of individuals - Minor damage. Some leaves damaged. Minor branches ~intact. Crown intact. Main limbs intact.	Majority healthy (Background levels) <> State of individuals - No obvious leaf or woody damage. *(or minority of each leaf 's surface affected*)	Majority healthy

Death of key species (especially of mature individuals).		High incidence. <> Most individuals - of - Most species.	Mod/high incidence. <> Many individuals - of - Several species.	Moderate incidence. <> Several individuals - of - Few species	Low incidence. <> Isolated individuals - of - Few species.	Limited death <> Deaths scarce, uncommon.	Deaths scarce, uncommon.

Health - Disease in predominant species Based on dieback. State if other _________		High impact. <> Consolidated (Most of the area.) (*eg >50%*) <> Most individuals - of - Most prone species. <> Most susceptible tree & understorey species affected.	High to moderate impact <> In several pockets &/or a disease front develops. (Much of area) (*eg >15-50%*) <> Many individuals - of - Several species <> Deaths common & majority (30-90%) of susceptible specie's plants affected.	Moderate impact <> Confined, likely to one pocket. (Part of area) (*eg >1-15%*) <> Several individuals - of - Few species. <> Odd, scattered deaths & minority (<30%) of susceptible specie's plants affected.	Low impact <> Isolated incidence. (Tiny area) (*eg 1%*) <> Isolated individuals - of - Few species <> Low impact. Few deaths.	Dieback free.	Dieback free (Lacking disturbance).

Health - Insect damage. Including: galls, lerps, leaf miners, wood borers, etc.		Insect damage high. <> State of species. Most individuals - of -	Insect damage mod/high <> State of species. Many individuals - of -	Insect damage moderate <> State of species. Several individuals - of -	Insect damage low. <> State of species. Isolated individuals - of -	Limited insect damage. <>	Limited insect damage (Lacking disturbance).

May manifest as significant crown damage.		Susceptible species. <> (Whole host populations) <> State of individuals - May be severely stressed or dying.	Susceptible species. <> (Most of host populations.) <> State of individuals - Extensive damage incl: Most leaves damaged (or few left). Crown fragmented. Many canopy branches dead; One or more dead stems.	Susceptible species <> (Parts of host populations) <> State of individuals - Minor/moderate damage. Some leaves dead/dying. Minor branches damaged. Crown intact. Main limbs intact	Susceptible species <> (Diffuse or minor.) <> State of individuals - Minor damage. Some leaves damaged. Minor branches ~intact. Crown intact. Main limbs intact.	<> <> State of individuals - No obvious leaf or woody damage. (*or minority of each leaf 's surface affected*)	

Health - Plant parasites. Chiefly mistletoe. High densities of quandong my indicate limited dispersal or channeled dispersal by vectors (esp. along road reserves). (Nuytsia, & sandalwood generally not present at high densities)		High incidence. <> State of species. Most individuals - of - Susceptible species. <> (Whole host populations) <> Several mistletoe per host and large infested host clusters or belts	Mod/high incidence. <> State of species. Many individuals - of - Susceptible species. <> (Most of host populations.) <> Several mistletoe per host and infested host clusters	Moderate incidence. <> State of species. Several individuals - of - Susceptible species. <> (Parts of host populations) <> 1 to 2 mistletoe per host +/- infested host clusters	Low incidence. <> State of species. Isolated individuals - of - Susceptible species <> (Diffuse or minor.) <> Mistletoe ~1 per host	Limited parasitism. <> State of species. Scarce and scattered. <> <> Mistletoe ~1 per host	Limited parasitism. <> State of species. Scarce and scattered.

Prescribed burning. Jarrah forest. (Burrows & Friend 1998)	P			(Every 6 – 10 yr overall.) High rainfall jarrah 6-7yr Low rainfall jarrah 8-10yr			
Jarrah forest general Outer interval (based on decline of quokka & ash-grey mouse) (Burrows et al 1999)	/\	Protracted 50 years	Extended	Long-unburnt 20-40 years			
Karri forest general High rainfall Invertebrates in wetter environments are more susceptible to fire at short intervals. (Burrows & Friend 1998)	\/	Repeated fire <6 yr rotation	Occasional fire <6 yr rotation	Minimum 6 yr rotation			

Jarrah forest High rainfall (>900mm) upland forest (Burrows & Friend 1998)	\/	Repeated fire <6 yr rotation	Occasional fire <6 yr rotation	Minimum 6 yr rotation	Typical fire frequency 6-12 yr	Mixed fire frequency <6, 6, 6-12 yr	
	/\	Protracted	Extended >18 yr	Long-unburnt 12-18 yr	Typical fire frequency 6-12 yr	Mixed fire frequency <6, 6, 6-12 yr	
Jarrah forest Low rainfall (<900mm) upland forest (Burrows & Friend 1998)	\/	Repeated fire <8 yr rotation	Occasional fire <8 yr rotation	Minimum 8 yr rotation	Typical fire frequency 8-16 yr	Mixed fire frequency <8, 8, 8-16 yr	
	/\	Protracted	Extended > 24 yr	Long-unburnt 16-24 yr	Typical fire frequency 8-16 yr	Mixed fire frequency <8, 8, 8-16 yr	
Jarrah forest High rainfall (>900mm) riparian (Burrows & Friend 1998)	\/	Repeated fire <12 yr rotation	Occasional fire <12 yr rotation	Minimum 12 yr rotation	Typical fire frequency 12-24 yr	Mixed fire frequency <12, 12, 12-24 yr	
	/\	Protracted	Extended > 36 yr	Long-unburnt 24-36 yr	Typical fire frequency 12-24 yr	Mixed fire frequency <12, 12, 12-24 yr	
Jarrah forest Low rainfall (<900mm) riparian (Burrows & Friend 1998)	\/	Repeated fire <16 yr rotation	Occasional fire <16 yr rotation	Minimum 16 yr rotation	Typical fire frequency 16-32 yr	Mixed fire frequency <16, 16, 16-32 yr	
		Protracted	Extended > 48 yr	Long-unburnt 32-48 yr	Typical fire frequency 16-32 yr	Mixed fire frequency <16, 16, 16-32 yr	
South-coast mallee heath (400mm) (Burrows & Friend 1998)	\/	Repeated fire <15 yr rotation	Occasional fire <15 yr rotation	Minimum 15 yr rotation	Typical fire frequency 15-20yr	Mixed fire frequency <15, 15, 15-20	
South-coast mallee heath (Burrows & Friend 1998)	/\	Protracted 50yr	Extended	Long-unburnt 20-40yr	Typical fire frequency 15-20yr	Mixed fire frequency <15, 15, 15-20	
		FFR (fire frequency ratio) = FI (fire interval)/LJP (longest juvenile period)					

FIRE FREQUENCY RISING & INTERVAL CONTRACTING Fires usually of low intensity.		Fire very frequent.	Fire frequent.	Fire becoming frequent.	Fire interval variable.	Fire interval range suits vegetation type/s. (This includes patches within them.)	

Fire scars on woody dominants. (Such as dead branches & hollowed-out stems.)		Most scars recent. Many dominants with scars.	Most scars recent. Several dominants with scars.	Most scars recent. Occasional dominants with scars.	Scars vary in age; old scars still evident. Few scars.	Scars vary in age;	
Fire-related death of woody plants		Death of many plants from several species.	Death of individuals of one or more species.	Some death may occur.	No deaths.	Mixed: In older patches limited death, in recently burnt patches more.	
Small-scale uniformity and openness of vegetation (***mainly understorey***).		*Tending uniform.* Uniform - strongly. <> Very open. All lower layers. (Accessible, no thickets). <> Fire & ≥ 1 other disturbance	 Uniform - fairly. <> Open. Most layers. <> Fire & ≥ 1 other disturbance	 Mottled - slightly. <&/OR > Plus 1 patch <> Plus one clump of unburnt, older plants <> Patches Confined <> Open (> denser) 1 or 2 layers. <> Fire & 1 other disturbance	 Mottled - partly. <&/OR > Plus 2 patches <> Plus some clumps of unburnt, older plants. <> Patches spreading <> Open to denser <> Only fire - no other disturbance	*Patches ~ evident.* (*irregular*) Mottled -fully. <&/OR > Plus ≥ 2 patches <> Plus many or big clumps of unburnt, older plants. <> Patches Spread-out <> Denser & open ('long' unburnt & recently burnt). <> Only fire - no other disturbance	
Presence of epicormic or basal sprouts on trees/woody plants; fire-related (not due to other causes eg drought). Understorey regrowth (greener, young & vigorous.)		Sprouts common. Much recent regrowth.	Sprouts occasional. Some recent regrowth.	Sprouts rare. Little recent regrowth.	 Foliage generally healthy.	In older patches sprouts absent. In recently burnt patches sprouts present. In older patches regrowth absent. In recently burnt patches regrowth present.	
Biomass stored in vegetation. Plant litter.		Limited biomass. Little litter, thin cover. Large logs nearly burnt away. Low humus.	Low to moderate biomass.	Moderate biomass. Moderate litter. Moderate debris, including logs. Moderate humus.	Moderate to high biomass.	In older patches high biomass. In recently burnt patches low biomass. In older patches high litter, debris & humus levels. In recently burnt patches low litter, debris & humus levels.	
Presence of perennial seeder species.		Many species may no longer be present.	Few species nearing maturity.	Many species nearing maturity.	Many species are mature & able to reproduce.	In older patches most species are mature & able to reproduce. In recently burnt patches fewer species are ready	

Presence of senescence.		(No senescence.)	(No senescence.)	(Little sign of senescence.)	(Little sign of senescence.)	to reproduce. (Likely signs of senescence; in older patches.)	
Presence of fire-ephemeral and ephemeral species. CONUNDRUM – frequent fire suits fire-ephemerals but at expense of other species.		Ephemerals abundant after fire.	Ephemerals becoming common after fire.	Ephemerals occasional after fire. Chance to reproduce increasing.	Ephemerals present after fire. Little patchwork.	Ephemerals present after fire. In older patches ephemerals may be absent or only in the soil seed reserve. In recently burnt patches ephemerals are likely to be present.	

FIRE FREQUENCY DECLINING & INTERVAL EXPANDING Fires usually of high intensity.		Fire very infrequent.	Fire infrequent.	Fire becoming infrequent.	Fire interval variable.	Fire interval range suits vegetation type/s. (This includes patches within them.)	
Fire scars on woody dominants. (Such as dead branches & hollowed-out stems.)		Scars very old. or Scars absent.	Most scars old. Very few scars.	Most scars aging. Occasional scars.	Scars vary in age. Few scars.	Scars vary in age. (Balance of recent & older burning).	
Fire-related death of woody plants		No death.	Little or no death.	Some death may occur.	No deaths.	Mixed: In older patches limited death, in recently burnt patches more.	
Small-scale uniformity and openness of vegetation. (***mainly understorey***).		*Tending uniform.* Uniform - strongly. <> Very dense. All lower layers. (Inaccessible thickets. Possible senescence.) <> Fire & ≥ 1 other disturbance	Uniform - fairly. <> Dense. Most layers. <> Fire & ≥ 1 other disturbance	Mottled - slightly. <&/OR > Plus 1 patch <> Plus one clump of burnt, younger plants <> Patches Confined <> Dense (>open) 1 or 2 layers. <> Fire & 1 other disturbance	Mottled - partly. <&/OR > Plus 2 patches <> Plus some clumps of burnt, younger plants. <> Patches spreading <> Dense to open <> Only fire - no other disturbance	*Patches ~ evident.* (*irregular*) Mottled -fully. <&/OR > Plus ≥ 2 patches <> Plus many or big clumps of burnt, younger plants. <> Patches Spread-out <> Open & dense (recently burnt & long unburnt). <> Only fire - no other disturbance	
Presence of epicormic or basal sprouts on trees/woody plants; fire-related (not due to other		Sprouts absent.	Sprouts rare.	Sprouts occasional.		In older patches sprouts absent. In recently burnt patches sprouts present.	

causes eg drought). Understorey regrowth (greener, young & vigorous.)		No recent regrowth.	Little recent regrowth.	Some recent regrowth.	Foliage generally healthy.	In older patches regrowth absent. In recently burnt patches regrowth present.	
Biomass stored in vegetation. Biomass includes *combustible* live & dead matter, old plants, understorey thickets, & foliage. Plant litter.		High biomass. High litter; thick cover. High debris, including logs. High humus.	Moderate to high biomass	Moderate biomass. Moderate litter. Moderate debris, including logs. Moderate humus.	Moderate to high biomass.	In older patches high biomass. In recently burnt patches low biomass. In older patches high litter, debris & humus levels. In recently burnt patches low litter, debris & humus levels.	
Presence of perennial seeder species. Presence of senescence.		Many species aged. Many perennial seeder species senescent. (Little recruitment.)	Many species aging. Few to many perennial seeder species becoming senescent.	Many species nearing maturity. (Little sign of senescence.)	Many species are mature & able to reproduce. (Little sign of senescence.)	In older patches most species are mature & able to reproduce. In recently burnt patches fewer species are ready to reproduce. (Likely signs of senescence; in older patches.)	
Presence of fire-ephemeral and ephemeral species.		Ephemerals absent (or confined to the soil seed reserve which may be declining).	Ephemerals scarce after fire. Opportunities to reproduce declining.	Ephemeral species occasional after fire. Opportunities to reproduce declining.	Ephemerals present after fire. Little patchwork.	Ephemerals present after fire. In older patches ephemerals may be absent or only in the soil seed reserve. In recently burnt patches ephemerals are likely to be present.	

FIRE IN WEED INOCULATED AREAS		High fire frequency. Weed increase rapid.		Moderate fire frequency. Weed increase steady.		Low fire frequency. Weed increase slowed.	
FIRE REGIME AS INFLUENCED BY FRAGMENTATION (EXTENT & INTERVAL).		Very small size; opportunity for patch burning low (<1ha - <100mx100m)	Small to medium size; opportunity for patch burning low to moderate. (1 to 10ha – 316mx316m)	Medium size; opportunity for patch burning moderate. (>10 to 100ha – 1kmx1km)	Medium to large size; opportunity for patch burning moderate to high. (>100 to 1000ha – 3160mx3160m)	Large size; opportunity for patch burning high. (>1000ha)	In small, isolated, remnants: Fire occurs within a range of intervals appropriate for the vegetation type/s. In large areas: A mix of fire intervals. A patchwork of coverage throughout an area. This is reflected by a mosaic of resources, increased interfaces, & heterogeneity.

[26c]Mediterranean climate of the south-west Exceptions – peat areas (lake beds, mound springs).							
[26d]The winter rainfall pre-dominant mallee zone bordering the south-west.							
[26e]Summer rainfall predominant. Annual grasslands of the Kimberley.							
[26f]Summer rainfall predominant. Near-coastal north-west soft-spinifex grasslands (pindan).							
[26g]Capricious rainfall (semi-arid and arid zones). Hard-spinifex grasslands.							

\/ HOW TO MOVE THIS FROM A LINEAR ARRAY TO A PATCH & TRACE OVERLAY IN TIME - IE BUILD IN A SEQUENTIAL SENSE??????

Fire intensity [Sneeuwjagt & Peet 1998] (Burrows and Friend 1998) {scorch Bell, McCaw &		[Intense wildfire] [Total live scrub consumed] (High intensity summer.)		[Moderate wildfire] [Total foliage consumed]		[Low intensity/prescribed fire] [Low foliage consumed] (Low intensity – spring, autumn)	

Burrows 1989}		(Crown damaged 4-6yrs to recover & flower) {20m scorch}		{8-10m scorch}		(Crown damage absent/rare.) {1-2m scorch}	
Fire intensity		High More risk of: i) altered soil chemical & physical properties; ii) volatilization & loss of nutrients in smoke & ash; iii) outright death or inviability of seed stores (esp. in soil).				Low Low risk of: i) altered soil chemical & physical properties; ii) volatilization & loss of nutrients in smoke & ash; iii) outright death or inviability of seed stores (esp. in soil).	
Fire intensity (General) (Burrows and Friend 1998)		Intense (~15t/ha or karri) >2000 kw/m^{-2} (jarrah general) (Extreme 15000 kw/m^{-2}; Bell, McCaw & Burrows 1989) 4000-6000 kw/ m^{-2} (heath wheatbelt)		Moderate (~8t/ha? jarrah) <600kw/m^{-1} (jarrah cambium injury threshold; Bell, McCaw & Burrows 1989) 700-1000 kw/m^{-2} (sheoak wheatbelt)		Low <350 kw/m^{-2} (prescribed burn jarrah – cool, moist conditions in spring or autumn) 200-300 kw/m^{-2} (wandoo wheatbelt)	
Fire size (General) (~Burrows and Friend 1998; *Christensen and Kimber 1975; Christensen cited in Burrows, Ward & Robinson 1999; N. Burrows pers. com.)		Large JF >3000 ha burns whole landscape~ or landsystem; range north to south 5000-10,000^. Western Desert 100,000ha+ ^.		Medium JF <2000ha in forest blocks~		JF >500ha in total to spread grazing pressure (but mosaic's component pockets can be small <32ha*) ((500ha or less is typical in London block at Walpole^))	
Fire size N. Burrows pers. com.^		Large More risk of : i) soil loss; ii) nutrient loss in smoke ash & runoff.				Small Low risk of: i) soil loss; ii) nutrient loss in smoke ash & runoff.	
Fire pattern Size & shape (presence of re-invasion areas for fauna eg phascogale & honey possum) (~Burrows and Friend 1998)		Uniform & high intensity &/or frequent low intensity (100% burnt) or (100% unburnt)		(50:50???) 2 ages		Patchy & low intensity (patchy – aim for 60-70% burnt and 30-40% unburnt~???). 2 or more ages	TAKE THIS FURTHER IT UNDERLIES A LOT & IS NOT YET ADJUSTED
Fire timing (Burrows and Friend 1998)	SW mediterranean	Repeatedly in spring & short interval	Repeatedly in the same season & short interval	Season varied (at least every second burn). Typical interval (Dry soil fire in summer	??	??	LESS IMPORTANT THAN INTERVAL

				& autumn (cf spring) gave highest level of seedling germination & survival due to winter rain follow-up.)			

FAUNA PRESENCE / FAUNA HABITAT PRESENCE

Native fauna present - vertebrates (mammals, reptiles, birds (emus esp.)) Presence at site indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens. *If level of observation is limited consider leaving this blank.	Absent	No activity &/or extremely damaging activity	Very old activity &/or Activity isolated &/or Intense & damaging activity &/or (0-15%)	Old & recent activity &/or Activity scattered Moderate to intense &/or (>15-30%)	Recent & old activity &/or Activity across the site &/or Moderate intensity &/or (>30-60%)	Recent ≥ old activity Low to moderate intensity &/or (>60-90%)	Present throughout Low to moderate intensity &/or (>90-100%)
[59]Native fauna likely habitat - vertebrates (MAMMALS REPTILES BIRDS (EMUS ESP.)) . P/A	Absent	No habitat	Low incidence habitat &/or (Likely habitat 0-15%)	Moderate incidence habitat &/or (Likely habitat >15-30%)	Mod to high incidence &/or (Likely habitat >30-60%)	High incidence habitat &/or (Likely habitat >60-90%)	Present throughout &/or (Likely habitat >90-100%)

[58]Native fauna -present invertebrates Presence at site indicated by sightings, nests, galls, eggs, cocoons, frass, etc.. *If level of observation is limited consider leaving this blank.	Absent	No activity &/or extremely damaging activity	Very old activity &/or Activity isolated &/or Intense & damaging activity &/or (0-15%)	Old & recent activity &/or Activity scattered Moderate to intense &/or (>15-30%)	Recent & old activity &/or Activity across the site &/or Moderate intensity &/or (>30-60%)	Recent ≥ old activity Low to moderate intensity &/or (>60-90%)	Present throughout Low to moderate intensity &/or (>90-100%)
[59]Native fauna likely habitat - invertebrates.. P/A	Absent	No habitat	Low incidence habitat &/or (Likely habitat 0-15%)	Moderate incidence habitat &/or (Likely habitat >15-30%)	Mod to high incidence &/or (Likely habitat >30-60%)	High incidence habitat &/or (Likely habitat >60-90%)	Present throughout &/or (Likely habitat >90-100%)

Indicators - Orchids Indicate: i) Mychorrhiza presence; ii) vector presence; iii) vector habitat presence; & iv) ~favourable fire regime.		No orchids present.	One species present. Individuals scarce.	At least one species present. Individuals common.	Several species present. Individuals scarce.	Several species present. Individuals common.	

FERAL PRESENCE / INCURSION

Feral vertebrate animals present. Indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens/warrens.		Recent ≥ old activity <&/or> Present throughout <> High intensity <> Several species Several signs/species <> (eg>50% cover)	Recent & old activity <&/or> Activity across the site <> Moderate to high intensity <> Several species Few signs/species <> (eg >15-50% cover)	Old & recent activity <&/or> Activity scattered <> Moderate intensity <> 1 (to 2) species 1 (to 2) signs/species or 1 species several signs <> (eg >5-15% cover)	Very old activity <&/or> Activity isolated <> Moderate to low intensity <> 1 species Few signs <> (eg 0-5% cover)	No activity	Absent - no history of feral intrusion.

Feral animal incursion distance Incursion distance (m) of feral animals into native vegetation remnants		If a remnant, ferals have penetrated over 100m.	If a remnant, ferals have penetrated 50-100m.	If a remnant, ferals have penetrated 20-50m.	If a remnant, ferals have penetrated 10-20m.	If a remnant, ferals have penetrated less than 10m.	

Old-world honeybee (other bee species are important), introduced ants (a range of ants species is important), introduced millipedes

Feral invertebrate animals present. Indicated by sightings, tracks, diggings, debris or nests. (What about incorporating bees.)	&/or (>90-100%)	Recent ≥ old activity &/or Present throughout &/or High intensity &/or (>60-90%)	Recent & old activity &/or Activity across the site &/or Moderate to high intensity &/or (>30-60%)	Old & recent activity &/or Activity scattered Moderate intensity &/or (>15-30%)	Very old activity &/or Activity isolated &/or Moderate to low intensity &/or (0-15%)	No activity	Absent - no history of feral intrusion.

TOTAL GRAZING

Total Grazing Note overgrazing from all sources (stock, feral & native) ___________ (If stock or feral animals are present italics may apply).		Grazing heavy. <> Most species grazed. (Mainly unpalatable species grazed) <> Individual plants heavily pruned. <> Regeneration from seed little or none. <> Most of area damaged (eg >50%); intense. <> *Soil surface highly disturbed.*	Grazing moderate to heavy. <> Many species grazed. Regeneration from seed little or none. <> Much of area damaged (eg >15-50%); intense. <> *Soil surface moderately disturbed.*	Grazing moderate. <> Several species grazed. (Some unpalatable species grazed) <> Individual plants moderately pruned <> Generally seedlings affected. <> Little of area damaged (eg >5-15%). <> *Soil surface slightly disturbed.*	Grazing low to moderate. <> Several species grazed. Some seedlings affected. <> Minor area of damage (eg 5-0%). <> (*Soil surface little disturbed*)	Grazing at appropriate levels. <> Select species grazed (Mainly palatable species grazed) <> Individual plants lightly pruned <> Few seedlings affected. <> Grazing spread evenly / less evident. <> (*Soil surface intact*)	Grazing at appropriate levels. Even spread permits vegetative and seedling regeneration. <> Grazing spread evenly.

GRAZING BY NATIVE ANIMALS

Grazing - by native animals. Note overgrazing from all sources (stock, feral & native) ___________		Grazing heavy. Many species grazed. (Mainly unpalatable species grazed)	Grazing moderate to heavy. Many species grazed.	Grazing moderate. Several species grazed. (Some unpalatable species grazed)	Grazing low to moderate. Several species grazed.	Grazing at appropriate levels. Select species grazed (Mainly palatable species grazed)	Grazing at appropriate levels.

