Australian Government

Department of
Environment and Conservation

Resource Condition Monitoring – Native Vegetation Integrity Project

Literature Review:

Vegetation Condition Assessment,
Monitoring & Evaluation

Version 4

Department of Environment and Conservation

October 2008

Department of Environment and Conservation
17 Dick Perry Drive
Kensington, Western Australia, 6151

Resource Condition Monitoring – Native Vegetation Integrity Project
Literature Review: Vegetation Condition Assessment, Monitoring & Evaluation. Version 4 (October 2008)

Contributing authors: Kristen Bleby, Judith Harvey, Mark Garkaklis and Leah Martin

Acknowledgements: Thank you to the following reviewers: Keith Claymore, Glen Daniels, Sophie Moller, Ken Wallace, and Jeff Richardson.

This project is funded by the Australian Government and the Government of Western Australia.

Table of Contents

1 Abstract

Significant loss, of and changes to, native vegetation in Australia since European settlement drives the need to conserve remnant vegetation. Effective conservation programs need accurate information about the extent and condition of the native vegetation that remains.

An effective conservation program must collect vital information and data on native vegetation condition, and fulfil its obligations to the Government, and the public or some other enforcement entity (Stem *et al.* 2005). Perhaps most important, however, is the need to assess whether a conservation program is effective and achieving its set goals and outcomes. The management body must be able to measure whether the program's set goals and outcomes were met, and report accordingly. For example, in order to establish if set goals and outcomes of maintained or improved vegetation condition are met, accurate information on native vegetation condition must be collected. If the goals (i.e. the higher order objectives to which a program is intended to contribute (MERI Framework 2008) or outcomes (i.e. intended results, effects, or consequences (beneficial or otherwise) that occur from carrying out a program or activity (Jakowyna 2008) are not met, then the data collected can be used to propose improvements to the conservation program in order to achieve the set goals and outcomes.

In many biodiversity-related programs, monitoring of vegetation condition can produce large quantities of data and trends of data over time against a long list of 'indicators'. Hence it is important to analyse these data and trends in the context of a framework that relates first and foremost to an overall question(s) resulting from the goals).

Many regional, state and federal government agencies in Australia have instituted policies that require native vegetation condition to be monitored over time (Newell *et al.* 2006). Despite this, a standard definition of 'condition' does not exist. Vegetation condition is a context-dependent concept (Tongway and Ludwig 1997). Different contexts include environmental drivers such as ecological processes and biodiversity conservation (Oliver *et al.* 2002). Therefore, vegetation condition should be defined specifically for each conservation program, depending on the program's goals. Vegetation condition data should only inform decision making when it is used alongside other information, such as management actions aimed to alleviate threats or aimed at reaching pre-determined vegetation states (Gibbons and Freudenberger 2006). Thus appropriate management questions need to be asked when defining vegetation condition.

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. For this project, 'integrity' is defined as both the extent and condition of native vegetation.

This review will explore monitoring and evaluating methods regarding the condition of native vegetation only. A review of vegetation extent and the current status of a vegetation extent map for Western Australia will be discussed in other *RCM – NVI Project* documents.

Traditionally, information about vegetation condition has been collected using on-ground assessment methods conducted at the scale of individual sites (Gibbon and Freudenberger 2006). More recently there is growing demand to use information on vegetation condition in a broader regional context and to monitor achievement, and to report on progress towards regional, state and national targets of vegetation condition (Parkes and Lyon 2006; Neldner 2006). Spatial modelling and remote sensing are newer tools that can increase the accuracy and value of assessing vegetation condition in conjunction with more commonly used site-scale on-ground assessment methods (Briggs and Freudenberger 2006). Vegetation condition can be assessed and mapped at regional scales with reasonable accuracy using remote sensing and/or abiotic variables (Drielsma and Ferrier 2006; Higgins 2006; Newell *et al.* 2006; Thackway and Lesslie 2006; Wallace *et al.* 2006; Zerger *et al.* 2006). Spatial models or maps of vegetation condition should be related to vegetation condition data from on-ground assessments (i.e. ground-truthing), which in turn should be related to benchmarks for desirable states of vegetation condition (Ayers *et al.* 2005; Gibbons and Freudenberger 2006; Parkes and Lyon 2006).

This review discusses the use of vegetation data as