	Area denuded (100->90%)	Individual plants heavily pruned. Regeneration from seed little or none. &/or Most of the area damaged (90->60%).	Regeneration from seed little or none. &/or Grazing damage through the area (60->30%).	Individual plants moderately pruned Generally seedlings affected. &/or Grazing disturbance in 30->15% of the area.	Some seedlings affected. &/or Grazing disturbance in 15-0% of the area.	Individual plants lightly pruned Few seedlings affected. &/or Grazing spread evenly / less evident.	Even spread permits vegetative and seedling regeneration. &/or Grazing spread evenly.

GRAZING BY INTRODUCED ANIMALS - record the ferals see PBP list main culprits

Grazing by stock (& or feral animals). Time since stock excluded ___________ *COMPARE ITALICS/\ USE THESE TWO	Area denuded (100->90%)	Grazing heavy. Likely ongoing & longstanding. Most species grazed. Most individuals/sps. Individual plants heavily pruned. Regeneration from seed little or none. *Soil surface highly disturbed.* &/or Most of the area damaged (90->60%).	Grazing moderate to heavy. Likely prolonged. Many species grazed. Many individuals/species. Regeneration from seed little or none. *Soil surface moderately disturbed.* &/or Much of area damaged (60->30%).	Grazing moderate. Likely intermittent. Several species grazed. Several individuals/sps. Individual plants moderately pruned Generally seedlings affected. *Soil surface slightly disturbed.* &/or Grazing disturbance in 30->15% of the area.	Grazing low to moderate. Likely intermittent. Several species grazed. Several individuals/sps Some seedlings affected. (*Soil surface little disturbed*) &/or Grazing disturbance in 0-15% of the area.	Grazing low. Little or no history of grazing Few species grazed. Several individuals/sps Individual plants lightly pruned Few seedlings affected. (*Soil surface intact*) &/or Grazing disturbance limited.	Never grazed
Grazing by feral animals. Time since ferals excluded ___________	Area denuded (100->90%)	Grazing heavy. Likely ongoing. Many species grazed. Individual plants heavily pruned. Regeneration from seed little or none. &/or Most of the area damaged (90->60%).	Grazing moderate to heavy. Likely prolonged. Many species grazed. Regeneration from seed little or none. &/or Grazing damage through the area (60->30%).	Grazing moderate. Likely intermittent. Several species grazed. Individual plants moderately pruned Generally seedlings affected. &/or Grazing disturbance in 30->15% of the area.	Grazing low to moderate. Likely intermittent. Several species grazed. Some seedlings affected. &/or Grazing disturbance in 0-15% of the area.	Grazing low. Little or no history of grazing Few species grazed. Individual plants lightly pruned Few seedlings affected. &/or Grazing disturbance limited.	Never grazed
[18c]Grazing focal areas (flowlines, floodplains & similar water gaining areas, well developed soils & sediments (loams, clay-loams, many clays).		Grazing heavy.	Grazing moderate to heavy	Grazing moderate.	Grazing low to moderate	Grazing low.	
[18d]Grazing general areas TOTAL GRAZING		Grazing heavy.	Grazing moderate to heavy	Grazing moderate.	Grazing low to moderate	Grazing low.	

CONTEXT

[55]Shape Interacts with condition (But independent of other intracondition measures.)		Site is long & narrow <50m wide (yet still retains vegetation in at least moderate	Site is a polygon with at least 50% wider than 50m.	Site is roughly a square or circular in shape, or is a polygon all with no part narrower than 100m		(Remnant very large. Shape incidental.) (Minor adjacent clearing)	(Not isolated)

		condition)					

APPENDIX 3: EXPANSION AND ADAPTATION OF THE KEIGHERY VEGETATION CONDITION SCALE & EQUIVALENTS INTO AN ARRAY OF SEPARATE ATTRIBUTES. THIS IS UNEDITED BUT INDICATES AN ELEMENT OF THE ITERATION BEHIND ATTRIBUTES.

Keighery, B.J. (1994) >>	Completely Degraded	(Degraded II)	Degraded (I)	Good	Very Good	Excellent	Pristine
	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.	(Very few values remaining.)	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.	Pristine or nearly so, no obvious signs of disturbance.
Croft et al (2005)		Very Poor	Poor	Moderate	Good	Excellent	
Native species diversity		0 20	21 40	41 50 60	61 80	81 100	
Weed species abundance		100 81	80 61	60 50 41	40 21	20 0	
Native species (richness) diversity ► Adjusted scale: Number of plant species:	Almost completely without native species. Isolated trees and shrubs. [Ky, T] *No likelihood that richness will be self-sustaining.[Cl]*	Severely altered, few remaining original species [M]. 0-20% of native flora composition. [Kn] Little likelihood richness can be (*maintained or*) re-established. [Cl] >0-20% native plant composition. 0-2 species [A]	*20-50% of native flora composition*. [Kn] (*Moderate to*) Low likelihood that richness can be maintained or re-established. [Cl] >20-40% native plant composition. 3-5 species [A]	Moderate likelihood that richness can be maintained or re-established. [Cl] >40-60% native plant composition >6 species [A]	50-80% of native flora composition [Kn]. Moderate to high likelihood that richness can be maintained. >60-80% native plant composition	80-100% of native flora composition. [Kn] High likelihood that species richness can be maintained. [Cl] >80-100% native plant composition	COMPOSITION 2
Weed abundance ◄ Aggressive invasives (outcompeting): Disturbance	Mainly weed or crop species. [Ky, T] " " (mostly disturbed,	Weeds throughout the	Usually with a range of weed species. Very aggressive weeds present. [Ky, T] Balance tipping to weeds	Weeds mainly non-aggressive species. Presence of some very aggressive weeds at high density is likely. [Ky, T] Weeds approaching equity.	Weeds mainly non-aggressive species. Some more aggressive weeds may be present. [Ky, T] Weeds scarce. (Weeds in	Weeds are non-aggressive species (implied at low levels). [Ky, T] Weeds none to very few.	Weeds an independent factor. Large conservation areas slow penetration from boundaries and nucleation by seeds (esp. via animal

opportunitists (follow change): Adjusted cover scale: BB (adjusted) Ka Map distribution [P]	mostly weeds)	area. [Cl] Weeds replacing native species. [M] Weeds in ≥80% of the area. Cover/abundance of weeds 60-100%. [Kn] (>80-<100%) <100->75% [B] 100-60% [Kn] Throughout site [P]	(may be >50%). [Cl] Weeds >50%.[B] Weeds in 60-80% of the area. Cover/abundance of weeds 20-60%. (any number of individuals). [Kn] (80->60%) 75->50% [B] 60-40% [Kn]	(Weeds in 20-50% of area [Cl]). (Weeds may be up to 50% of (*remnant*) area) [M] Weeds >20-<50%. [B] Weeds in @50% (40-60%) of the area. (60->40%) 50->25% [B] 40-20% [Kn] Spot occurrences [P]	<20% of area [Cl]). Weeds <20%.[B] Weeds in 20-40% of the area. Cover/abundance of weeds 5-20%. [Kn] (40->20%) 25->5% [B] 20-5% [Kn] Edges, tracks, cleared areas [P]	Few or localized weeds[M] Few or no weeds.[B] Weeds in ≤20% of area. Cover/abundance of weeds <5%. [Kn] (20-0%) <5% [B] <5% [Kn] Disturbed areas only [P]	vectors). Weeds a subcomponent. Small remnants faster penetration from large perimeters brimming with weed sources. Weeds a sub- to main component. WEED
Composition of weeds List species___[A, P]	> 10 weed species present [A]		5-10 weed species present [A]		1-5 weed species present [A]		No weed species present [A]
Incursion distance (m) of weeds into native vegetation remnants in the vicinity of sites [A]. Record distance ____[A]		Weeds intrude more than 100m into remnant [A] Obviously weedy throughout [A]	Weeds intrude 50-100m into remnant [A] Patchily weedy throughout [A]	Weeds intrude 20-50m into the remnant [A]	Weeds intrude 10-20m into remnant [A] Weedy around edges [A]	Weeds intrude less than 10m into remnant [A] No or very slightly weedy [A]	No weeds FRAGMENTED
Presence of weeds in native vegetation remnants (% projective foliage cover within 100m of remnant edge). [A]	>70% [A]	50-70% [A]	30-50% [A]	15-30% [A]	(>5-15% [A])	<5% [A]	FRAGMENTED
Structure ►	Structure not intact. (Loss of diverse layers). [Ky, T]	Widespread loss of vertical structure. Little likelihood that structure can be re-established.	Severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. [Ky, T] Some vertical structure missing. Low likelihood that structure can be maintained or re-	Significantly altered. Retains basic vegetation structure or ability to regenerate it. [Ky, T] Possible modification to structure (due to modified fire regimes). Moderate chance of maintaining	Structure altered. [Ky, T] Good likelihood structure can be maintained. Possible modification to structure (due to changes in fire regimes). High likelihood that structure	Intact vegetation structure. [Ky]	

Adjusted scale: [B] [Kn]		[Cl] Structure disappeared. [Kn] Structure severely altered. [B]	established. [Cl] Structure nearly completely modified. [Kn] Community simplified. [B] Often with shrub & ground cover sparse or absent. [M]	structure. [Cl] All expected layers present, but may be sparse. [B]	can be maintained. [Cl] Structure modified or nearly so. [Kn] All expected layers present, but may be sparse. [B]	Structure intact or nearly so. [Kn] All expected layers present. [B]	COMPOSITION/ STRUCTURE 3
Recruitment ◄ (<u>State if stages present & their % cover</u>) Seedlings: Saplings: Population age/stage balanced: (Consider if cohorts of plants that have not yet set seed are present.)	No recruitment [A]. (NB rare in some communities such as salmon gum)	Recruitment disrupted and most species appear senescent. [Cl]	Recruitment disrupted and most woody species appear senescent. [Cl] (More than one population affected). Understorey & groundlayer not self-maintaining. [M] ≤5% [A]	Localised recruitment and populations of some species may be senescent. [Cl] >5-15% [A]	Seedling recruitment evident. Healthy population size (age/stage) structure apparent. [Cl] More than one wave of recruitment may be apparent. Saplings evident. Limited senescence. Natural regeneration occurring. [M] >15-30% [A]	(Seedling recruitment evident. Healthy population size (age/stage) structure apparent. [Cl]) More than one wave of recruitment may be apparent. Saplings evident. Self-maintaining. [M] >30% [A]	Regeneration occurring in the appropriate timeframe. (In older vegetation, or fire-exclusion areas, this may be at low rates and over long timeframes.) REGENERATION 1
General Health [B, A] % plants with significant health problems [A]. Describe symptoms & cause if known separately for trees, mallees, shrubs ([A] – NB scorecard & site form diverge).	Graveyard death All or most trees >70% [A]	May be severely stressed [B]. May be dying or dead [M]. Several trees with health problems; >50-70% [A]. Numerous tree stumps from poor health. Canopy reduction eg stags [P]. FRAGMENTED AREAS: Signs of stress amplified by narrow shape <50m wide [B].	Signs of stress [B]. Few trees with health problems; >30-50% [A].	>15-30% [A].	Signs of stress [M]. >5-15% [A].	Healthy [M]. No trees with health problems.	THREATS DISTURBANCE
Tree health basic	All large trees dead		>50% of large trees dead.		<50% of large trees dead.		
Tree health ◄ (Dieback.) Disease [P]	Graveyard death	Dieback widespread. Much of the area and most susceptible species affected.	Dieback evident. [Ky] Several individuals, several species. In several pockets.	Dieback evident. [Ky] Few individuals, few species. Localised (likely 1 pocket).	Dieback evident. [Ky] Early stages. Few individuals, few species.	Dieback free.	Dieback free. THREATS DISTURBANCE

Tree health ◄ (Insect damage incl: galls, lerps, leaf miners, wood borers, etc.) [P]		Insect damage widespread. Most of the area and most susceptible species affected.	Insect damage evident. Much of the populations of susceptible species affected.	Insect damage evident. Parts of the populations affected.	Localised insect damage evident. Mainly confined to individuals.	Limited insect damage.	Limited insect damage. THREATS DISTURBANCE
Tree health ◄ (Mistletoe & other plant parasites).		Parasites widespread. Most of the area and most susceptible species affected.	Parasites evident. Much of the populations of susceptible species affected.	Parasites evident. Sectors of the plant populations affected.	Parasites evident. Mainly confined to individuals.	Limited parasitc plant damage.	Limited parasitc plant damage. THREATS DISTURBANCE
Tree habitat. Tree hollow (P/A in mature trees [P]). Logs. ◄□ Number of hollows (>3cm & above DBH) [A]. □ Number of large standing dead trees (viz. >30cm at DBH; or a large mallee >15cm at DBH) [A]. □ P/A of areas of trees (plus or minus understorey) [P]		All young trees. Scarce hollows. Scarce logs. All small. No hollows. [A]	Mainly young trees. Few hollows. Few logs. All small.	Mix of young & maturing trees. Some hollows. Some logs. Small & medium sizes. 1-2 trees with hollows. [A]	Mix of young & maturing trees. Some hollows. Some logs. Small & medium sizes.	Range of young to mature trees. Hollows evident. Logs evident. Small, medium & large. 3-6 trees with hollows. [A]	Range of young to mature trees. Hollows evident. Logs evident. Small, medium & large. HETEROGENEITY
Logging. ◄ For forest or woodland, and trees or tall shrubs (suited to fence posts). (One or more descriptor may apply). (Part of scheme [P])	Heavy logging or clear-felling.	Heavy logging. Most cohorts or age-classes of dominant species affected	Moderate to heavy logging. Ongoing logging. More than one round of logging evident. Mix of medium to smaller stumps, & larger older stumps, evident. Most trees of small diameter. Multi-stemmed coppicing from stumps evident.	Moderate logging. Some cohorts or age-classes of dominant species affected.	Limited to moderate logging. Mix of a few old & large and smaller stumps. Only a few trees of larger diameter. Some multi-stemmed coppicing from stumps	Limited and/or long-past logging. Some old & large stumps present. Some trees of larger diameter? Little multi-stemmed coppicing from stumps.	None (or limited and/or long-past logging.) Tree diameters relatively large. Mature or maturing trees are present in the population. THREATS DISTURBANCE
Firewood collection. ◄ Recent, fresh sawdust & cuts [P]. NOTE:______	Heavy firewood collection. Area denuded.	Heavy firewood collection. Area denuded.	Moderate to heavy firewood collection.	Moderate firewood collection.	Limited to moderate firewood collection.	Limited firewood removal.	None. (To very limited). THREATS DISTURBANCE
Thickets or refuge areas. ◄□ P/A of areas of dense understorey [P].	Absent.	Absent.	Poorly developed or disrupted. Very limited in extent.	Moderately developed. Scattered patches. Some thickening of layers in the undergrowth.	Moderately to well developed. Consolidated thickets in continuous bands through	Well developed through much of the area or adjacent areas (within 100 to 200m).	Well developed through much of the area or adjacent areas (within 100 to 200m).

Intact or interconnecting shrubland/heathland canopy offering nesting and foraging habitat for fauna [A]. (One or more descriptor may apply).		No shrub cover [A].	Shrub cover <20% [A].		the area. Shrub cover 20-40% [A].		HETEROGENEITY
Presence of ecotones and a mosaic of patches. At site and adjacent to it.	Uniform age and type of vegetation.	Relatively uniform. Ecotones scarce. Patches scarce.		Parts of the area heterogeneous in terms of age and type of vegetation. Some ecotones present.		Fairly heterogeneous. Eoctones common. Patches common.	Heterogeneous or mosaic mixture of ages and types of vegetation. HETEROGENEITY
Grazing ◄ By stock. Time since stock excluded [A]		Grazing heavy. Most of the area damaged (80-100%). Many species grazed. Regeneration from seed little or none. Set stock rates [A] Very heavy grazing [M]	[Grazing evident.] Grazing moderate to heavy. Grazing damage throughout the area (60-<80%). Many species grazed. Regeneration from seed little or none. Rotationally grazed [A] Heavy, prolonged, grazing pressure [M]	[Grazing evident.] Grazing moderate. Grazing disturbance in 40-<60% of the area. Several species grazed. Strategically grazed [A]	[Grazing evident.] Grazing low to moderate. Grazing disturbance in 20 to <40% of the area. Several species grazed. Moderate grazing pressure [M]	Grazing low. Grazing disturbance in <20% of the area. Few species grazed. Few seedlings affected. Historically grazed [A] Little or no history of grazing [M]	Grazing absent. DISTURBANCE Never grazed [A]
Grazing ◄ By native animals. Note overgrazing from all sources (feral & native) [P]		Grazing heavy. Most of the area damaged (80-100%). Many species grazed. Regeneration from seed little or none.	Grazing moderate to heavy. Grazing damage throughout the area (60-<80%). Many species grazed. Regeneration from seed little or none.	Grazing moderate. Grazing disturbance in 40-<60% of the area. Several species grazed.	Grazing low to moderate. Grazing disturbance in 20 to <40% of the area. Several species grazed.	Grazing at appropriate levels. Spread in a way that still permits vegetative and seedling regeneration.	Grazing at appropriate levels. Spread in a way that still permits vegetative and seedling regeneration. PROCESS-BALANCED OR DISTURBANCE
Disturbance ◄ Soil and/or substrate disturbance. Such as trampling, tracks, road-works, earthworks and mining. Erosion. (State form of disturbance.)		Impact chronic. Affecting 80-100% of the area. Disturbance incidence very high [Kn]	Impact severe. [Ky, T] Widespread high level disturbance affecting 60-<80% of the area. Disturbance incidence high [Kn]	Very obvious signs of multiple disturbance. [Ky, T] Widespread high level disturbance affecting 40 to <60% of the area.	Obvious signs of disturbance. [Ky, T] Generally low-level disturbance. May be high in small patches. Affecting 20 to <40% of the area. Minor signs of disturbance [Kn]	Disturbance to individual species. [Ky, T] Localised low-level disturbance. Affecting 0 to <20% of the area. No or minimal signs of disturbance [Kn, M]. Confined to small areas [M]	No obvious signs of disturbance (caused by colonial settlement). [Ky, T] THREATS DISTURBANCE

Recently cleared (< 2years) (after Perkins 2002)		Low resilience Soils modified; cultivated &/or pasture improved; imported material. + Normally exotic dominated		Moderate resilience Soils unmodified; uncultivated + Exotic dominated		High resilience Soils unmodified; uncultivated + Native dominated	
Historically cleared (>2 years) (after Perkins 2002) or recurrently disturbed	Very low resilience Soils modified; cultivated &/or pasture improved; imported material. + Normally exotic dominated	Low resilience Soils unmodified; uncultivated + Exotic dominated		Moderate resilience Soils unmodified; uncultivated + Native dominated			
((Double up)) Fire management regime – intensity & frequency. [A]		Site wild-fired or deliberately burnt every 2-3years [A]		Site experiences hazard-reduction burns every 10+ years. [A]		Site not burnt in past 20 or more years. [A]	
Estimate time since fire [P] <2y, <5y, <10y, <20y, >20y							
Fire ◄ (●Timing; ●Frequency/interval; ● Intensity; ●Extent.) Vegetaion type Fire intolerant Fire tolerant Weed free Weed inoculated (type & degree) The correct interval may	Fire too frequent. Some life forms may be missing. For example acacias that take about 5 years to mature and deposit sufficient seed in the soil will decline if the interval is only 3 years. Fire too infrequent. Each fire tends to be extensive & cover the		[Very frequent fire.] Fire regime altered and structure clearly affected.	[Very frequent fire.] Fire regime altered and this may have changed the structure.	[Repeated fires.] Modified fire regimes (structure altered).	Some evidence of fire regime change. ●Most perennial species present in a mature form and able to reproduce.	In large areas. A mix of fire intervals. A patchwork of coverage throughout an area. This is reflected by a mosaic of resources, increased interfaces, & heterogeneity. In small, isolated, remnants the fire interval is appropriate to the vegetation. A range of native plant

be shown by: ●orchids; Or the presence and/or higher density of facultative or obligate fire ephemeral species in the genera: ●(pancontinental) Codoncarpus, Gyrostemon, Haloragis, Austrostipa; ●Anthocercis, Tersonia, Glichrocaryon, Dysphania, Trachymene, Sida.	entire area and render the vegetation of uniform age [P] since fire and inter-fire interval. In a small isolated area this risk is high. Or annual species with seed that survives 30years will decline if the interval is more than 30 years. Fire too intense [P]: ●fire scars high up; ●trees suckering from the trunk (as well as branches); Fire too intense and/or too frequent: ●major trunk damage.	●Bare soil with evidence of encroaching or accelerated wind or water erosion. ●Little buildup of biomass in the vegetation. ●Very little plant litter, thin where present. ●Large logs nearly burnt away [P] ●Whole plants or cohorts of plants dead. [P] ●Introduced grasses form much of the ground cover. ●Fire scars on many dominants, such as dead branches and hollowed-out stems. ●Little senescent vegetation.					life forms from herbaceous to woody, from annual to perennial, and from seeder to sprouter is present. ●Bare, unconsolidated, soil surface small in extent. Mainly near natural flow-lines. ●Much biomass in standing vegetation (more mature individuals of key species may be present). Understorey thickets may be present, and/or the overstorey may be closed and the abundance or richness or diversity of understorey may be low. ●In places much accumulation of plant litter, debri and humus. Layers thick. ●Low incidence of fire-related death of plants. ●Low incidence of fire scars. ● No introduced, fire-responsive species, such as grasses, present. ●Some vegetation may be senescent in places.
Fire frequency declining and interval increasing . Fire exclusion in fire adapted vegetation. Either actively enforced or arises by neglect or isolation. Layers in the vegetation tend to become uniform in age and structure. When fires eventually	Fire too infrequent. Populations of perennial plants, including dominants, senescent. Some ephemeral species are absent (long unrecorded) in the area.	Vegetation thick, rank, overgrown and possibly senescent. Much biomass stored in vegetation. Much leaf litter. Much humus. Few ephemeral species present. No fire scars or		Some plants/species starting to become senescent. Fire-ephemeral species becoming more scarce. Opportunities for fire-ephemeral species to reproduce declining.			Fire at the appropriate interval for the vegetation type. Key perennials, perhaps even dominants, mature, but not senescent. Ephemeral species with finite seed life in the soil are present.

occur they are relatively large, intense, and cover much of the area.		epicormic or basal resprouting of trees.					
Fire frequency rising and interval contracting. Fire is occurring regularly in fire-adapted vegetation. Layers in the vegetation tend to become uniform in age and structure. Species which can regenerate rapidly by sprouting or germination are favoured & dominate.	Fire too frequent. Certain species may be excluded. For example mulga or Acacia transluscens with soft spinifex. Or other species amongst annual sorghum.	Vegetation open, not impenetrable, no senescent plants. Lower levels of biomass stored in vegetation. Annual species common. Fire scars and/or epicormic sprouts and/or basal sprouts common on trees.		Little or no evidence of plant senescence. Fire-ephemeral species becoming more common. Opportunities for fire-ephemeral species to reproduce increasing.			Fire at the appropriate interval for the vegetation type. Key perennials, perhaps even dominants, mature, but not senescent. Ephemeral species with finite seed life in the soil are present.
Clearing ◄	"Parkland cleared" At best only a few, isolated, overstorey plants present. Totally cleared [B]	*Heavy clearing*. 80 – 100% clearing.	Partial (*to heavy*) clearing. 60 - <80% clearing.	Partial clearing. 40 - <60% clearing.	*Little clearing*. 20 - <40% clearing.	*Little or no clearing*. 0 - <20%.	*No clearing*. THREATS DISTURBANCE
Sivicultural management of forests							
	Completely Degraded	(Degraded II)	Degraded (I)	Good	Very Good	Excellent	Pristine
Bioturbation							FLOWS
Landscape function measures							FLOWS
Road density (infrastructure)							LANDSCAPE CONTEXT - MATRIX
Invasive species							LANDSCAPE CONTEXT - MATRIX

◄ - INDICATES A SELF-CONTAINED MEASURE THAT CAN BE DERIVED FROM THE AREA AND WITHOUT REFERENCE TO A BENCHMARK; ► - INDICATES A MEASURE THAT MAY REQUIRE SOME TERMS OF REFERENCE; □ - ADDED ATTRIBUTE.
WITH REGARD TO WEEDS A DISTRICT OR REGIONAL GUIDE MAY BE NECESSARY &/OR A WEED COURSE.

Sources:

De-novo entries in pink; Keighery 1994 (italics- inferred); Connell 1995; Croft et al 2005; Kaesehagen 1994; MYB 1993; Bushland Benefits.

	Completely Degraded	(Degraded II)	Degraded (I)	Good	Very Good	Excellent	Pristine
WOODLAND Y/N? Degree of woodland structural complexity (number of strata present. & projective foliage cover) [A]. Projective foliar cover [adjusted]/Per layer crown cover [P]	No layers present. [A] <5% [adj]	1 layer present but <30% foliage cover per layer [A] >5-10% [adj] >2-10% [P]	2 layers present & >30% foliage cover per layer [A] >10-30% [adj] >10-30% [P]	>30-50% [adj] >30(-50%) [P]	3 or more layers present but <30% foliage cover per layer [A] >50-70% [adj] (>50-)70% [P]	>70% [adj] >70% [P]	+/- HETEROGENEITY
SHRUBLAND Y/N? Degree of shrubland structural complexity (number of strata present & projective foliage cover) [A]	No layer present [A]	1 layer present but <30% foliage cover per layer [A]	2-3 layers present & >30% foliage cover per layer [A]		3 or more layers present but <30% foliage cover per layer [A]	>3 layers present & >30% cover per layer	+/- HETEROGENEITY
GROUNDCOVER Y/N? Percentage projective foliage cover of herb (*or groundcover*) stratum [A]	(None-) <2% [A]	>2-10% [A]	>10-30% [A]	>30-50% [A]	>50-70% [A]	>70% [A]	+/- HETEROGENEITY
CRYPTOGRAM Y/N? Percentage projective foliage cover of intact cryptogram layer [A]. Moss beds (for fungi habitat) [P].	(None-) <5% [A]	>5-10% [A]	>10-30% [A]	>30-50% [A]	>50-70% [A]	>70% [A]	+/- HETEROGENEITY
LITTER Y/N? Percentage projective foliage cover of leaf/bark/branches (,10cm diam.)/other plant material litter layer [A] (of native plant origin). ((given a low score of 3 – [A])) Litter depth [A] □ Litter is fungi/invertebrate habitat [P].	(None-) <5% [A]	(>5-15%)	(>15-30%)	>30-50% [A]	>50-70% [A]	>70% [A]	+/- HETEROGENEITY

COARSE DEBRIS Y/N? Percentage of area with coarse woody debris (incl. logs >10cm diam). ((Site form & scorecard differ)) [A] P/A:____________ [A] Large logs [P]	Absent					Common	HETEROGENEITY
ROCKS Y/N? Presence of rocks (>10cm diam) and/or boulders on the ground. [A, P] Rocks present. □ Outcrops present. □							HETEROGENEITY *** NO BEARING INDEPENDENT OF CONDITION
NORMALY BARE Y/N? Naturally bare areas [VAST]							HETEROGENEITY *** NO BEARING INDEPENDENT OF CONDITION

	Completely Degraded	(Degraded II)	Degraded (I)	Good	Very Good	Excellent	Pristine
Hydrology + Areal extent/history of waterlogging [A] Flooding/rise in groundwater table suspected [P] (Dead stags of gums, sheaoaks, etc). (Often linked to redirection of drainage directly to low-lying areas.)	Most of site affected by seasonal waterlogging [A]	50% of site affected by seasonal waterlogging [A] Very heavy waterlogging. Swamp tolerant plants replacing original species [M].	10-50% of site affected by seasonal waterlogging [A] Altered hydrology evident [M, B] (including waterlogging [M]).	<10% of site affected by waterlogging [A]			THREAT DISTURBANCE
Hydrology – Drought/lowering of the watertable suspected. [P] (Latter often linked to a source of abstraction, a dam, or to a natural waterbody that is receding).	Graveyard death of overstorey (and perhaps some deep-rooted overstorey)	Whole areas with dead overstorey (and perhaps some deep-rooted overstorey).	Pockets of dead overstorey.	Scattered individual overstorey plants stressed or dying.	Scattered individual overstorey plants stressed.		THREAT DISTURBANCE
Salinity secondary [P] Sec. sal. P/A [P]_______ *Proximity of (secondary) salt outbreak to drainage line [M]* Time since salt outbreak began/detected. [A] (These may = trend each) Action taken on salinity. Fencing; planting salt tolerant species; deep drainage to direct sub-surface salt away from crops [A] + planting	(May be) Heavily impacted by secondary salinity [B]. *(Proximity) Riparian* [M] and/or (Secondary) Salt outbreaks at site – severity high ['S3'-M]	(May be) Salt tolerant plants replacing original species. Quite heavy salinity [M] *(Proximity) <200m* [M] and/or (Secondary) Salt outbreaks at site – severity moderate ['S2'-M]	Signs of secondary salinity. [M] *(Proximity) <500m* [M] and/or (Secondary) Salt outbreaks at site – severity low ['S1'-M]	*(Proximity) <1000m* [M] and/or (Secondary) Salt outbreaks in local landscape – severity high ['S3'-M]	*(Proximity) >1000m* [M] and/or (Secondary) Salt outbreaks in local landscape – severity moderate ['S2'-M]	*Distant (or only primary-with intact diversity)* [+] and/or (Secondary) Salt outbreaks in local landscape – severity low ['S1'-M]	*Absent (or only primary with intact diversity)* [+] and/or No (secondary) salt outbreaks [A] THREAT DISTURBANCE

deep-rooted species higher in the profile.							
Erosion P/A_____________[P, A] Severity and areal extent of soil erosion associated with the site [A]	Heavily impacted by wind erosion (eg blowout or obvious dune-like deposition [B]	Severe (>75% of the site) [A]	Signs of erosion [M] Moderate (51-75% of the site) [A]	Slight (25-50% of the site) [A]	Minimal (<25% of the site)	(Low to none <5%)	THREAT DISTURBANCE
Soil structure [M]			(General) change in soil structure [M]		Change in soil structure localized [M]		THREAT DISTURBANCE
Wetland eutrophication [P]							THREAT DISTURBANCE
Resource extraction [P] Mining______________ Construction__________ Material _____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________							THREAT DISTURBANCE
Enrichment planting with non-local plants. [P]							THREAT DISTURBANCE
Rubbish dumping [P] Material _____________ Commenced __________ Ended _______________ Duration _____________ Rehabilitation _________							THREAT DISTURBANCE
Service corridors [P]							THREAT DISTURBANCE
Track proliferation [P]							THREAT DISTURBANCE
Off-road vehicle disturbance [P]							THREAT DISTURBANCE
Shape Interacts with condition [B] (But independent of other intracondition measures.)		Site is long & narrow <50m wide (yet still retains vegetation in at least moderate condition) [B]	Site is a polygon with at least 50% wider than 50m. [B]	Site is roughly a square or circular in shape, or is a polygon all with no part narrower than 100m [B]			

Presence of feral animals at site indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens/warrens. [A, P]			>50% feral animal invasion/presence [A]	10-50% feral animal presence [A]	<10% feral animal presence [A]		
Incursion distance (m) of feral animals into native vegetation remnants [A]		Ferals occur more than 100m into remnant. [A]	Ferals occur 50-100m into remnant. [A]	Occur 20-50m into remnant. [A]	Occur 10-20m into remnant. [A]	Do not occur more than 10m into remnant.	FRAGMENTED
Native fauna [P] Presence at site indicated by sightings, tracks, diggings, scats, kills/food debris or roosts/dens.							
Native fauna [P] Likely habitat exists at site.							
Native fungi. Presence.							

APPENDIX 4: BUSHLAND SURVEY SHEETS FROM KEIGHERY 1994.

Vegetation Survey Sheet 1 (From Keighery 1994.)

BUSHLAND AREA____

DATABASE SITE NUMBER______________________________**STRUCTURAL PLANT COMMUNITY NO.**______

DATE TRIP________ **BOTANIST**______________**RECORDERS**____________________________

DATE TRIP________ **BOTANIST**______________**RECORDERS**____________________________

DATE TRIP________ **BOTANIST**______________**RECORDERS**____________________________

1. LOCATION of the QUADRAT/SAMPLE POINT

Mud Map Draw a sketch of the location of the site below.

Indicate location on Map 4 for PBP NAIA Templates.

From '*Bushland Plant Survey*' written by B. Keighery (1994) and published by the Wildflower Society of WA (Inc.), PO Box 64 Nedlands WA 6008.

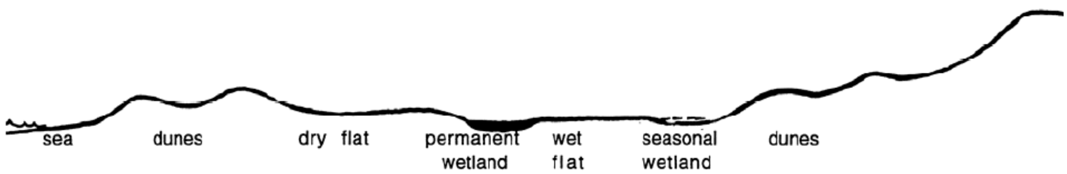
↑ N

Road Location				
Geographic Location	**Latitude**	S	**Longitude**	E
GPS Used:	yes/no	***GPS Datum OR Reference Map Used:***		
Photograph	Photographer's Name		Photo No.	

Topographic position Circle position of site on the transect (alter the transect if necessary eg. for Jarrah Forest)

SWAN COASTAL PLAIN

Upland or Wetland? (circle one)



2. SITE DATA Circle the correct response.

Slope: **flat gentle steep**	***Aspect:*** **N NE E SE S SW W NW na**
Surface Soil: sand, loamy sand, sandy loam, loam, clay, gravel/laterite ***Colour***	
Exposed rock: ***type***	% surface
Sub-surface Soil: sand, loamy sand, sandy loam, loam, clay, gravel/laterite ***Colour***	
Rock: ***type***	depth to rock

Drainage: **well mod poor**	**depth water** cm	***Wet:*** **all year winter/spring na**

Litter: % cover	***Bare Ground*** % cover
Depth cm	

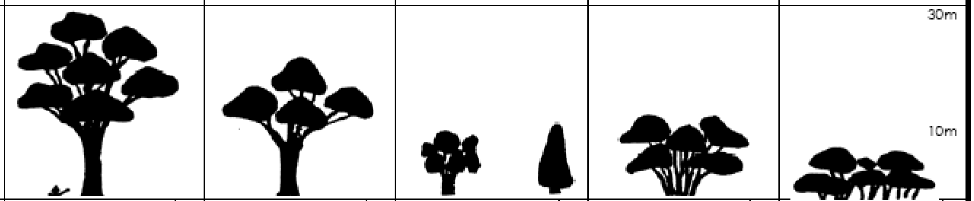
Vegetation Survey Sheet 2 (From Keighery 1994.)

3. VEGETATION STRUCTURE AND COVER

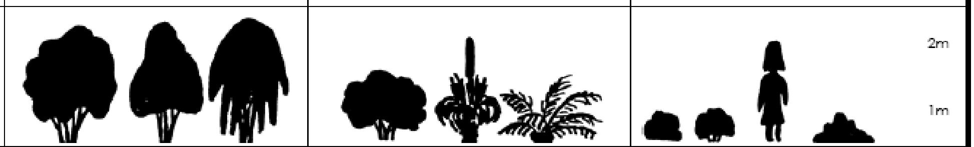
From '*Bushland Plant Survey*' written by B. Keighery (1994) and published by the Wildflower Society of WA (Inc.), PO Box 64 Nedlands WA 6008.

For each layer **record – appropriate growth form, cover class** (see below) and **dominant species** in their order of dominance, up to a maximum of 3 species. If more than 3 species are obviously dominant record as many as appropriate to describe each layer. For NVIS record max. height of layer & % crown cover to nearest 5%.

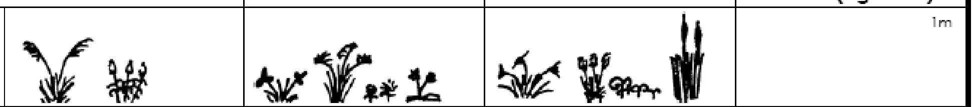
Cover Class	2 – 10%	10 – 30%	30 – 70%	over 70%



	TREES						MALLEES			
	over 30m		10 – 30m		under 10m		over 8m		under 8m	
GROWTH FORM										
COVER CLASS (%)		#		#		#		#		#
HEIGHT & CROWN COVER (NVIS)										
DOMINANT SPECIES										



	SHRUBS				SHRUBS	
	over 2m		2m – 1m		under 1m	
GROWTH FORM						
COVER CLASS (%)		#		#		#
HEIGHT & CROWN COVER (NVIS)						
DOMINANT SPECIES						



	GRASSES		HERBS		SEDGES		OTHER (eg. ferns)	
GROWTH FORM								
COVER CLASS (%)		#		#		#		#
HEIGHT & CROWN COVER (NVIS)								
DOMINANT SPECIES								

4. VEGETATION CONDITION (see Keighery 1994 in Appendix 4 of PBP NAIA Templates)		
1 'PRISTINE'		COMMENTS (give reasoning for choice)
2 EXCELLENT		
3 VERY GOOD		
4 GOOD		
5 DEGRADED		

From '*Bushland Plant Survey*' written by B. Keighery (1994) and published by the Wildflower Society of WA (Inc.), PO Box 64 Nedlands WA 6008.

Vegetation Survey Sheet 3 (From Keighery 1994.)

5. SPECIES PRESCENCE **Label** each plant with **plant's number, site code, date and plant's name or working name if required**

Database SITE No	
Date	

Record on sheet
- **Column 1** **plant name**
- **Column 2** **plant number**
- **Column 3** **identification checked -** √ when checked

From '*Bushland Plant Survey*' written by B. Keighery (1994) and published by the Wildflower Society of WA (Inc.), PO Box 64 Nedlands WA 6008.

TREES	No	ID	SHRUBS (cont.)	No	ID	HERBS (cont.)	No	ID
MALLEES								
			GRASSES					
SHRUBS								
						SEDGES		
			HERBS					

Icon Flora Species (Note on list above if present)	Icon Community (tick if an icon community)
Description of Structural Plant Community No. __ (see Appendix 2 of PBP NAIA Templates)	

Vegetation Survey Sheet 4 (From Keighery 1994.)

Keighery Condition Scale (Keighery 1994)
Pristine Pristine or nearly so, no obvious signs of disturbance
Excellent Vegetation structure intact; disturbance affecting individual species; weeds are non-aggressive species
Very good Vegetation structure altered; obvious signs of disturbance *For example, disturbance to vegetation structure caused by repeated fires; the presence of some more aggressive weeds; dieback; logging; grazing*
Good Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. *For example, disturbance to vegetation structure caused by very frequent fires; the presence of some very aggressive weeds at high density; partial clearing; dieback; grazing.*
Degraded Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. *For example, disturbance to vegetation structure caused by very frequent fires; the presence of very aggressive weeds; partial clearing; dieback; grazing*
Completely Degraded The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. *These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.*

From '*Bushland Plant Survey*' written by B. Keighery (1994) and published by the Wildflower Society of WA (Inc.), PO Box 64 Nedlands WA 6008.

APPENDIX 5: SOME TRIAL FIELD SHEETS

PHYSICAL SITE DETAILS

DATE: ___________________________ RECORDERS: __________________________________

PROJECT: _________________________ SITE: ___________________________

SITE FORMAT & DIMENSIONS: ____ IS THE SITE UNIFORM? – MAP ZONES ____________________

OBSERVATION CODE (STANDARD PLOT ARRAY): ______________________________________

OBSERVATION QUALITY: __________________________

Keighery 1994

LOCATION: ____

____

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude

GPS used: yes/no DGPS used: yes/no LOCATION IN PLOT (NW CNR/CENTRE/OTHER): ____

Central 25mx25m plot

CENTROID:

GPS datum: ______________________ Lat: ________________________________ Long: ___________________________________ Altitude: __________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: ______________________ Lat: ________________________________ Long: ___________________________________ Altitude: __________________

BEARINGS:

Diagonal__________________Corner boundary bearings:______________________________&_________________________________

PHOTOS: photographer: __________________ format: ___________________ code: ____

Other plot____________________

CENTROID:

GPS datum: ______________________ Lat: ________________________________ Long: ___________________________________ Altitude: __________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: ______________________ Lat: ________________________________ Long: ___________________________________ Altitude: __________________

BEARINGS:

Diagonal__________________Corner boundary bearings: ______________________________&_________________________________

PHOTOS: photographer: __________________ format: ___________________ code: ____

Landform & Soils

SLOPE: flat/ gentle/ steep ASPECT: N/ NE/ E/ SE/ S/ SW/ W/ NW OR n/a

SURFACE SOIL: Colour: _________________ Texture: sand/ loamy sand/ sandy loam/ loam/ clay/ gravel

EXPOSED ROCK (type and % of surface):

SUB-SURFACE SOIL: Colour: _____________ Texture: sand/ loamy sand/ sandy loam/ loam/ clay/ gravel

UNDERLYING ROCK (type and depth if known):

DRAINAGE: well/ moderate/ poor WET: all year/ winter and spring only OR n/a

CURRENT WATER DEPTH: _________ cm

LITTER (% cover & depth):________ _____________ BARE GROUND (% cover)

Topographic Position Circle position of point described on a transect diagram of site below.

beach, primary dunes, secondary dunes, swale, hinterland dunes, undulating/plain, permanent wetland, undulating wet flat, seasonal wetland, foothill, scarp, hill, mountain
creek, river floodplain, river bank, estuary, river mouth,
lowerslope, midslope, upperslope, crest, ridge, foreslope/backslope
VEGETATION: ____
VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____
TIME SINCE FIRE: ____
NOTES: ____

SEASON: _________________________________ WEATHER DATA: ____
AMBIENT WEATHER INFORMATION: ?????????????????

SHEET FOR ESTIMATING BASIC CATEGORIES IN THE 25MX25M QUADRAT

Layer	Height /depth [A]	Quadrat	Comment	Gaps in canopy % [B]	Live cover % [C]							Dead cover % [D]			Stress rating [E]	Stressed cover %	Note
Disturbed		10			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
		25															
Weed		10															
		25															
Bare ground		10															
		25															
Rock [F]		10															
		25															
Cryptogam		10															
		25															
Litter		10															
		25															
Logs		10			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
		25															
Ground –cover Foliage		10															
Bark/ limbs		10		----------													
Foliage		25															
Sedge/grass Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25															
Low shrub Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
High shrub Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25															
Over-storey Foliage		10															
Bark/limbs		10		----------													
Foliage		25															
% free of any canopy		10															
		25															

[A] m – tree, mallee, shrub ≥ 1m; cm - rest; [B] to convert canopy to foliar cover; [C] for <1 show if 0/0.01/0.1; [D] only significant % (>0.1%); [E] 0-None, 1 – Low, 2- Mod, 3 – High; [F] Rock – also use for naturally bare areas eg dunes.

Comments:	Wet/dry or overcast(%cloud cover)/sunny or hazy/clear
Stressed by:	Disease/pests/grazing/disturbance DEFINE STRATA DIMENSIONS

SPECIES SHEET - THIS CAN BE EITHER FULL SPECIES OR BY KEY DOMINANTS (UP TO 3 PER LAYER)

Lifeform Layer (tree, mallee, shrub, herb, sedge, rush, grass, other, crypto-gram)	Height (m – tree, mallee, shrub ≥ 1m; cm - rest)	Exotic /weed (*)	Species	% gaps in canopy cover Canopy cover to foliar cover.	% cover – alive (for <1 show if 0, 0.01, or 0.1)							% cover – dead (only signif. %)	No. plants – alive (1, 5, 10, 50, 100, 500, 1000)	No. plants – dead (only signif. no.)	Health - stress rating 1 - Low 2- Mod 3 - High	Health - % cover stress-ed	Note
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	
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25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	

A1	A2	A3
B1	B2	B3
C1	C2	C3

Grid for mapping zones in the array.

SHEET FOR RECORDING SALIENT DIFFERENCES BETWEEN QUADRATS IN THE ARRAY

MEASURE	A1	A2	A3	B1	B2	B3	C1	C2	C3
OVER ALL									
NATIVE PLANTS TOTAL COVER									
NATIVE PLANTS COMPOSITION									
NATIVE PLANTS DENSITY									
NATIVE PLANTS STRATA									
NATIVE PLANTS HEALTH									
WEED TOTAL COVER									
WEED COMPOSITION									
WEED STRATA									
PROCESSES									
THREATS									
SOIL									
TOPOGRAPHY									
ALTITUDE									
WATER GAINING AREAS									
SOIL GAINING AREAS									
RIPARIAN									
WETLAND									

POSSIBLE SAMPLE POINT RATING (2M RADIUS EG FOR DIEBACK)

COORDINATES	CELL	10mx10m CORNER	25mx25m CORNER	IMPACT High	IMPACT Moderate	IMPACT Low	IMPACT None	
	A1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	A2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	A3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					

CLUSTER

DO EXCEPTIONS – RATE EXTREME OR UNUSUAL CELLS (EG LEAST, MOST, TYPICAL)

SHEET TO MARK FEATURES ON CLUSTER SURROUNDS

<table>
<tr><td>NW</td><td>N</td><td>NE</td></tr>
<tr><td>W</td><td><table><tr><td>A1</td><td>A2</td><td>A3</td></tr><tr><td>B1</td><td>B2</td><td>B3</td></tr><tr><td>C1</td><td>C2</td><td>C3</td></tr></table>B2</td><td>E</td></tr>
<tr><td>SW</td><td>S</td><td>SE</td></tr>
</table>

<table>
<tr><td>NW</td><td>N</td><td>NE</td></tr>
<tr><td>W</td><td><table><tr><td>A1</td><td>A2</td><td>A3</td></tr><tr><td>B1</td><td>B2</td><td>B3</td></tr><tr><td>C1</td><td>C2</td><td>C3</td></tr></table>B2</td><td>E</td></tr>
<tr><td>SW</td><td>S</td><td>SE</td></tr>
</table>

<table>
<tr><td>NW</td><td>N</td><td>NE</td></tr>
<tr><td>W</td><td><table><tr><td>A1</td><td>A2</td><td>A3</td></tr><tr><td>B1</td><td>B2</td><td>B3</td></tr><tr><td>C1</td><td>C2</td><td>C3</td></tr></table>B2</td><td>E</td></tr>
<tr><td>SW</td><td>S</td><td>SE</td></tr>
</table>

MAIN DIAGONAL TRANSECT POINT INTERCEPT DATA (per 25mx25m plot diagonal; 50cm interval; uppermost layer recorded first.)

POINT TRANSECT SHEET SITE:______________QUADRAT:______________DATE:______________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogram	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Low shrub foliage	Low shrub bark/limbs	High shrub foliage	High shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body	Other (eg dieback)
0.5																				
1.0																				
1.5																				
2.0																				
2.5																				
3.0																				
3.5																				
4.0																				
4.5																				
5.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
5.5																				
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6.5																				
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7.5																				
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9.5																				
10.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
10.5																				
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11.5																				
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14.5																				
15.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
15.5																				
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16.5																				
17.0																				
17.5																				
18.0																				
18.5																				
19.0																				
19.5																				
20.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
20.5																				
21.0																				
21.5																				
22.0																				
22.5																				

POINT TRANSECT SHEET SITE:_____________ QUADRAT:_____________ DATE:_____________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogram	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Low shrub foliage	Low shrub bark/limbs	High shrub foliage	High shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body	Other (eg dieback)
23.0																				
23.5																				
24.0																				
24.5																				
25.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
25.5																				
26.0																				
26.5																				
27.0																				
27.5																				
28.0																				
28.5																				
29.0																				
29.5																				
30.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
30.5																				
31.0																				
31.5																				
32.0																				
32.5																				
33.0																				
33.5																				
34.0																				
34.5																				
35.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
35.5																				
36.0																				
36.5																				
37.0																				
37.5																				
38.0																				
38.5																				
39.0																				
39.5																				
40.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
40.5																				
41.0																				
41.5																				
42.0																				
42.5																				

APPENDIX 5: SOME TRIAL FIELD SHEETS

PHYSICAL SITE DETAILS

DATE: __________________________ RECORDERS: _________________________________

PROJECT: ________________________ SITE: __________________________

SITE FORMAT & DIMENSIONS: ____ IS THE SITE UNIFORM? – MAP ZONES ___________________

OBSERVATION CODE (STANDARD PLOT ARRAY): _____________________________________

OBSERVATION QUALITY: _________________________

Keighery 1994

LOCATION: ____

____

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude

GPS used: yes/no DGPS used: yes/no LOCATION IN PLOT (NW CNR/CENTRE/OTHER): ____

Central 25mx25m plot

CENTROID:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

BEARINGS:

Diagonal_________________Corner boundary bearings:_____________________________&________________________________

PHOTOS: photographer: _________________ format: __________________ code: ____

Other plot___________________

CENTROID:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

BEARINGS:

Diagonal_________________Corner boundary bearings: _____________________________&________________________________

PHOTOS: photographer: _________________ format: __________________ code: ____

Landform & Soils

SLOPE: flat/ gentle/ steep ASPECT: N/ NE/ E/ SE/ S/ SW/ W/ NW OR n/a

SURFACE SOIL: Colour: ________________ Texture: sand/ loamy sand/ sandy loam/ loam/ clay/ gravel

EXPOSED ROCK (type and % of surface):

SUB-SURFACE SOIL: Colour: ____________ Texture: sand/ loamy sand/ sandy loam/ loam/ clay/ gravel

UNDERLYING ROCK (type and depth if known):

DRAINAGE: well/ moderate/ poor WET: all year/ winter and spring only OR n/a

CURRENT WATER DEPTH: _________ cm

LITTER (% cover & depth):________ ____________ BARE GROUND (% cover)

Topographic Position Circle position of point described on a transect diagram of site below.

beach, primary dunes, secondary dunes, swale, hinterland dunes, undulating/plain, permanent wetland, undulating wet flat, seasonal wetland, foothill, scarp, hill, mountain
creek, river floodplain, river bank, estuary, river mouth,
lowerslope, midslope, upperslope, crest, ridge, foreslope/backslope
VEGETATION: ____
VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____
TIME SINCE FIRE: ____
NOTES: ____

SEASON: __________________________________ WEATHER DATA: ____
AMBIENT WEATHER INFORMATION: ?????????????????

SHEET FOR ESTIMATING BASIC CATEGORIES IN THE 25MX25M QUADRAT

Layer	Height /depth [A]	Quadrat	Comment	Gaps in canopy % [B]	Live cover % [C]							Dead cover % [D]			Stress rating [E]	Stressed cover %	Note
Disturbed		10			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
		25															
Weed		10															
		25															
Bare ground		10															
		25															
Rock [F]		10															
		25															
Cryptogam		10															
		25															
Litter		10															
		25															
Logs		10			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
		25															
Ground –cover Foliage		10															
Bark/ limbs		10		----------													
Foliage		25															
Sedge/grass Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25															
Low shrub Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25			<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
High shrub Foliage		10															
Bark/limbs		10	Non-photosynthetic	----------													
Foliage		25															
Over-storey Foliage		10															
Bark/limbs		10		----------													
Foliage		25															
% free of any canopy		10															
		25															

[A] m – tree, mallee, shrub ≥ 1m; cm - rest; [B] to convert canopy to foliar cover; [C] for <1 show if 0/0.01/0.1; [D] only significant % (>0.1%); [E] 0-None, 1 – Low, 2- Mod, 3 – High; [F] Rock – also use for naturally bare areas eg dunes.

Comments:	Wet/dry or overcast(%cloud cover)/sunny or hazy/clear
Stressed by:	Disease/pests/grazing/disturbance DEFINE STRATA DIMENSIONS

SPECIES SHEET - THIS CAN BE EITHER FULL SPECIES OR BY KEY DOMINANTS (UP TO 3 PER LAYER)

Lifeform Layer (tree, mallee, shrub, herb, sedge, rush, grass, other, crypto-gram)	Height (m – tree, mallee, shrub ≥ 1m; cm - rest)	Exotic /weed (*)	Species	% gaps in canopy cover Canopy cover to foliar cover.	% cover – alive (for <1 show if 0, 0.01, or 0.1)							% cover – dead (only signif. %)	No. plants – alive (1, 5, 10, 50, 100, 500, 1000)	No. plants – dead (only signif. no.)	Health - stress rating 1 - Low 2- Mod 3 - High	Health - % cover stress-ed	Note
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	
10x10																	
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10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10																	
25x25																	
10x10					<1	>1-5	>5-10	>10-25	>25-50	>50-75	>75-100						
25x25																	

A1	A2	A3
B1	B2	B3
C1	C2	C3

Grid for mapping zones in the array.

SHEET FOR RECORDING SALIENT DIFFERENCES BETWEEN QUADRATS IN THE ARRAY

MEASURE	A1	A2	A3	B1	B2	B3	C1	C2	C3
OVER ALL									
NATIVE PLANTS TOTAL COVER									
NATIVE PLANTS COMPOSITION									
NATIVE PLANTS DENSITY									
NATIVE PLANTS STRATA									
NATIVE PLANTS HEALTH									
WEED TOTAL COVER									
WEED COMPOSITION									
WEED STRATA									
PROCESSES									
THREATS									
SOIL									
TOPOGRAPHY									
ALTITUDE									
WATER GAINING AREAS									
SOIL GAINING AREAS									
RIPARIAN									
WETLAND									

POSSIBLE SAMPLE POINT RATING (2M RADIUS EG FOR DIEBACK)

COORDINATES	CELL	10mx10m CORNER	25mx25m CORNER	IMPACT High	IMPACT Moderate	IMPACT Low	IMPACT None	
	A1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	A2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	A3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	B3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C1	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C2	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					
	C3	NW	NW					
		NE	NE					
		SE	SE					
		SW	SW					

CLUSTER

DO EXCEPTIONS – RATE EXTREME OR UNUSUAL CELLS (EG LEAST, MOST, TYPICAL)

SHEET TO MARK FEATURES ON CLUSTER SURROUNDS

NW	N	NE
W	A1 A2 A3 B1 B2 B3 C1 C2 C3 B2	E
SW	S	SE

NW	N	NE
W	A1 A2 A3 B1 B2 B3 C1 C2 C3 B2	E
SW	S	SE

NW	N	NE
W	A1 A2 A3 B1 B2 B3 C1 C2 C3 B2	E
SW	S	SE

MAIN DIAGONAL TRANSECT POINT INTERCEPT DATA (per 25mx25m plot diagonal; 50cm interval; uppermost layer recorded first.)

POINT TRANSECT SHEET SITE:______________QUADRAT:______________DATE:______________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogram	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Low shrub foliage	Low shrub bark/limbs	High shrub foliage	High shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body	Other (eg dieback)
0.5																				
1.0																				
1.5																				
2.0																				
2.5																				
3.0																				
3.5																				
4.0																				
4.5																				
5.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
5.5																				
6.0																				
6.5																				
7.0																				
7.5																				
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8.5																				
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9.5																				
10.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
10.5																				
11.0																				
11.5																				
12.0																				
12.5																				
13.0																				
13.5																				
14.0																				
14.5																				
15.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
15.5																				
16.0																				
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19.0																				
19.5																				
20.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
20.5																				
21.0																				
21.5																				
22.0																				
22.5																				

POINT TRANSECT SHEET SITE:_____________QUADRAT:_____________DATE:_____________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogram	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Low shrub foliage	Low shrub bark/limbs	High shrub foliage	High shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body	Other (eg dieback)
23.0																				
23.5																				
24.0																				
24.5																				
25.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
25.5																				
26.0																				
26.5																				
27.0																				
27.5																				
28.0																				
28.5																				
29.0																				
29.5																				
30.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
30.5																				
31.0																				
31.5																				
32.0																				
32.5																				
33.0																				
33.5																				
34.0																				
34.5																				
35.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
35.5																				
36.0																				
36.5																				
37.0																				
37.5																				
38.0																				
38.5																				
39.0																				
39.5																				
40.0																				
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By	O
40.5																				
41.0																				
41.5																				
42.0																				
42.5																				

METHODS

1. <u>Location of Sites</u>

Four study sites were selected in Unallocated Crown Land off Military Rd at Caraban in the Shire of Gingin north of Yanchep, Western Australia. The sites were located within a study area previously established by the Department of Environment and Conservation (DEC) in 2008 to research the impact of fire and grazing on vegetation regeneration. The DEC sites comprised two adjacent 75m x 75m plots in an area that had not been burnt for 23 years, and another two adjacent 75m x 75m plots that underwent a controlled burn in June 2008 (Reaveley et al., 2009). One of each of the unburnt and burnt pairs was fenced robustly to exclude grazing from animals capable of going over, through or under fencelines, such as kangaroos, pigs and rabbits (Reaveley et al., 2009).

Each of the four study sites for the Native Vegetation Integrity (NVI) project comprised an array of 9 adjoining quadrats. The nine quadrats each measured 30m x 30m, to form a square measuring 90m x 90m. The centre cell, B2, of each array formed the focal point of the study and so was located within the 75m x 75m DEC sites to maximise the use of existing infrastructure (predominantly fencing). A 10m x 10m quadrat was established on the north-west corner within cell B2 of each array (see Figure x for layout).

The four treatments for each study site of the NVI project at Caraban were:

- Unburnt and Unfenced (UB/UF)
- Unburnt and Fenced (UB/F) – grazing excluded
- Burnt and Fenced (B/F) – grazing excluded, and
- Burnt and Unfenced (B/UF)

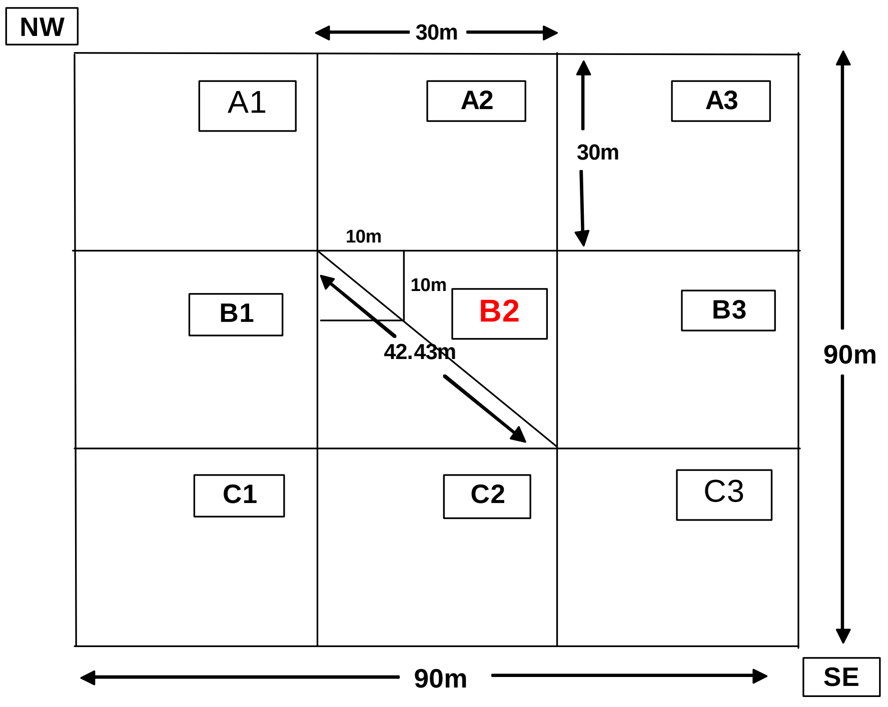

Figure x. Layout of the nine 30m x 30m cells that form each of the four arrays at Caraban. Cell B2 from each array was the subject of detailed vegetation condition assessment for the NVI project.

2. Time of Sampling

Sampling for this study was conducted in winter, between 30th June and 14th July 2009. At this time of year it is expected that a small part of the compliment of annual plants (including geophytes) would be missing, although many were emerging during sampling. NB. Groundwater drawdown may be a variable relating to vegetation condition at this site.

3. Physical Site Details

Location and physical details of each B2 quadrat was recorded on a field data sheet and included:

- Date
- Site ID
- Description of location
- Latitude and longitude of NW corner and central point along transect
- Description of landform and soils
- Topographic position
- Vegetation type
- Fire history
- Season and current weather conditions

The Physical Site Details for Caraban can be found on page x of the appendix.

4. Equipment Used in the Field

1. 100m transect tapes
2. 50m transect tapes
3. compass
4. optical square
5. RCM manual and field work sheets
6. digital or print film camera
7. Clipboard, pencils and erasers
8. Flagging tape
9. Plant identification books
10. Global Positioning System (GPS)
11. Differential Global Positioning System (DGPS)
12. flower presses and newspaper
13. fencing droppers (to mark out corners of quadrats)
14. jewellers tags and envelopes (to label plant specimens)
15. field herbarium
16. orange poly rope (to mark out borders)
17. optical square
18. rubber mallet
19. wire, metal tags and punches

5. Establishing Quadrats

- Quadrat B2 was the only quadrat from each array that was formally marked out.

- 30m x 30m quadrats were marked out using a compass and optical square. A 10m x 10m quadrat was established in the NW corner of the 30m x 30m quadrat.
- A transect was established along the diagonal between the north-west corner and south-east corner of the 30m x 30m quadrat, passing through the south-east corner of the 10m x 10m quadrat (see Figure x). Length of the transect within the 10m x 10m quadrat is calculated as being 14.14m, and 42.43m within the 30m x 30m quadrat.
- Fence droppers were used to mark corners of the 30m x 30m quadrat, corners of the 10m x 10m quadrat, and the central point along the transect. Within the quadrat, the north-west corner was common to both the 30m x 30m quadrat and 10m x 10m quadrat (see Figure x). Fence droppers were sprayed with pink paint for identification and to distinguish between other research sites within the study area. Using metal tags, fence droppers were labelled with the site location, site number/name and aspect (ie NW, SW etc).
- Using a differential Global Positioning System (DGPS), GPS coordinates and elevation were recorded at the north-west corner of the quadrat and the central point along the transect. GPS coordinates for the four B2 cells at Caraban are listed in the Physical Site Details field sheet on page x of the Appendix.
- Photos were taken from the north-west corner of each quadrat from a point far enough back so that the north-eastern and south-western extremities of the quadrat could be encompassed in the line of view if possible. A site identifier was included in the NW frame so that site photos could be distinguished easily at a later date (a sheet of A4 paper with the site location and number would suffice). In some instances the boundary of the quadrat was obscured due to tall vegetation, in which case the photograph was taken from the closest available vantage point to the north-west corner. Photos were also taken from the northern and western boundary of the quadrat.

6. <u>Data Collection</u>

6.1 Quadrat data: in each 10m x 10m quadrat and 30m x 30m quadrat within cell B2 the following data was collected:

a) Plant species composition orientated measures
  - Plant species
  - % canopy cover per species (alive)
  - % canopy cover per species (dead)
  - estimate per species of canopy gap in order that foliar cover could be derived if required. In theory:
    estimated cover – estimated gaps = % cover.
  - no. of plants alive (for each species)
  - no. of plants dead (for each species)
  - stress rating (for each species)
  - %stress cover (for each species)
  - median height per species

Two specimens from each plant species within the 10m x 10m quadrat and 30m x 30m quadrat were taken for identification. Plant specimens included fruit and flowers where possible. These samples were labelled with the location, site, date and an allocated identification number. One sample was mounted in the field herbarium, and the other was pressed in a flower press to be sent to the WA Herbarium for formal identification.

b) Site attribute oriented measures (% cover)

- disturbance
- total weed cover
- bare ground
- rock
- cryptogam
- litter
- logs
- groundcover
- sedges/grasses
- sub-shrubs (<0.5m)
- shrubs (0.5m – 1.8m)
- overstorey (>1.8m)

6.2 Transect data: data were recorded at 0.5m intervals along the transect established between the north-west corner and the south-east corner of each 30m x 30m quadrat. Observations included all vegetative and non-vegetative material above and below the tape measure. The following observations were recorded:

- disturbance
- weeds
- bare ground
- rock
- cryptogam (eg moss, lichen)
- litter
- logs
- ground cover: foliage (ground cover was generally limited to *Drosera*, orchid species and *Stylidium*)
- ground cover: bark/limbs
- sedge/grass: foliage
- sedge/grass: bark/limbs
- sub-shrub: foliage (shrubs <0.5m)
- sub-shrub: bark/limbs (shrubs <0.5m)
- shrub: foliage (shrubs >0.5m)
- shrub: bark/limbs (shrubs >0.5m)
- over storey: foliage
- over storey: bark/limbs

Criteria for transect data:

(i) where more than one category was present on the ground (ie bare ground, rocks, moss, litter, cryptogam and ground cover), all categories were recorded for that point on the transect and % cover was estimated for each category

(ii) observations of both foliage and/or bark and stems were recorded independently. The separation of foliage and bark offers potential scope for remote sensing trials.

(iii) grasses and sedges were recorded as a separate category from sub-shrubs

(iv) distinction between sedges and grasses was recorded

(v) plants resembling grasses or sedges (eg *Dasypogon* species) were categorised as such.

(vi) observations of ground cover, sedges, grasses, sub-shrubs, shrubs and over storey were recorded even where only a small amount of plant material crossed the point on the transect.

(vii) bark/limbs for associated categories included dead plant material

(viii) by default, *absence* of canopy cover can also be estimated from the field data sheet, providing the format allows observations to be measured and recorded at each increment along the transect.

7. <u>Time Required</u>

The average time taken for three field staff to complete sampling at each of the four arrays was 2 days. The breakdown of tasks was as follows:

Table x. Number of people and time taken to complete all tasks per array at Caraban,

Task	No. of people involved	Hours/days to complete task
1. setting up the 30 x 30m quadrat, and 10 x 10m quadrat (including photos, marking fence droppers etc)	2	1-2 hrs
2. in the 10 x 10m quadrat: • Collection of plant species • Labelling and mounting plant species into field herbarium • Estimation of % cover	1	1 day
3. in the 30 x 30m quadrat: • Searching for species found in the 10 x 10m quadrat • Locating, labelling and mounting plant specimens not found in the 10 x 10m quadrat • Estimation of % cover • Density (number of individuals per species)	2	1 day
4. Transect	1	2 – 4 hrs
5. Array mapping & % cover estimates of cell B2, based on categories as per the Transect Data Field Sheet	1	1 day
6. Condition rating	1	½ day
7. % cover for remainder of array: • Overstorey (in this case, split into dominant lifeforms ie trees) • Tall understorey (>1m) • Understorey (<1m – this formed the majority of understorey) • Disturbance • Bare ground • Litter • Trunks	1	½ - 1 day
8. Mounting plant species into flower press for identification at the WA Herbarium	1	2 – 4 hrs

8. Limitations

Quadrats:

- % cover was estimated as a visual agglomeration for each species or other category. Consequently there will be some variation due to factors such as observer differences, and visibility within the quadrat (ie vegetation density). Some of the variation was reduced by using a set scale for each quadrat size, and by standardising observer estimates based on a common area.
- Scale of magnitude estimates of plant species.

Transect:

- Low density of points: although 0.5m increments along the transect were manageable and functional, the resulting gaps in observations is considerable and may result in skewed data analyses.
- Point bias: skewed results from limitations in identifying a single point both above and below the target point on the tape measure.

References

Reaveley, A., Bleby, K., Valentine, L. and Wilson, B. (March 2009). *Fire and the Banksia Woodlands of the Swan Coastal Plain – Fuel Reduction Burns and Water Recharge on the Gnangara Mound: Preliminary Report.* DEC and CSIRO

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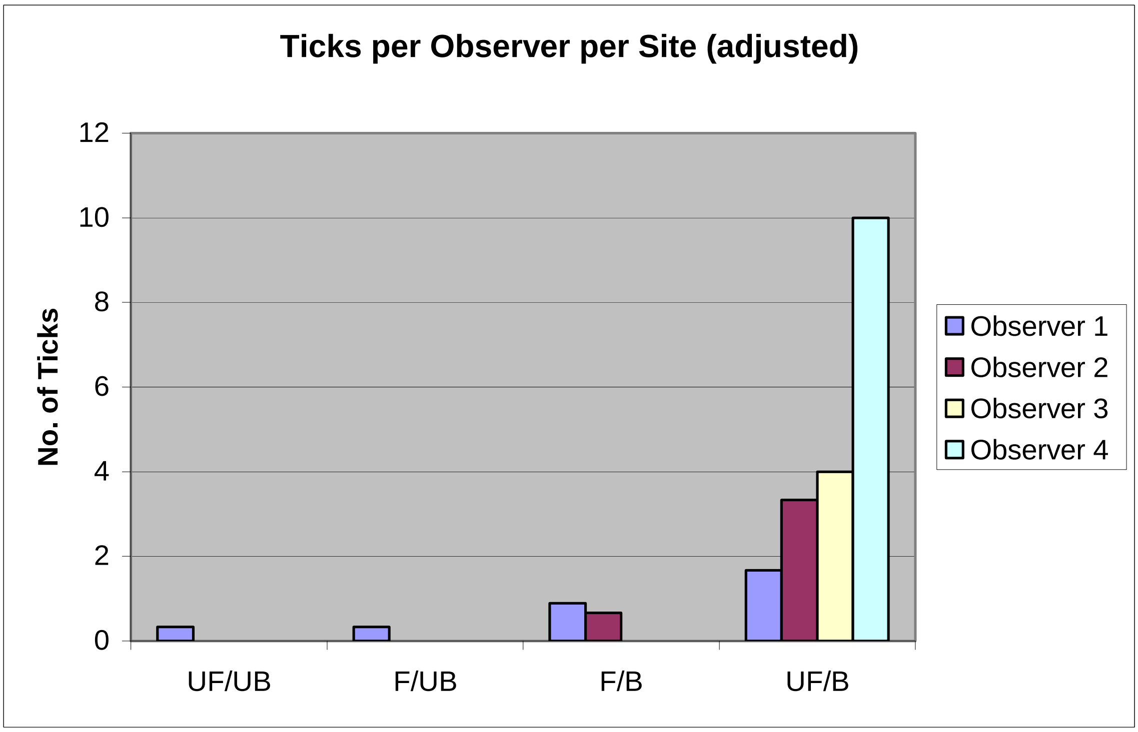

Figure x. Ticks carried by 4 observers during sampling at the four sites at Caraban. Time spent at each site varied between observers, therefore data has been adjusted to reduce bias in the results for number of ticks per site:

1. Observers 1, 3 and 4 spent 2 days in quadrat B2 of each site (standard variable)
2. Observer 2 spent only one day at each site, but moved through all 9 quadrats of each array [(Obs 2*2)/9].
3. Observer 1 moved through all 9 quadrats of each array (Obs 1/9)

The results show that the greatest number of ticks were collected by all Observers in the Unfenced/Burnt array, where fauna such as kangaroos would have grazed on newly emerging seedlings and sprouting vegetation in the post-fire period. Observations during sampling reflect a higher level of grazing in the Unfenced/Burnt array than the other three treatments at Caraban.

Results: Flora

A total of 31 Families representing 106 flowering plant taxa were found in the four 30m x 30m B2 quadrats at Caraban (Table x. Appendix page x). One hundred and three of these taxa were natives, and 3 were weeds (*Gladiolus* sp, *Carpobrotus edulis* and *Lupinus* sp). The most common taxa were Myrtaceae and Proteaceae (both with 11 taxa); Papilionaceae, Asparagaceae and Stylidiaceae (7 taxa); Orchidaceae, Haemodoraceae and Cyperaceae (6 taxa); and Restionaceae, Poaceae and Dilleniaceae (4 taxa) (see Table x, below).

Table x. Families with the greatest representation of genera and spp.

Families with the most genera/spp	Genera	spp
MYRTACEAE	9	11
PROTEACEAE	7	11
PAPILIONACEAE	7	7
ASPARAGACEAE	3	7
STYLIDIACEAE	1	7
ORCHIDACEAE	5	6
HAEMODORACEAE	4	6
CYPERACEAE	3	6
RESTIONACEAE	4	4
POACEAE	3	4
DILLENIACEAE	1	4

Fifty taxa were common to all four of the 30m x 30m B2 quadrats from each array; sixteen taxa were found in three of the four 30m x 30m B2 quadrats; sixteen taxa were common to two 30m x 30m quadrats, and 27 taxa were found in only one 30m x 30m B2 quadrat (see Table x, Appendix page x).

Weed species *Carpobrotus edulis*, *Lupinus* sp. and *Gladiolus* sp. were all observed in the Unfenced/Unburnt B2 30 x 30m quadrat. The only weed species found in the Fenced/Unburnt and Unfenced/Burnt B2 30 x 30m quadrats was *Gladiolus* sp., with *Carpobrotus edulis* the only weed species in the 30 x 30m B2 Fenced/Burnt quadrat.

PLANT SPECIES COMMON TO B2 CELLS IN EACH ARRAY

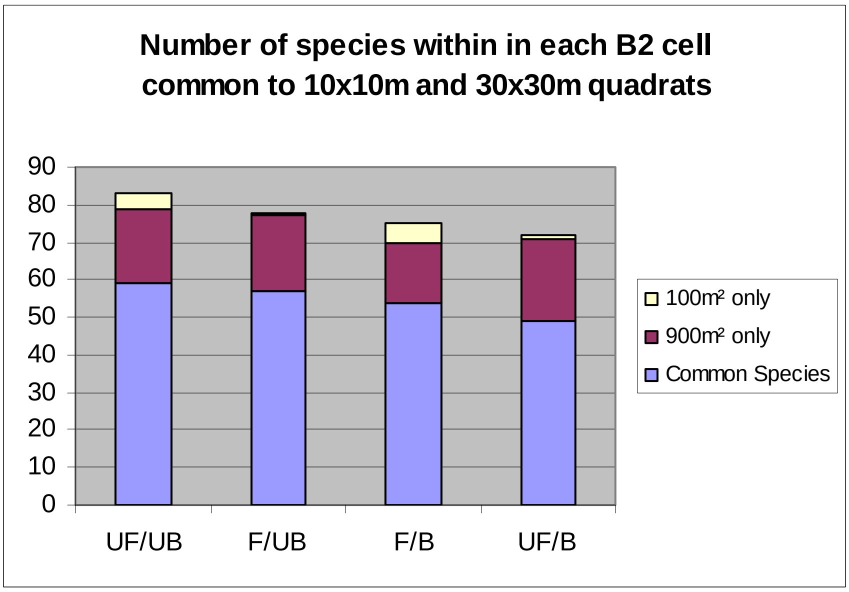

Figure x. Plant species at the four Caraban sites that occur in:

1. both the 10m x 10m quadrat and 30m x 30m quadrat (outside the 10m x 10m quadrat);
2. only in the 10m x 10m quadrat; and
3. only in the 30m x 30m quadrat (outside the 10m x 10m quadrat).

The data shows:

- relative consistency in the total number of species in Banksia woodland
- that the 30m x 30m quadrat consistently collected 20-30% more species not found in the 10m x 10m quadrat. It could be expected that more time spent in the 30m x 30m quadrat would have returned an even larger number of additional species not found in the 10m x 10m quadrat. Sample size is a limiting factor of a 10m x 10m quadrat, as it is unable to capture diversity at a community level.
- that the species richness within the four Caraban sites is similar to that of Community 23b of the Swan Coastal Plain, which typically has a mean species richness of 53.8 in a 10m x 10m plot (Gibson et al., 1994) (see Table x).
- a mean of about 6 species less were encountered in the burnt 30m x 30m plots, compared to the unburnt 30m x 30m plots.

Table x. Species richness within the 10mx10m and 30mx30m plots of each B2 quadrat at the four Caraban sites.

	10mx10m	30mx30m
Unfenced/Unburnt	63	83
Fenced/Unburnt	58	78
Fenced/Burnt	59	75
Unfenced/Burnt	50	72

Table x. Summary of plant species recorded in the four B2 quadrats at Caraban 2009

Family no.	Family name	Species (Caraban)	Weeds	Genera per family	Species per family
31	POACEAE	*Aira* sp. seedlings			
		Amphipogon sp.			
		Amphipogon sp. seedlings			
		Amphipogon turbinatus			
		Austrodanthonia ?caespitosa			
		Austrodanthonia sp.		3	4
32	CYPERACEAE	*Lepidosperma* aff. sp. Coastal Dunes (R.J. Cranfield 9963)			
		Lepidosperma leptostachyum			
		Lepidosperma pubisquameum			
		Mesomelaena pseudostygia			
		Schoenus clandestinus			
		Schoenus curvifolius		3	6
39	RESTIONACEAE	*Alexgeorgia nitens*			
		Chordifex sinuosus			
		Desmocladus flexuosus			
		Hypolaena exsulca		4	4
55	HAEMODORACEAE	*Anigozanthos ?humilis*			
		Conostylis aculeata subsp. *cygnorum*			
		Conostylis setigera			
		Haemodorum laxum			
		Haemodorum spicatum			
		Phlebocarya ciliata		4	6
60	IRIDACEAE	*Gladiolus* sp.	1		
		Patersonia occidentalis		2	2

Table x. Summary of plant species recorded in the four B2 quadrats at Caraban 2009

Family no.	Family name	Species (Caraban)	Weeds	Genera per family	Species per family
66	ORCHIDACEAE	*Caladenia flava* subsp. *flava*			
		Leporella fimbriata			
		Microtis ? sp.			
		Pterostylis sanguinea			
		Pterostylis sanguinea			
		Pyrorchis nigricans		5	6
70	CASUARINACEAE	*Allocasuarina fraseriana*			
		Allocasuarina humilis		1	2
90	PROTEACEAE	*Adenanthos cygnorum*			
		Banksia attenuata			
		Banksia dallaneyii var. *dallaneyii*			
		Banksia ilicifolia			
		Banksia menziesii			
		Conospermum canaliculatum			
		Hakea ruscifolia			
		Persoonia comata			
		Petrophile linearis			
		Petrophile macrostachya			
		Stirlingia latifolia		7	11
97	LORANTHACEAE	*Nuytsia floribunda*		1	1
106	AMARANTHACEAE	*Ptilotus manglesii*		1	1
110	AIZOACEAE	*Carpobrotus edulis*	1	1	1
143	DROSERACEAE	*Drosera erythrorhiza*			
		Drosera macrantha subsp. *macrantha*			
		Drosera parvula		1	3

Table x. Summary of plant species recorded in the four B2 quadrats at Caraban 2009

Family no.	Family name	Species (Caraban)	Weeds	Genera per family	Species per family
163	MIMOSACEAE	*Acacia huegelii*			
		Acacia sessilis			
		Acacia stenoptera		1	3
165	PAPILIONACEAE	*Bossiaea eriocarpa*			
		Daviesia nudiflora			
		Gastrolobium capitatum			
		Gompholobium tomentosum			
		Hovea trisperma var. *trisperma*			
		Jacksonia sternbergiana			
		Lupinus sp.	1	7	7
175	RUTACEAE	*Philotheca spicata* subsp. Moore River National Park (G & D Woodman Op47)		1	1
215	RHAMNACEAE	*Cryptandra pungens*		1	1
226	DILLENIACEAE	*Hibbertia acerosa*			
		Hibbertia huegelii			
		Hibbertia hypericoides			
		Hibbertia subvaginata		1	4
263	THYMELAEACEAE	*Pimelea sulphurea*		1	1
273	MYRTACEAE	*Beaufortia elegans*			
		Calytrix flavescens			
		Calytrix fraseri			
		Eremaea asterocarpa var. *asterocarpa*			
		Eremaea pauciflora			
		Eucalyptus todtiana			
		Kunzea glabrescens			
		Leptospermum spinescens			
		Melaleuca trichophylla			

Table x. Summary of plant species recorded in the four B2 quadrats at Caraban 2009

Family no.	Family name	Species (Caraban)	Weeds	Genera per family	Species per family
273	MYRTACEAE	*Scholtzia involucrata*			
		Verticordia nitens		9	11
276	HALORAGACEAE	*Gonocarpus cordiger*		1	1
281	APIACEAE	*Xanthosia huegelii*		1	1
288	EPACRIDACEAE	*Conostephium pendulum*			
		Leucopogon conostephioides		2	2
341	GOODENIACEAE	*Dampiera linearis*			
		Scaevola repens		2	2
343	STYLIDIACEAE	*Stylidium ?bicolor*			
		Stylidium ?diuroides			
		Stylidium carnosum			
		Stylidium neurophyllum			
		Stylidium repens			
		Stylidium scariosum			
		Stylidium schoenoides		1	7
345	ASTERACEAE	*Asteraceae* sp. seedlings			
		Senecio ?hispidulus var. *hispidulus*		2	2
39B	ANARTHRIACEAE	*Lyginia barbata*			
		Lyginia imberbis		1	2
54B	ASPARAGACEAE	*Laxmannia ramosa*			
		Lomandra caespitosa			
		Lomandra hermaphrodita			
		Lomandra preissii			
		Thysanotus arbuscula			
		Thysanotus sparteus			
		Thysanotus thyrsoideus		3	7

Table x. Summary of plant species recorded in the four B2 quadrats at Caraban 2009

Family no.	Family name	Species (Caraban)	Weeds	Genera per family	Species per family
54C	DASYPOGONACEAE	*Calectasia narragarra*			
		Dasypogon bromeliifolius		2	2
54D	XANTHORRHOEACEAE	*Xanthorrhoea gracilis*			
		Xanthorrhoea preissii			2
54J	COLCHICACEAE	*Burchardia congesta*		1	1
54P	HEMEROCALLIDACEAE	*Arnocrinum preissii*			
		Corynotheca micrantha var. *elongata*		2	2

Figure x. Percentage cover of the Unfenced/Unburnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

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Figure x. Percentage cover of the Fenced/Unburnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

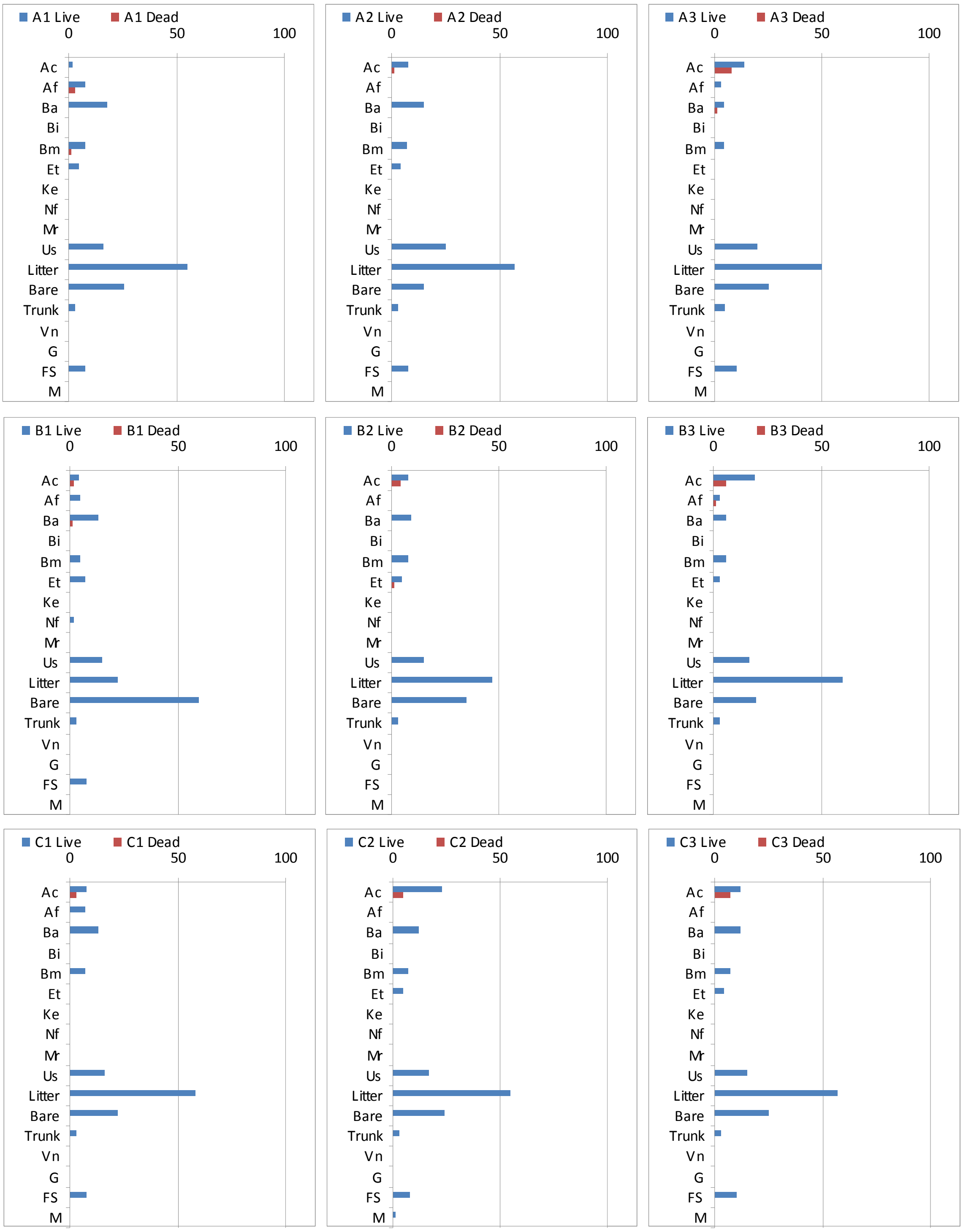


Figure x. Percentage cover of the Fenced/Burnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

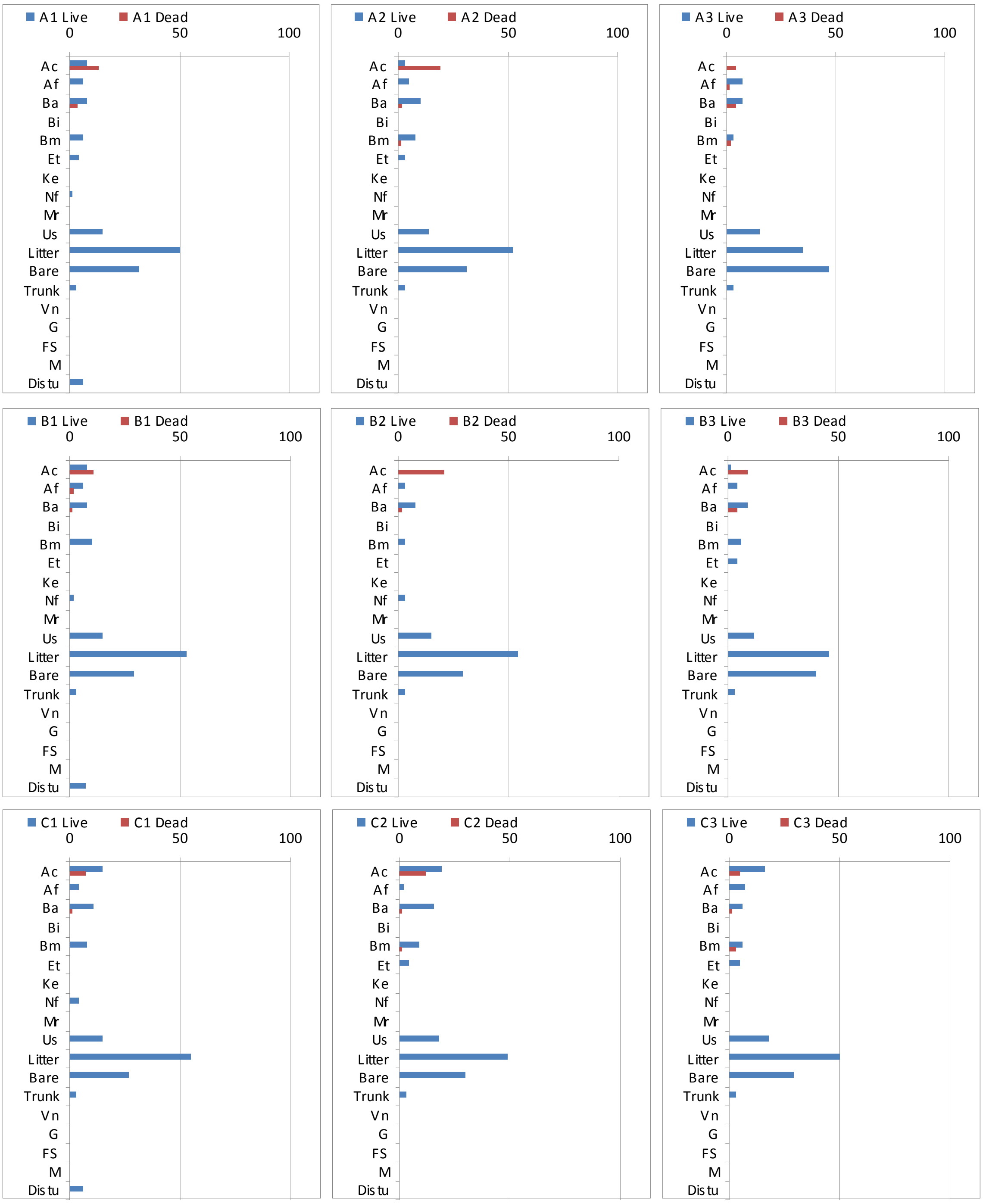


Figure x. Percentage cover of the Unfenced/Burnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

Table x. Percentage cover of the Unfenced/Unburnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

	A1 Live	A1 Dead		A2 Live	A2 Dead		A3 Live	A3 Dead
Ac	0	0	Ac	0	0	Ac	0	0
Af	0	0	Af	0	0	Af	0.01	0
Ba	28	0	Ba	20	0	Ba	5	0.2
Bi	0	0	Bi	0	0	Bi	0	0
Bm	3	0	Bm	2	0	Bm	9	0
Et	12	0	Et	5	0	Et	7	0
Ke	0	0	Ke	0	0	Ke	0.5	0
Nf	0	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	45	0	Us	45	0	Us	45	0
Litter	35	0	Litter	35	0	Litter	35	0
Bare	15	0	Bare	15	0	Bare	15	0
Trunk	5	0	Trunk	5	0	Trunk	5	0
Vn	0.2	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	0	0	Disturbance	0	0	Disturbance	6	0

	B1 Live	B1 Dead		B2 Live	B2 Dead		B3 Live	B3 Dead
Ac	0	0	Ac	0	0	Ac	0	0
Af	0	0	Af	0	0	Af	0	0
Ba	12	1	Ba	15	0	Ba	8	0
Bi	0	0	Bi	0	0	Bi	0	0
Bm	4	0	Bm	5	0	Bm	8	0
Et	7	0	Et	4	0	Et	5	0
Ke	0	0	Ke	0	0	Ke	0.1	0
Nf	0	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	45	0	Us	45	0	Us	45	0
Litter	38	0	Litter	40	0	Litter	35	0
Bare	12	0	Bare	10	0	Bare	15	0
Trunk	5	0	Trunk	5	0	Trunk	5	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	0	0	Disturbance	0	0	Disturbance	7	0

	C1 Live	C1 Dead		C2 Live	C2 Dead		C3 Live	C3 Dead
Ac	0	0	Ac	0	0	Ac	0	0
Af	0	0	Af	0	0	Af	0	0
Ba	12	3	Ba	9	0	Ba	12	0
Bi	0	0	Bi	0	0	Bi	0	0
Bm	4	0	Bm	6	0	Bm	2	1
Et	4	0	Et	5	0	Et	5	0
Ke	0	0	Ke	1	0	Ke	0	0
Nf	0	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	50	0	Us	45	0	Us	45	0
Litter	38	0	Litter	45	0	Litter	40	0
Bare	12	0	Bare	5	0	Bare	10	0
Trunk	6	0	Trunk	5	0	Trunk	5	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0.01	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	0	0	Disturbance	0	0	Disturbance	6	0

Table x. Percentage cover of the Fenced/Unburnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

	A1 Live	A1 Dead		A2 Live	A2 Dead		A3 Live	A3 Dead
Ac	14	0	Ac	9	0	Ac	6	0
Af	0.5	0	Af	7	0	Af	11	0
Ba	9	0	Ba	8	1	Ba	9	0.5
Bi	0	0	Bi	0	0	Bi	0	0
Bm	10	0.3	Bm	9	0	Bm	9	0
Et	2	0	Et	13	0	Et	7	0
Ke	0.5	0	Ke	0	0	Ke	0	0
Nf	3	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	60	0	Us	50	0	Us	50	0
Litter	23	0	Litter	35	0	Litter	40	0
Bare	12	0	Bare	10	0	Bare	5	0
Trunk	5	0	Trunk	5	0	Trunk	5	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	7	0	Disturbanc	7	0	Disturbanc	9	0

	B1 Live	B1 Dead		B2 Live	B2 Dead		B3 Live	B3 Dead
Ac	2	0	Ac	4	0	Ac	1	0
Af	0	0	Af	0	0	Af	9	0
Ba	15	0	Ba	8	0	Ba	4	0
Bi	0	0	Bi	0	0	Bi	0	0
Bm	6	0.5	Bm	4	0	Bm	2	0.3
Et	7	0	Et	4	0	Et	7	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	0	0	Nf	0.2	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	60	0	Us	50	0	Us	55	0
Litter	20	0	Litter	35	0	Litter	37	0
Bare	15	0	Bare	10	0	Bare	3	0
Trunk	5	0	Trunk	3	0	Trunk	5	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	0	0	Disturbanc	0	0	Disturbanc	7	0

	C1 Live	C1 Dead		C2 Live	C2 Dead		C3 Live	C3 Dead
Ac	2	0	Ac	3	0	Ac	0.5	0
Af	0	0	Af	0	0	Af	3	0
Ba	10	1	Ba	5	0	Ba	8	0
Bi	0	0	Bi	0	0	Bi	0	0
Bm	5	0.5	Bm	0	1	Bm	2	0.2
Et	8	0	Et	3	0	Et	8	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	0	0	Nf	0.5	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	60	0	Us	70	0	Us	75	0
Litter	25	0	Litter	18	0	Litter	15	0
Bare	10	0	Bare	10	0	Bare	7	0
Trunk	5	0	Trunk	2	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	7	0	Disturbanc	7	0	Disturbanc	9	0

Table x. Percentage cover of the Fenced/Burnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

	A1 Live	A1 Dead		A2 Live	A2 Dead		A3 Live	A3 Dead
Ac	2	0.5	Ac	8	1	Ac	14	8
Af	8	3	Af	0	0	Af	3	0.5
Ba	18	0	Ba	15	0.5	Ba	4	1
Bi	0	0	Bi	0	0	Bi	0.1	0
Bm	8	1	Bm	7	0	Bm	4	0
Et	5	0	Et	4	0.5	Et	0	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	0	0	Nf	0	0	Nf	0.2	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	16	0	Us	25	0	Us	20	0
Litter	55	0	Litter	57	0	Litter	50	0
Bare	26	0	Bare	15	0	Bare	25	0
Trunk	3	0	Trunk	3	0	Trunk	5	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	8		FS	8		FS	10	0
M	0	0	M	0	0	M	0	0
Disturbance	10.5	0	Disturbanc	10	0	Disturbanc	10	0

	B1 Live	B1 Dead		B2 Live	B2 Dead		B3 Live	B3 Dead
Ac	4	2	Ac	8	4	Ac	19	6
Af	5	0	Af	0	0	Af	3	1
Ba	13	1	Ba	9	0.5	Ba	6	0.5
Bi	0	0	Bi	0	0	Bi	0	0
Bm	5	0	Bm	8	0	Bm	6	0
Et	7	0	Et	5	1	Et	3	0.1
Ke	0	0	Ke	0	0	Ke	0	0
Nf	2	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	15	0	Us	15	0	Us	17	0
Litter	22	0	Litter	47	0	Litter	60	0
Bare	60	0	Bare	35	0	Bare	20	0
Trunk	3	0	Trunk	3	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	8	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	10	0	Disturbanc	0	0	Disturbanc	0	0

	C1 Live	C1 Dead		C2 Live	C2 Dead		C3 Live	C3 Dead
Ac	8	3	Ac	23	5	Ac	12	7
Af	7	0	Af	0	0	Af	0	0
Ba	13	0.5	Ba	12	0.3	Ba	12	0
Bi	0	0	Bi	0.5	0.5	Bi	0	0
Bm	7	0	Bm	7	0	Bm	7	0
Et	0	0	Et	5	0	Et	4	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	0	0	Nf	0.1	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	16	0	Us	17	0	Us	15	0
Litter	58	0	Litter	55	0	Litter	57	0
Bare	22	0	Bare	24	0	Bare	25	0
Trunk	3	0	Trunk	3	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	8	0	FS	8	0	FS	10	0
M	0	0	M	1	0	M	0	0
Disturbance	10.5	0	Disturbanc	10	0	Disturbanc	10	0

Table x. Percentage cover of the Unfenced/Burnt array at Caraban for each of the 25m x 25m quadrats in a 3 x 3 array.

	A1 Live	A1 Dead		A2 Live	A2 Dead		A3 Live	A3 Dead
Ac	8	13	Ac	3	19	Ac	0	4
Af	6	0.5	Af	5	0.5	Af	7	1
Ba	8	3.5	Ba	10	1.5	Ba	7	4
Bi	0	0	Bi	0	0	Bi	0	0
Bm	6	0.5	Bm	8	1	Bm	3	2
Et	4	0	Et	3	0	Et	0	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	1	0	Nf	0.1	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	15	0	Us	14	0	Us	15	0
Litter	50	0	Litter	52	0	Litter	35	0
Bare	32	0	Bare	31	0	Bare	47	0
Trunk	3	0	Trunk	3	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	6	0	Disturbance	0	0	Disturbance	0	0

	B1 Live	B1 Dead		B2 Live	B2 Dead		B3 Live	B3 Dead
Ac	8	11	Ac	0	21	Ac	1	9
Af	6	2	Af	3	0	Af	4	0.5
Ba	8	1	Ba	8	1.5	Ba	9	4
Bi	0	0	Bi	0.1	0	Bi	0	0
Bm	10	0.2	Bm	3	0	Bm	6	0
Et	0	0	Et	0	0	Et	4	0
Ke	0	0	Ke	0	0	Ke	0	0
Nf	2	0	Nf	3	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	15	0	Us	15	0	Us	12	0
Litter	53	0	Litter	54	0	Litter	46	0
Bare	29	0	Bare	29	0	Bare	40	0
Trunk	3	0	Trunk	3	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0		FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	7	0	Disturbance	0	0	Disturbance	0	0

	C1 Live	C1 Dead		C2 Live	C2 Dead		C3 Live	C3 Dead
Ac	15	7	Ac	19	12	Ac	16	5
Af	4	0	Af	2	0.5	Af	7	0.5
Ba	11	1	Ba	15.5	1	Ba	6	1
Bi	0	0	Bi	0	0.5	Bi	0	0
Bm	8	0.5	Bm	9	1	Bm	6	3
Et	0	0	Et	4	0	Et	5	0.2
Ke	0	0	Ke	0	0	Ke	0	0
Nf	4	0	Nf	0	0	Nf	0	0
Mr	0	0	Mr	0	0	Mr	0	0
Us	15	0	Us	18	0	Us	18	0
Litter	55	0	Litter	49	0	Litter	50	0
Bare	27	0	Bare	30	0	Bare	29	0
Trunk	3	0	Trunk	3	0	Trunk	3	0
Vn	0	0	Vn	0	0	Vn	0	0
G	0	0	G	0	0	G	0	0
FS	0	0	FS	0	0	FS	0	0
M	0	0	M	0	0	M	0	0
Disturbance	6	0	Disturbance	0	0	Disturbance	0	0

Table x. Auxiliary table to Percent covers of Caraban arrays.

Ac	Adenanthos cygnorum
Af	Allocasuarina fraseriana
Ba	Banksia attenuata
Bi	Banksia ilicifolia
Bm	Banksia menzesii
Et	Eucalyptus todtiana
Ke	Kunzea ericifolia
Nf	Nuytsia floribunda
Mr	Macrozamia reidlei
Us	Understorey
Litter	Litter
Bare	Bare
Trunk	Trunk
Vn	Verticordia nitens
G	Gladioli
FS	Fence Strip
M	Macrozamia
Disturbance	Disturbance

Constructing Venn Diagrams from the Transect Data Field Sheet

1. Transect Data

A transect data field sheet is an essential item that will be required to record data along your transect. A transect data field sheet template has been provided on Page x of the Appendix, however the data sheet can be tailored to suit specific terrains or situations.

The Transect Data Field Sheet included herein has been designed to record all vegetative and non-vegetative material at every half meter along the transect. By default, this also records any absence of cover along the transect. Provision has been made to record observations of foliage, and/or bark and stems of each canopy, and to determine combinations of canopies that occur together at any one point.

1.1 Increment size

Observations were recorded along the transect at intervals of 0.5m. Although this interval bracket presented limitations, it was found to be functional, manageable and achievable at a timely pace with efficiency generally improving over time. Intervals less than 0.5m can be arduous over long distances, particularly in very dense vegetation types with tall overstoreys, and may compromise precision as a result of merging boundaries due to difficulty distinguishing points above and below the tape measure. This is particularly apparent where vegetation is dense, and where overstorey canopies are at considerable height.

For ease of recording data, and for data analysis, the transect data field sheet has been designed to capture multiple features at each increment along the transect. In arranging the data field sheet in this manner it is possible to determine canopy cover, absence of canopy cover, and other listed features such as bare ground, litter etc at any one point along the transect with ease.

1.2 Point bias

Without specific instruments and equipment, often impractical and encumbering to take in the field, it is almost impossible to eradicate bias completely when recording observations at a particular point. Consequently a suitable method of identifying a target point above and below the tape measure needs to be established. The chosen method must remain constant for each quadrat sampled, and should be documented on the data sheet for consistency of any future monitoring at the same site. As an example, if a patch of bare ground has a uniform but sparse cover of fine gravel, a point on the ground could fall on either the gravel or bare ground. Alternatively there may be several categories present at any one point, such as cryptogam covered with litter, in which case you will need to record both. Although the data sheet template has been designed to allow multiple entries at each increment, its design does not allow for discrimination regarding percentage cover of multiple entries at any one point. To reduce the likelihood of skewed results it may be necessary to use a radius of, perhaps, 1cm from the target point on the ground and estimate the proportion of each element within the specified area, such as 0.4 rock/0.6 bare ground, or to number the elements in order of their abundance, 1: cryptogam; 2: litter etc.

2. Transect data analysis:

The percentage of vegetation cover along the transect has been expressed in a Venn diagram, as shown on pages x-x of the Appendix. A Venn diagram provides a good visual representation of canopy cover, absence of canopy cover, and the extent to which canopies overlap. However, a limiting factor of Venn diagrams is that they are capable of representing no more than three representative categories without becoming encumbered with an overload of interpretable information. Additionally, there appears to be no way of linking data when generating a Venn diagram, resulting in inaccurate graphic representation of data.

Venn diagrams were used to represent two analyses of canopy cover at Caraban:

i) Major canopies
- O: overstorey (> 1.8m)
- S: mid-storey (shrubs 0.5 – 1.8m)
- SS: groundcover (subshrubs, incorporating sedges, grasses and herbs <0.5m)

ii) Sub-shrub canopies
- SS: sub-shrubs <0.5m
- SG: sedges and grasses
- H: herbs

Steps to producing a Venn Diagram of major canopy cover:

1. Using information from the Transect Data Field Sheet a table was constructed to record the occurrence of the three major canopies (O, S and SS), and all combinations of overlapping canopies (O+S, S+SS, O+SS, O+S+SS), along the transect at 0.5m increments. Canopy presence is observed when either bark and/or foliage is recorded at any one point. By default, absence of canopy was also extrapolated from the transect observations, and recorded in a separate table. The table for both presence and absence of canopy cover was divided into 5m blocks for ease of analysis.
2. Each category of canopy cover, or canopy overlap, from each 5m block was added together and divided by the total number of half-meter increments in the transect. There are 85 half-meter increments in a transect of 42.5m. This figure was then multiplied by 100 to give the percentage cover for that canopy or canopy overlap along the transect.
3. To calculate the *total* percentage of canopy cover along the transect, the percentages of each canopy and canopy overlap were added together. This figure was subtracted from 100 (100% = total area of the quadrat) to calculate the absence of canopy cover along the transect.

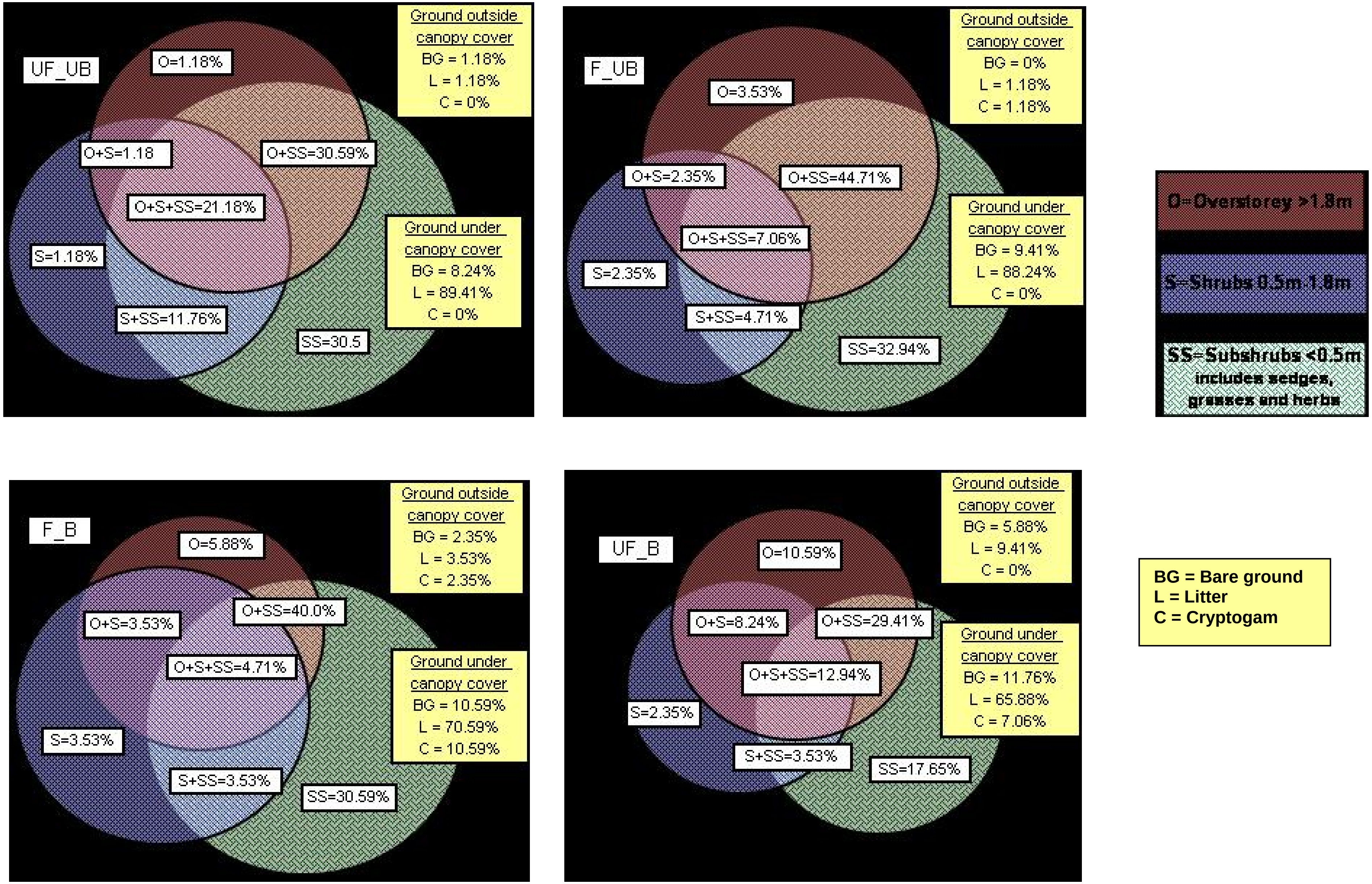


Figure x. Using transect data, percentage cover of each canopy, and percentage of the area outside any canopy cover, within cell B2 per site at Caraban (not corrected for gaps in canopy or definition of a point on transect).

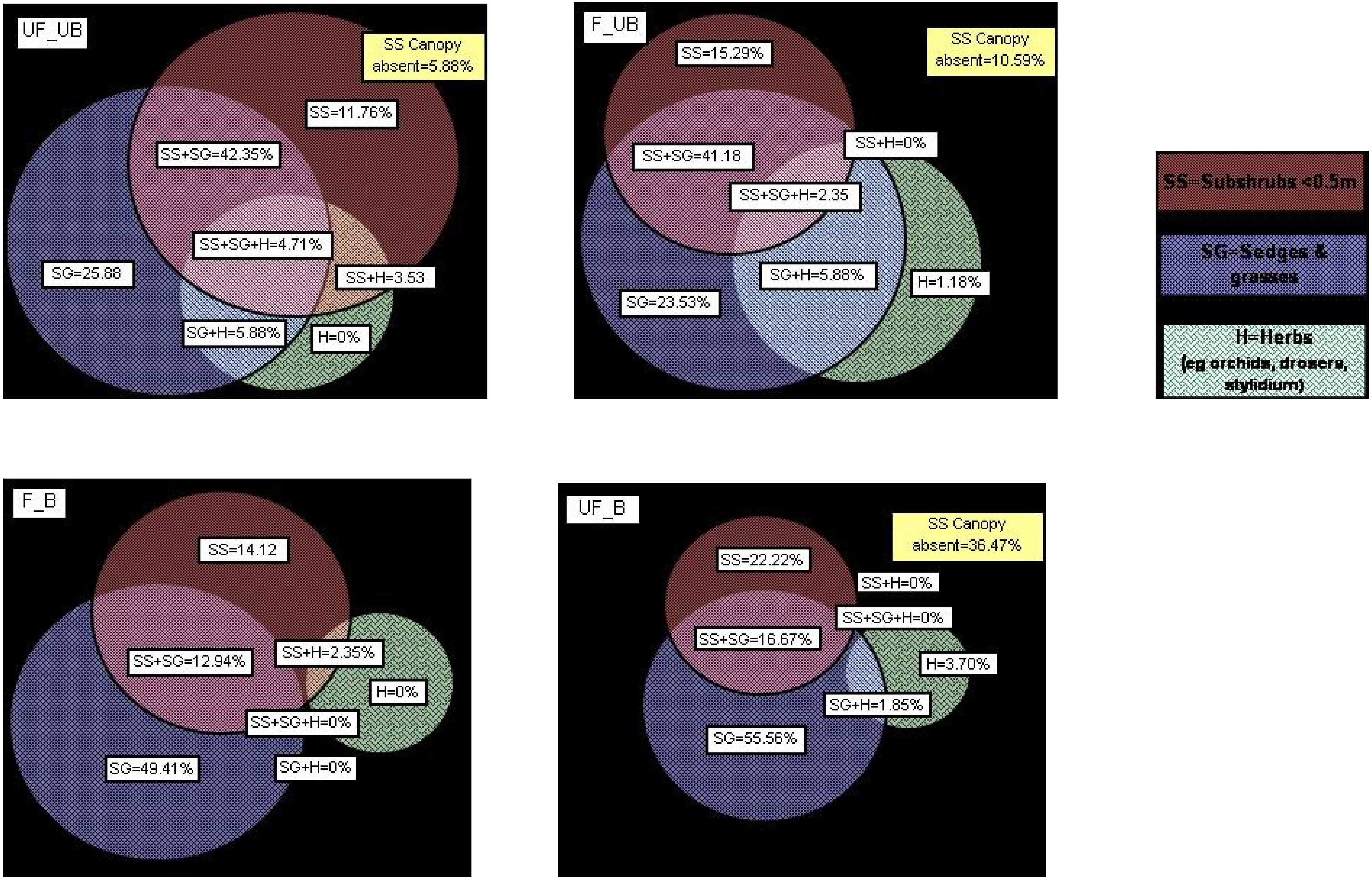


Figure x. Using transect data, percentage cover of the sub-shrub categories within cell B2 of each site at Caraban (not corrected for gaps in canopy or definition of a point on transect).

POINT TRANSECT SHEET SITE:______________QUADRAT:______________DATE:______________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogam	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Sub-shrub foliage	Sub-shrub bark/limbs	Shrub foliage	Shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body
0.5																			
1.0																			
1.5																			
2.0																			
2.5																			
3.0																			
3.5																			
4.0																			
4.5																			
5.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
5.5																			
6.0																			
6.5																			
7.0																			
7.5																			
8.0																			
8.5																			
9.0																			
9.5																			
10.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
10.5																			
11.0																			
11.5																			
12.0																			
12.5																			
13.0																			
13.5																			
14.0																			
14.5																			
15.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
15.5																			
16.0																			
16.5																			
17.0																			
17.5																			
18.0																			
18.5																			
19.0																			
19.5																			
20.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
20.5																			
21.0																			
21.5																			
22.0																			
22.5																			

POINT TRANSECT SHEET SITE:______________ QUADRAT:______________ DATE:______________

	Disturbed	Weed	Bare ground	Rock or permanent bare	Cryptogram	Litter	Logs	Ground –cover foliage	Ground –cover bark/limbs	Sedge/Grass foliage	Sedge/Grass bark/limbs	Low shrub foliage	Low shrub bark/limbs	High shrub foliage	High shrub bark/limbs	Over-storey foliage	Over-storey bark/limbs	Boundary (soil &/or veget'n)	Water body
23.0																			
23.5																			
24.0																			
24.5																			
25.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
25.5																			
26.0																			
26.5																			
27.0																			
27.5																			
28.0																			
28.5																			
29.0																			
29.5																			
30.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
30.5																			
31.0																			
31.5																			
32.0																			
32.5																			
33.0																			
33.5																			
34.0																			
34.5																			
35.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
35.5																			
36.0																			
36.5																			
37.0																			
37.5																			
38.0																			
38.5																			
39.0																			
39.5																			
40.0																			
	D	W	B	R	C	Li	Lo	Gf	Gb	SGf	SGb	Ssf	Ssb	Sf	Sb	Of	Ob	W	By
40.5																			
41.0																			
41.5																			
42.0																			
42.5																			

Other (eg dieback)
O
O
O
O

Other (eg dieback)
O
O
O
O

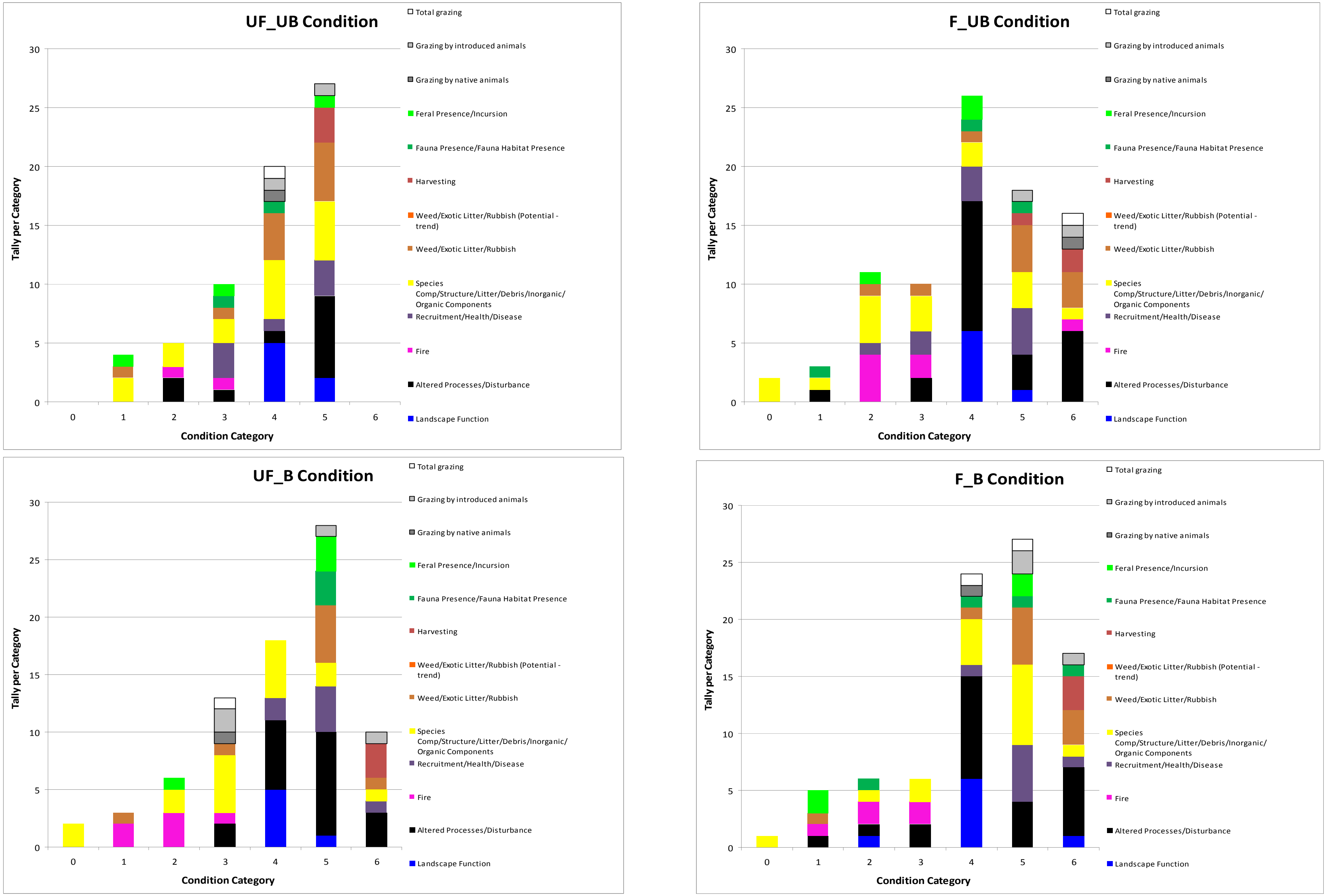


Figure x. Vegetation condition attributes and their ratings in each of the B2 quadrats of the four arrays at Caraban, *unabridged version - the underlying condition scores are from the forerunner of the information on the datasheets in this appendix, which is yet to be graphed.*

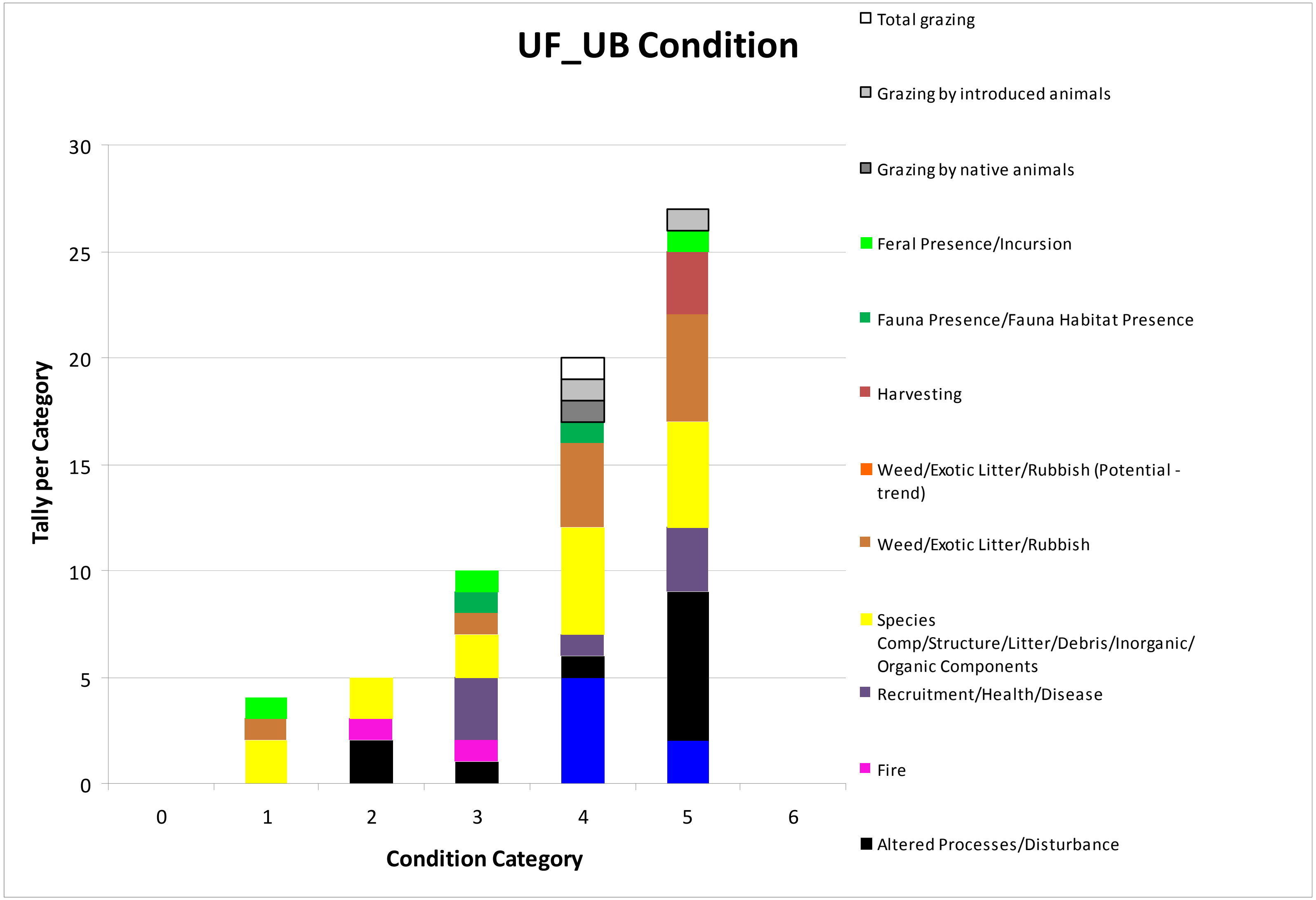


Figure x. Vegetation condition attributes and their scores within cell B2 of the Unfenced/Unburnt array at Caraban, unabridged version.

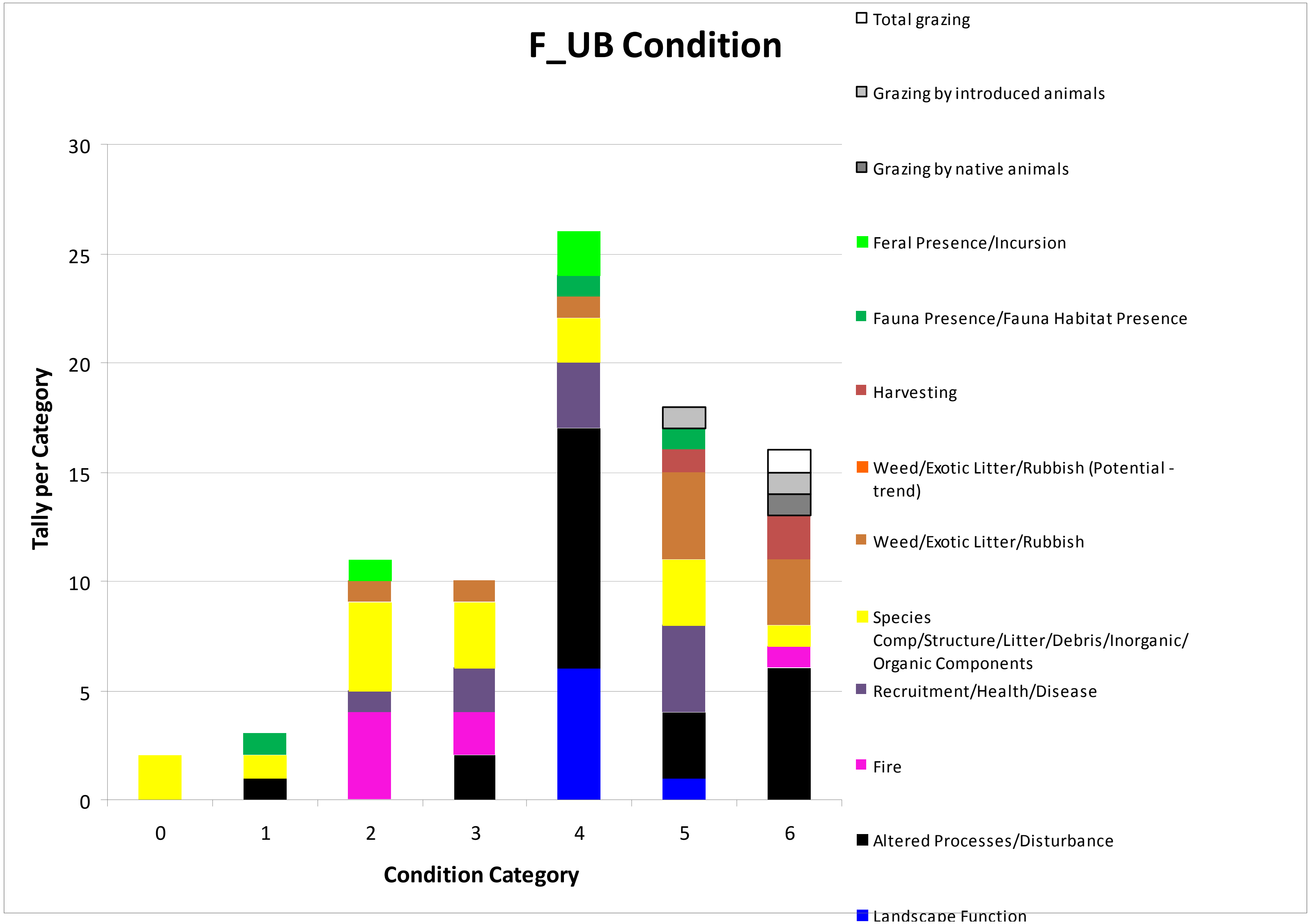


Figure x. Vegetation condition attributes and their scores within cell B2 of the Fenced/Unburnt array at Caraban, unabridged version.

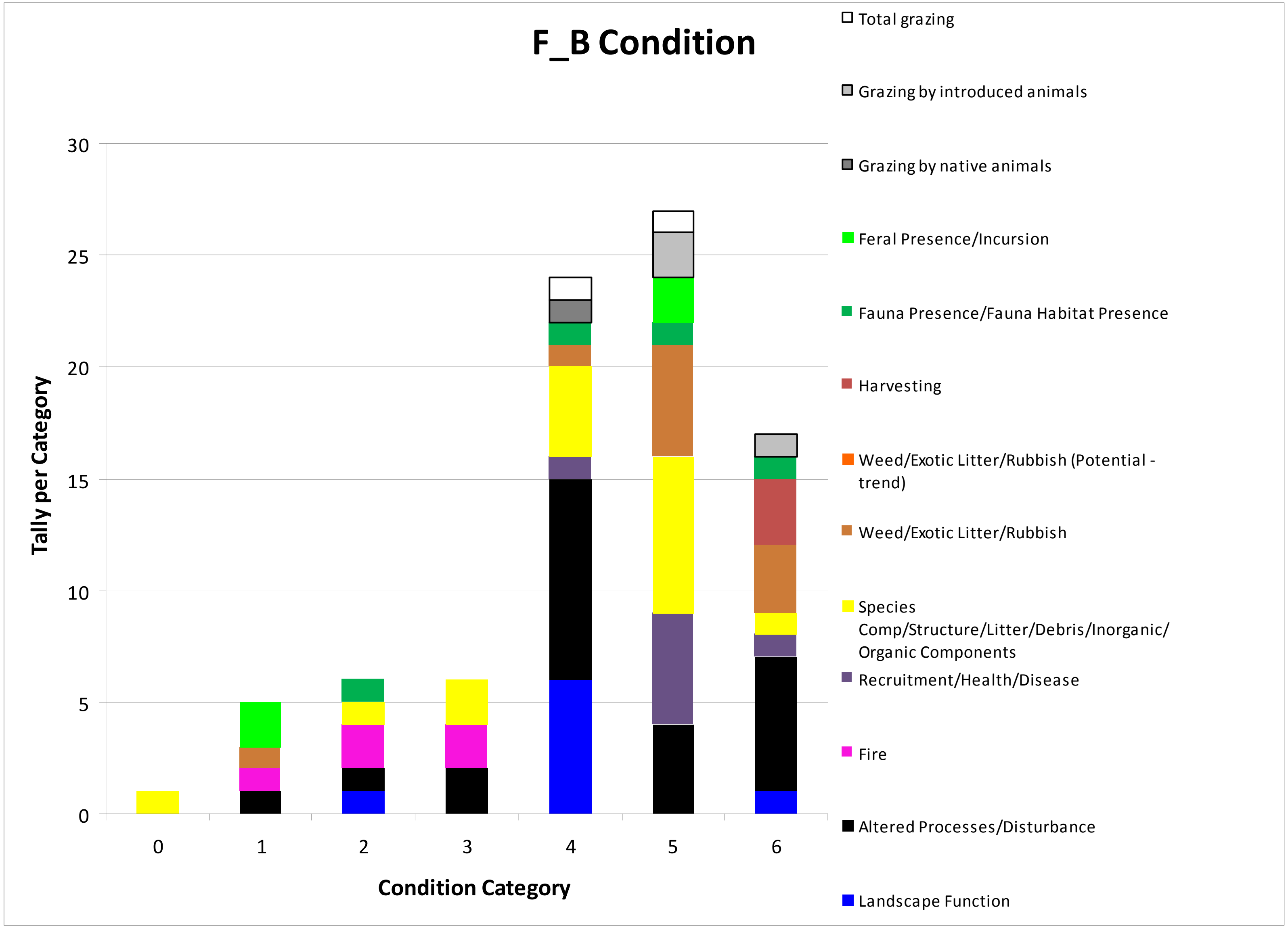


Figure x. Vegetation condition attributes and their scores within cell B2 of the Fenced/Burnt array at Caraban, unabridged version.

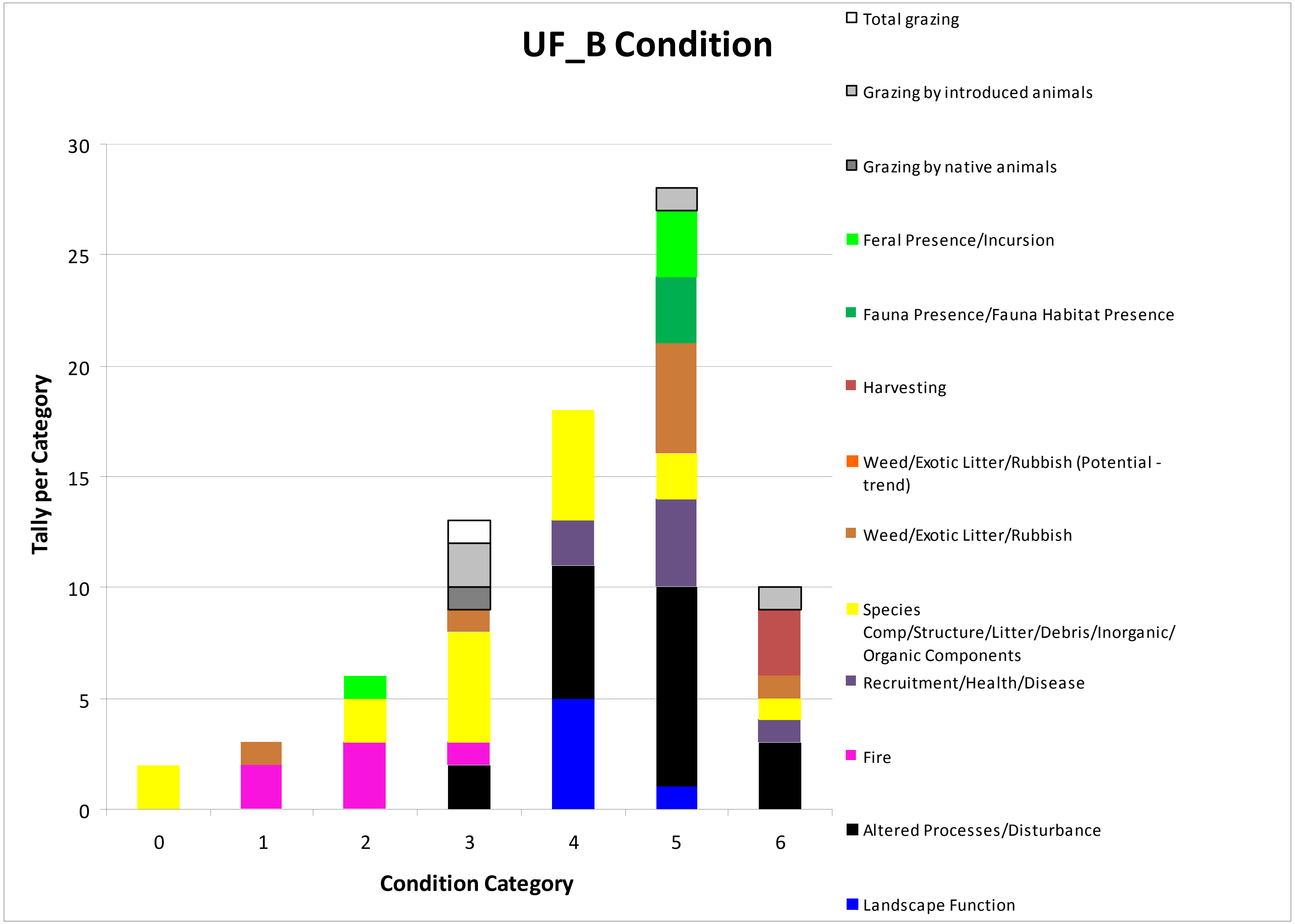


Figure x. Vegetation condition attributes and their scores within cell B2 of the Unfenced/Burnt array at Caraban, unabridged version.

UNFENCED/UNBURNT

ALTERNATIVE SINGLE CONDITION SCORE (B2+ = rest of array; B2/2 = second visit)

SHORT SCALE						B2 Short K			

REDUCED ATTRIBUTE SET [NA - not applicable if not assessable; Some attributes may require a default - to be shown as a tick box.]

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄					B2		
VEGETATION STRUCTURE	4A	◄			C1	< B2 Drought >			
TREE HABITAT	4A	◄	B2			B2/2			
INTERCONNECT-ING CANOPY	4A	◄		B2					B2
THICKETS	4A	◄		B2					B2
OPEN AREAS	4A	◄		B2					B2
ECOTONES / PATCHWORK	4A	◄	B2						B2
SURFACE STABILITY	1M	◄				B2			
LITTER	1M	◄			B2				
BIOTURBATION	1M	◄				B2 (nests) vertebrates			
EROSION / DEPOSTION	6D	►					B2		
INFRASTRUCTURE CHARACTERISTICS	6D	►				B2+	B2		
EXTENT OF CLEARING	6D	►				B2+ (firebreak)	B2		
RESOURCE EXTRACTION	6D	►					B2		
WATERLOGGING OR DROUGHT	6D	►		Watertable decline B2					
SALINITY - SECONDARY	6D	►							B2
HARVESTING OF BIOMASS	6D	►					B2 >		
WEEDS LINKED TO DISTURBANCE	5W	►					~ B2		
WEEDS - NON-DISTURBANCE	5W	►					~ B2		B2
RECRUITMENT	2R	◄			B2				
HEALTH - GENERAL	2R	◄			B2/2	B2<Dasypogon Acacia?			
DEATH OF KEY SPECIES	2R	◄			B2/2	B2 Banksias Dasypogon			
FIRE FREQUENCY RISING	1M	◄			B2/2	B2			
FIRE FREQUENCY DECLINING	1M	◄							B2
NATIVE FAUNA PRESENT - VERT	1M	◄				B2/2	Cockatoos Kangaroos B2 >		
FERAL ANIMALS PRESENT	6D	►		C1 B2 scats –pigs?	B2/2				
TOTAL GRAZING	1M	◄			B2	B2/2			
DISTURBANCE	6D	►				B2			
RESILIENCE	2R	◄					B2		
TOTAL (-3C)									

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*	B2	B2	B2	B2	B2	B2	B2	B2	B2
GROUP LIKE QUADS BY STATE	A1	B2	B2	B2	B2	B2	B2	B2	B2
US							B2		

MS								B2	
LS							B2		

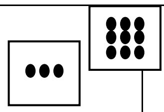
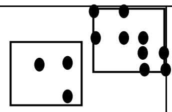
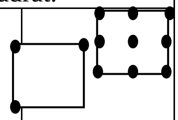
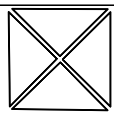
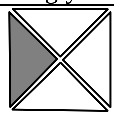
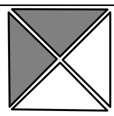
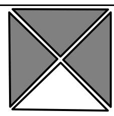
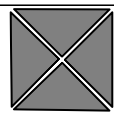
PATTERN - is there obvious clumping or is there very even distribution throughout? Default to intermediate if unsure. Basic pattern matching is represented below by indicative placement of dots over the quadrat.						
						
		Clumped	Converging	Intermediate	Separating	Dispersed
	Overstorey			X		
	Understorey (may be further split)			X		
CONNECTING - is there continuity between foliage in each of the quarters formed by the diagonals? Can climbing animals move through the canopy or midstorey interrupted by only small gaps (@10-30cm)? Count the number of quarters with a presence and score accordingly.						
						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	A1,A2,A3 B1,B2,B3 C1,C2,C3				
	Understorey (may be further split)	A1,A2,A3 B1,B2,B3 C1,C2,C3				
THICKETS - does close proximity of growth forms create merged entities that provide refuge and continuous cover? Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	A1,A2,A3 B1,B2,B3 C1,C2,C3				
	Understorey	A1,A2,A3 B1,B2,B3 C1,C2,C3				
ECOTONES - are there distinct interfaces between vegetation types in any of the quarters? Thicket/open interfaces are also relevant. Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	A1,A2,A3 B1,B2,B3 C1,C2,C3				
	Understorey	A1,A2,A3 B1,B2,B3 C1,C2,C3				

Table 8.2.2.B): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

<u>Unfenced/Unburnt Cell A1</u>

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)			✓		
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell A2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell A3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	0.2				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell B1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	1				
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell B2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell B3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell C1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell C2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Unfenced/Unburnt Cell C3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		61	13	4	1	

Fenced/Unburnt

ALTERNATIVE SINGLE CONDITION SCORE (B2+ = rest of array; B2/2 = second visit)

SHORT SCALE									
						B2 Short	K		

REDUCED ATTRIBUTE SET [NA - not applicable if not assessable; Some attributes may require a default - to be shown as a tick box.]

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄					B2		

			VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
VEGETATION STRUCTURE	4A	◄			(A1,A2,A3,B1,B2,B3, C1,C2,C3) minor	B2 drought Dasypogon			
TREE HABITAT	4A	◄			B2 (no hollows)				
INTERCONNECT-ING CANOPY	4A	◄		B2					B2
THICKETS	4A	◄			B2				B2
OPEN AREAS	4A	◄		B2					B2
ECOTONES / PATCHWORK	4A	◄	B2						B2
SURFACE STABILITY	1M	◄				B2			
LITTER	1M	◄			B2				
BIOTURBATION	1M	◄				B2			
EROSION / DEPOSTION	6D	►					B2		
INFRASTRUCTURE CHARACTERISTICS	6D	►				B2+	B2		
EXTENT OF CLEARING	6D	►				B2+ firebreak fence	B2		
RESOURCE EXTRACTION	6D	►					B2 >		
WATERLOGGING OR DROUGHT	6D	►							
SALINITY - SECONDARY	6D	►					B2 >		
HARVESTING OF BIOMASS	6D	►					B2		
WEEDS LINKED TO DISTURBANCE	5W	►					B2		
WEEDS - NON-DISTURBANCE	5W	►							
RECRUITMENT	2R	◄				B2			
HEALTH - GENERAL	2R	◄				B2			
DEATH OF KEY SPECIES	2R	◄			B2 Banksias Dasypogon				
FIRE FREQUENCY RISING	1M	◄			B2 little senesc-ence, scars recent				
FIRE FREQUENCY DECLINING	1M	◄							B2
NATIVE FAUNA PRESENT - VERT	1M	◄	B2						
FERAL ANIMALS PRESENT	6D	►				Old B2			
TOTAL GRAZING	1M	◄					Ceased B2		
DISTURBANCE	6D	►				B2			
RESILIENCE	2R	◄				Pigs B2			
TOTAL (-3C)									

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*	B2	B2	B2	B2	B2	B2	B2	B2	B2
GROUP LIKE QUADS BY STATE	A1	A1	A1	B2	B2	A1	A1	A1	A1

US							B2	Banksia	
MS								B2	
LS							B2	Dasypn	

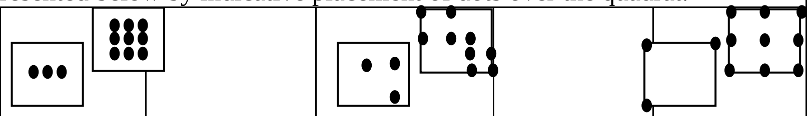
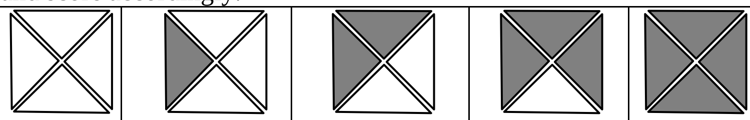
PATTERN - is there obvious clumping or is there very even distribution throughout? Default to intermediate if unsure. Basic pattern matching is represented below by indicative placement of dots over the quadrat.						
						
		Clumped	Converging	Intermediate	Separating	Dispersed
	Overstorey			X		
	Understorey (may be further split)			X		
CONNECTING - is there continuity between foliage in each of the quarters formed by the diagonals? Can climbing animals move through the canopy or midstorey interrupted by only small gaps (@10-30cm)? Count the number of quarters with a presence and score accordingly.						
						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey (may be further split)	X				
THICKETS - does close proximity of growth forms create merged entities that provide refuge and continuous cover? Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey	A1,A2,A3 B1,B2, B3 C3	(C1, C2) small			
ECOTONES - are there distinct interfaces between vegetation types in any of the quarters? Thicket/open interfaces are also relevant. Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey					
	Understorey					

Table 8.2.2.B): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

<u>Fenced/Unburnt Cell A1</u>

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	0.3				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell A2

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	1				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell A3

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	0.5				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell B1

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	0.5				
	Disturbance1					
	Disturbance2					
	Litter	✓				
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell B2

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell B3

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	0.3				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell C1

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)			✓		
	Bare	✓				
	Dead (or split into stressed & dead)	1.5				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

<u>Fenced/Unburnt Cell C2</u>

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)				✓	
	Bare	✓				
	Dead (or split into stressed & dead)					
	Disturbance1	✓				
	Disturbance2					
	Litter	✓				
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

Fenced/Unburnt Cell C3

COVER (%) - record the cover category for each feature						
		<0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)				✓	
	Bare	✓				
	Dead (or split into stressed & dead)	0.2				
	Disturbance1	✓				
	Disturbance2					
	Litter	✓				
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
			1		1	3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		63	5	4	1	

FENCED/BURNT

ALTERNATIVE SINGLE CONDITION SCORE (B2+ = rest of array; B2/2 = second visit)

SHORT SCALE						K B2short			

REDUCED ATTRIBUTE SET [NA - not applicable if not assessable; Some attributes may require a default - to be shown as a tick box.]

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄					B2		
VEGETATION STRUCTURE	4A	◄			A1,A2,A3,B1,B2, C1,C2,C3minor	< Banksia B2 death			
TREE HABITAT	4A	◄				B2 no hollows			
INTERCONNECT-ING CANOPY	4A	◄		B2					
THICKETS	4A	◄			B2 Adenanthos				
OPEN AREAS	4A	◄				B2 fire			
ECOTONES / PATCHWORK	4A	◄			B2				
SURFACE STABILITY	1M	◄				Digging B2			
LITTER	1M	◄		B2					
BIOTURBATION	1M	◄				Ants B2			
EROSION / DEPOSTION	6D	►					B2		
INFRASTRUCTURE CHARACTERISTICS	6D	►				Firebreak B2+	B2		
EXTENT OF CLEARING	6D	►				Firebreak B2+	B2		
RESOURCE EXTRACTION	6D	►					B2>		
WATERLOGGING OR DROUGHT	6D	►			B2 drawdown				
SALINITY - SECONDARY	6D	►					B2>		
HARVESTING OF BIOMASS	6D	►					B2>		
WEEDS LINKED TO DISTURBANCE	5W	►				< B2			
WEEDS - NON-DISTURBANCE	5W	►					B2>		B2
RECRUITMENT	2R	◄					< B2		
HEALTH - GENERAL	2R	◄		B2 insects on Dasypogon			B2 death fire related		
DEATH OF KEY SPECIES	2R	◄				B2 Banksia			
FIRE FREQUENCY RISING	1M	◄			< B2				
FIRE FREQUENCY DECLINING	1M	◄							B2
NATIVE FAUNA PRESENT - VERT	1M	◄		B2 fence					
FERAL ANIMALS PRESENT	6D	►					B2 fence		
TOTAL GRAZING	1M	◄					B2		
DISTURBANCE	6D	►				B2			
RESILIENCE	2R	◄					B2 >		
TOTAL (-3C)									

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*	B2	B2	C3	B2	B2	C3	B2	C3	C3
GROUP LIKE QUADS BY STATE	A1	A1	A1	A1	B2	B2	A1	A1	A1

US							B2		
MS								B2	
LS								B2 fire	

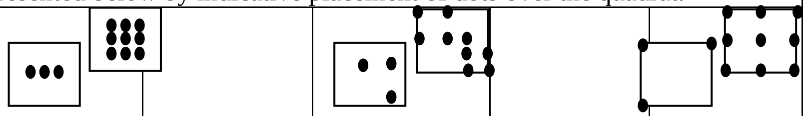
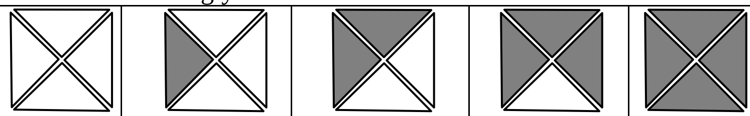
PATTERN - is there obvious clumping or is there very even distribution throughout? Default to intermediate if unsure. Basic pattern matching is represented below by indicative placement of dots over the quadrat.						
						
		Clumped	Converging	Intermediate	Separating	Dispersed
	Overstorey			X		
	Understorey (may be further split)	B3 C2	A3	A1, A2 B1, B2 C1 C3		
CONNECTING - is there continuity between foliage in each of the quarters formed by the diagonals? Can climbing animals move through the canopy or midstorey interrupted by only small gaps (@10-30cm)? Count the number of quarters with a presence and score accordingly.						
						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey (may be further split)	A1,A2,A3 B1,B2 C1	C2	B3		C3
THICKETS - does close proximity of growth forms create merged entities that provide refuge and continuous cover? Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey	A1 B1,B2 C1	A2		C2	A3 B3 C3
ECOTONES - are there distinct interfaces between vegetation types in any of the quarters? Thicket/open interfaces are also relevant. Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey		A2		C2	A3 B3 C3

Table 8.2.2.B): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

<u>Fenced/Burnt Cell A1</u>

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

<u>Fenced/Burnt Cell A2</u>

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)		✓			
	Bare	✓				
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell A3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell B1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare			✓		
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell B2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell B3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare	✓				
	Dead (or split into stressed & dead)	✓				
	Disturbance1			✓		
	Disturbance2					
	Litter					
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell C1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell C2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m		✓			
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

Fenced/Burnt Cell C3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
						3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		62	7		2	

UNFENCED/BURNT

ALTERNATIVE SINGLE CONDITION SCORE (B2+ = rest of array; B2/2 = second visit)

SHORT SCALE						K B2short			

REDUCED ATTRIBUTE SET [NA - not applicable if not assessable; Some attributes may require a default - to be shown as a tick box.]

		A	VERY DEGRADED	DEGRADED	GOOD	VERY GOOD	EXCELLENT	P	NA
PLANT SPECIES COMPOSITION	3C	◄					B2		

VEGETATION STRUCTURE	4A	◄			A1,A3,B3,C3 B2	Drought death Thicket death	Banksias Adenanthos		
TREE HABITAT	4A	◄			B2 mix of ages				
INTERCONNECT-ING CANOPY	4A	◄		B2					
THICKETS	4A	◄			B2				
OPEN AREAS	4A	◄			B2				
ECOTONES / PATCHWORK	4A	◄		B2					
SURFACE STABILITY	1M	◄				Digging B2			
LITTER	1M	◄		B2					
BIOTURBATION	1M	◄				B2			
EROSION / DEPOSTION	6D	►					B2		
INFRASTRUCTURE CHARACTERISTICS	6D	►				B2+	B2		
EXTENT OF CLEARING	6D	►				B2+	B2		
RESOURCE EXTRACTION	6D	►					B2		
WATERLOGGING OR DROUGHT	6D	►			B2 drawdown				
SALINITY - SECONDARY	6D	►					B2>		
HARVESTING OF BIOMASS	6D	►					B2>		
WEEDS LINKED TO DISTURBANCE	5W	►					B2		
WEEDS - NON-DISTURBANCE	5W	►				B2 gladiolus			
RECRUITMENT	2R	◄				B2			
HEALTH - GENERAL	2R	◄					< B2		
DEATH OF KEY SPECIES	2R	◄				< B2			
FIRE FREQUENCY RISING	1M	◄		B2>					
FIRE FREQUENCY DECLINING	1M	◄							B2
NATIVE FAUNA PRESENT - VERT	1M	◄					B2		
FERAL ANIMALS PRESENT	6D	►					< B2		
TOTAL GRAZING	1M	◄			B2				
DISTURBANCE	6D	►				Digging B2			
RESILIENCE	2R	◄					B2		
TOTAL (-3C)									

ARRAY (75mx75m LAYOUT) - ABRIDGED ASSESSMENT OF STATE (* ie are they largely the same vegetation or other cover type?)

QUADRAT	A1	A2	A3	B1	B2	B3	C1	C2	C3
GROUP LIKE QUADS BY TYPE*	B2	B2	A3	B2	B2	A3	B2	B2	A3
GROUP LIKE QUADS BY STATE	A3	B2	A3	B2	B2	A3	B2	B2	A3

US							B2		
MS							B2		
LS							B2		

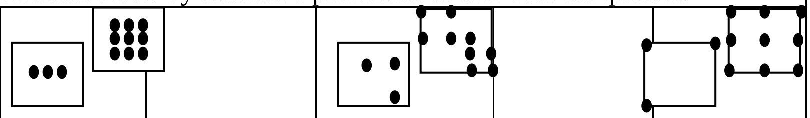
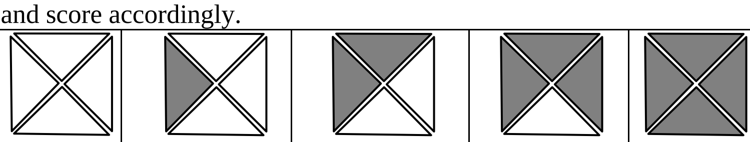
PATTERN - is there obvious clumping or is there very even distribution throughout? Default to intermediate if unsure. Basic pattern matching is represented below by indicative placement of dots over the quadrat.						
						
		Clumped	Converging	Intermediate	Separating	Dispersed
	Overstorey			X		
	Understorey (may be further split)	A1 B2 C3	A2 B1 C2	A3 B3		
CONNECTING - is there continuity between foliage in each of the quarters formed by the diagonals? Can climbing animals move through the canopy or midstorey interrupted by only small gaps (@10-30cm)? Count the number of quarters with a presence and score accordingly.						
						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey (may be further split)	A3 B3	C3		A1 B2 C2	A2 B1 C1
THICKETS - does close proximity of growth forms create merged entities that provide refuge and continuous cover? Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey		A3	C3		A1,,A2 B1,B2 C1,C2
ECOTONES - are there distinct interfaces between vegetation types in any of the quarters? Thicket/open interfaces are also relevant. Count the number of quarters with a presence and score accordingly.						
		0 quarters	1 quarter	2 quarters	3 quarters	4 quarters
	Overstorey	X				
	Understorey		A3	C3		A1,A2 B1,B2 C1,C2

Table 8.2.2.B): Assessing heterogeneity or diversity using the array – an adapted example. Fill out the sheet for each 25mx25m.

<u>Unfenced/Burnt Cell A1</u>

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell A2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)		✓			
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell A3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare			✓		
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter		✓			
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell B1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell B2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)	✓				
	Understorey Shrubs >2m					
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)		✓			
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell B3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell C1

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1	✓				
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell C2

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

Unfenced/Burnt Cell C3

COVER (%) - record the cover category for each feature						
		>0-20	21-40	41-60	61-80	81-100
	Overstorey (eg trees/mallees)		✓			
	Understorey Shrubs >2m	✓				
	Understorey Shrubs <2m (or split into Shrubs 1-2m & Shrubs et al <1m)	✓				
	Bare		✓			
	Dead (or split into stressed & dead)	✓				
	Disturbance1					
	Disturbance2					
	Litter			✓		
HEIGHT (m) - record the cover category for each feature						
	Overstorey (can show recruitment)	<0.5	0.5-1.0	>1.0-1.5	>1.5-2.0	>2.0
		2				3
	Understorey	<0.5	0.5-1.0	>1.0-2.0	>2.0-3.0	>3.0
		56	7	2		1

PHYSICAL SITE DETAILS

DATE: 30/06/09; 02/07/09; 03/07/09 RECORDERS: NC, AH, SD

PROJECT: NVI: Caraban SITE: Unfenced/Unburnt B2

SITE FORMAT & DIMENSIONS: Entire array mapped; B2 assessed IS THE SITE UNIFORM? – MAP ZONES ___________________

OBSERVATION CODE (STANDARD PLOT ARRAY): ________________

OBSERVATION QUALITY: _________________________

Keighery 1994

LOCATION: 6.7kms north along Military Rd from the intersection of Wanneroo Rd; turn west into Coppino Rd off Military Rd, keeping west through junction, and travel 1.925km along Coppino Rd; travel ~500m north along firebreak. Fenced/Unburnt trial starts 12.5m to the west of the track, and the Unfenced/Unburnt trial begins 150m west more than that (ie 12.5m + 150m west of the track). Edge of B2 is 117.5m west. Burnt trial replicates this to the east.

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude

GPS used: yes DGPS used: yes LOCATION IN PLOT: B2: NW corner and centre of 30m x 30m

Central 30mx30m plot

CENTROID:	Lat: (DGPS) 31º 22' 14.03"	Long: (DGPS) 115º 40' 16.74"	Altitude: (DGPS) 14m	(PDOP 1.8)
GPS datum: GDA94	Lat: (GPS) 31º 22' 14.1"	Long: (GPS) 115º 40' 16.8"	Altitude: (GPS) 49m	
NORTH-WEST CORNER:	Lat: (DGPS) 31º 22' 13.597"	Long: (DGPS) 115º 40' 16.173"		
GPS datum: GDA94	Lat: (GPS) 31º 22' 13.7"	Long: (GPS) 115º 40' 16.2"	Altitude: (DGPS) 16m	(PDOP 2.2)

BEARINGS:

Diagonal 135º SE NW Corner boundary bearings: 180º S & 90º E

PHOTOS: photographer: _________________ format: __________________ code: ______________

Other plot :
CENTROID:
GPS datum: ________ Lat: ______________________ Long: ____________________________ Altitude: ___________________

NORTH-WEST CORNER:
GPS datum: _____________________Lat:____________________________Long: __________________________ Altitude: ____________

BEARINGS:
Diagonal___________________Corner boundary bearings: ________________________________&___________________________________

PHOTOS: photographer: ___________________ format: ____________________ code: __________________

Landform & Soils
SLOPE: flat; gentle ASPECT: SE
SURFACE SOIL: Colour: yellow/white Texture: sand
EXPOSED ROCK (type and % of surface): n/a
SUB-SURFACE SOIL: Colour: yellow Texture: sand
UNDERLYING ROCK (type and depth if known):
DRAINAGE: well-drained WET: winter
CURRENT WATER DEPTH: ? 0.5m?
LITTER (% cover & depth):_________ _____________ BARE GROUND (% cover)

Topographic Position: undulating/plain

VEGETATION: *B. attenuata* / *B. menzesii* / *E. todtiana* woodland 8 – 10m

VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____
TIME SINCE FIRE: > 5yr (10 yr?)
NOTES: ____

SEASON: Winter WEATHER DATA: 3 wet days (~ 20mm)
AMBIENT REMOTE SENSING INFORMATION: ?????????????????

Fire - some blackboys with significant skirts
- Banksia seedlings with subsequent growth stages

Approximate ratio of 1 node seedlings (B2): 15 *B. attenuata* : 3 *B. menzesii* in 30 x 30m plot (: ≤ 1 *E. todtiana* in C3; 2 in A2)

PHYSICAL SITE DETAILS
DATE: 3/07/2009 RECORDERS: NC, AH, SD
PROJECT: NVI Caraban SITE: Fenced/Unburnt B2
SITE FORMAT & DIMENSIONS: Entire array mapped; B2 assessed IS THE SITE UNIFORM? – MAP ZONES________
OBSERVATION CODE (STANDARD PLOT ARRAY): ______________________________________
OBSERVATION QUALITY: __________________________
Keighery 1994
LOCATION: 6.7kms north along Military Rd from the intersection of Wanneroo Rd; turn west into Coppino Rd off Military Rd, keeping west through junction, and travel 1.925km along Coppino Rd; travel ~500m north along firebreak. Fenced/Unburnt trial starts 12.5m to the west of the track. Burnt trial replicates this to the east.

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude
GPS used: yes DGPS used: yes LOCATION IN PLOT: B2: NW corner and centre of 30m x 30m

Central 30mx30m plot
CENTROID:
GPS datum: GDA94 Lat: (DGPS) 31º22'14.017" Long: (DGPS) 115º40'20.127" Altitude: (DGPS) 15m (PDOP 1.9)
GPS datum: GDA94 Lat: (GPS) 31º22'14.0" Long: (GPS) 115º40'20.1" Altitude: (GPS) 47m

NORTH-WEST CORNER:
GPS datum: GDA94 Lat: (DGPS) 31º22'13.53" Long: (DGPS) 115º40'19.561" Altitude: (DGPS) 14m (PDOP 1.7)
GPS datum: GDA94 Lat: (DGPS) 31º22'13.5" Long: (DGPS) 115º40'19.7" Altitude: (GPS) 45m

BEARINGS:
Diagonal__________________Corner boundary bearings:______________________________&_________________________________

PHOTOS: photographer: ________________ format: _________________ code: ____

Other plot__________________

CENTROID:

GPS datum: ____________________ Lat: _____________________________ Long: ________________________________ Altitude: ________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: ____________________ Lat: _____________________________ Long: ________________________________ Altitude: ________________

BEARINGS:

Diagonal________________Corner boundary bearings: ___________________________&______________________________

PHOTOS: photographer: ________________ format: _________________ code: _______________

Landform & Soils

SLOPE: flat/ gentle slope ASPECT: n/a

SURFACE SOIL: Colour: White Texture: sand

EXPOSED ROCK (type and % of surface):

SUB-SURFACE SOIL: Colour: yellow Texture: sand

UNDERLYING ROCK (type and depth if known):

DRAINAGE: well-drained WET: winter and spring only

CURRENT WATER DEPTH: 6m?

LITTER (% cover & depth):________ ___________ BARE GROUND (% cover)

Topographic Position undulating/plain

VEGETATION: *Banksia attenuata* and *B. menzesii* woodland with scattered *Eucalyptus todtiana* and *Allocasuarina fraseriana*

VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____

TIME SINCE FIRE: > 5yr (10 yr?)

SEASON: late winter WEATHER DATA: Fine 18º (as for last day on UF/UB)

AMBIENT REMOTE SENSING INFORMATION: ?????????????????

General: compared to Unfenced/Unburnt

1. **Allocasuarina fraseriana** in (10 x 10m) and (30 x 30m) + more of its litter – heavy blanket to ≥ 2-3cm under canopy (compared with 1cm elsewhere)
2. bare area appears greater and/or understorey (typically 50 – 60cm) is less abundant/lower cover
3. less area dug over and generally ≥ 1year older, though most now covering over
4. fungal fruiting bodies appearing more commonly (soil cracked); though 2 days more sun/post rain compared to Unfenced/Unburnt
5. *Conostylis setigera*, *Schoenus curvifolius* and *Dasypogon* not grazed, so more obvious
6. little oval-leafed orchid quite common (though 2 days post rain may be a factor compared with Unfenced/ Unburnt plot).

Approximate ratio of 1 node seedlings (B2): 13 *B. attenuata* : 2 *B. menzesii* : 2 *E. todtiana* in 30m x 30m plot

PHYSICAL SITE DETAILS
DATE: 7/06/2009 RECORDERS: NC, AH, SD
PROJECT: NVI: Caraban SITE: Fenced/Burnt: B2
SITE FORMAT & DIMENSIONS: Entire array mapped; B2 assessed IS THE SITE UNIFORM? – MAP ZONES ___________________
OBSERVATION CODE (STANDARD PLOT ARRAY): ____________________________________
OBSERVATION QUALITY: _________________________
Keighery 1994
LOCATION: 6.7kms north along Military Rd from the intersection of Wanneroo Rd; turn west into Coppino Rd off Military Rd, keeping west through junction, and travel 1.925km along Coppino Rd; travel ~500m north along firebreak. Fenced/Burnt trial starts 12.5m to the east of the track, and the Unfenced/Burnt trial begins 150m east more than that (ie 12.5m + 150m east of the track). Edge of B2 is 117.5m east. Unburnt trial replicates this to the west.

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude
GPS used: yes DGPS used: yes LOCATION IN PLOT: B2: NW corner and centre of 30m x 30m

<u>Central 30mx30m plot</u>
CENTROID:
GPS datum: GDA94 Lat: (DGPS) 31º22'14.012" Long: (DGPS) 115º40'24.157" Altitude: (DGPS) 13m (PDOP 1.7)
GPS datum: GDA94 Lat: (GPS) 31º22'14.1" Long: (GPS) 115º40'24.2" Altitude: (GPS) 49m (5m accuracy)

NORTH-WEST CORNER:
GPS datum: GDA94 Lat: (DGPS) 31º22'13.585" Long: (DGPS) 115º40'23.638" Altitude: (DGPS) 16m (PDOP 1.8)
GPS datum: GDA94 Lat: (GPS) 31º22'13.6" Long: (GPS) 115º40'23.6" Altitude: (GPS) 49m (5m accuracy)

BEARINGS:
Diagonal_________________Corner boundary bearings: 90º East & 180º South
PHOTOS: photographer: _________________ format: __________________ code: ____________________

Other plot___________________
CENTROID:
GPS datum: ____________ Lat: _________________ Long: __________________ Altitude: ___________

NORTH-WEST (OR EQUIVALENT) CORNER:
GPS datum: ____________ Lat: _________________ Long: __________________ Altitude: ___________

BEARINGS:
Diagonal_________________Corner boundary bearings: _________&__________
PHOTOS: photographer: _________________ format: __________________ code: ___________

Landform & Soils
SLOPE: gentle ASPECT: NE/ E/ SE
SURFACE SOIL: Colour: White Texture: sand
EXPOSED ROCK (type and % of surface):
SUB-SURFACE SOIL: Colour: yellow Texture: sand
UNDERLYING ROCK (type and depth if known):
DRAINAGE: well-drained WET: winter and spring only
CURRENT WATER DEPTH: ≥6m
LITTER (% cover & depth):________ ____________ BARE GROUND (% cover)

Topographic Position hinterland dunes, undulating/plain. Upperslope.

VEGETATION: *Banksia attenuata, B. menzezii*, *Eucalyptus todtiana* woodland

VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____

TIME SINCE FIRE: ≥ 1 year
NOTES: ____

SEASON: Winter WEATHER DATA: _______________________
AMBIENT REMOTE SENSING INFORMATION: ??????????????????

Approximate ratio of 1 node seedlings (B2): 23 *B. attenuata* : 7 *B. menzesii* in 30m x 30m plot

PHYSICAL SITE DETAILS
DATE: 9/07/2009 RECORDERS: NC, AH, SD
PROJECT: NVI Caraban SITE: Unfenced/Burnt: B2
SITE FORMAT & DIMENSIONS: Entire array mapped; B2 assessed IS THE SITE UNIFORM? – MAP ZONES ___________________
OBSERVATION CODE (STANDARD PLOT ARRAY): _____________________________________
OBSERVATION QUALITY: _________________________
Keighery 1994
LOCATION: 6.7kms north along Military Rd from the intersection of Wanneroo Rd; turn west into Coppino Rd off Military Rd, keeping west through junction, and travel 1.925km along Coppino Rd; travel ~500m north along firebreak. Fenced/Burnt trial starts 12.5m to the east of the track, and the Unfenced/Burnt trial begins 150m east more than that (ie 12.5m + 150m east of the track). Edge of B2 is 117.5m east. Unburnt trial replicates this to the west.

Locality map. A to-scale map is required, a statemap (eg 1:25000, 1:50000) is an appropriate basis. Include well estimated distances from fixed landmarks such as road and fence junctions and bearings Do not rely soley on GPS for planning and relocation. It is desirable that the key points are well marked on an aerial photograph at an appropriate scale. (Source map scale: Source map name:)

Latitude & Longitude
GPS used: yes DGPS used: no LOCATION IN PLOT: B2: NW corner and centre of 30m x 30m

<u>Central 30mx30m plot</u>
CENTROID:
GPS datum: GDA94 Lat: 31º22'13.9" Long: 115º40'27.7" Altitude: 45m (5m accuracy)

NORTH-WEST (OR EQUIVALENT) CORNER:
GPS datum: GDA94 Lat: 31º22'13.5" Long: 115º40'27.1" Altitude: 44m (5m accuracy)

BEARINGS:
Diagonal_________________Corner boundary bearings:_____________________________&________________________________
PHOTOS: photographer: _________________ format: __________________ code: __________________________

Other plot___________________

CENTROID:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

NORTH-WEST (OR EQUIVALENT) CORNER:

GPS datum: _____________________ Lat: _______________________________ Long: __________________________________ Altitude: _________________

BEARINGS:

Diagonal_________________Corner boundary bearings: _____________________________&________________________________

PHOTOS: photographer: _________________ format: __________________ code: __________________________________

Landform & Soils

SLOPE: gentle ASPECT: NE/ E

SURFACE SOIL: Colour: White Texture: sand Bassendean dunes?

EXPOSED ROCK (type and % of surface): n/a

SUB-SURFACE SOIL: Colour: Yellow Texture: sand

UNDERLYING ROCK (type and depth if known):

DRAINAGE: well-drained WET: winter and spring only

CURRENT WATER DEPTH: 6m

LITTER (% cover & depth):________ ____________ BARE GROUND (% cover)

Topographic Position: hinterland dunes, undulating/plain

VEGETATION: *Banksia attenuata*, *B. menzezii*, *Eucalyptus todtiana* woodland

VEGETATION TYPE/LANDSYSTEM FROM STATE MAPPING: ____

TIME SINCE FIRE: ≥ 1 year

NOTES: ____

SEASON: Winter WEATHER DATA: cloudy, scattered showers, mainly dry intervals

AMBIENT REMOTE SENSING INFORMATION: ?????????????????

Approximate ratio of 1 node seedlings (B2): 5 *B. attenuata* : 5 *B. menzesii* in 30m x 30m plot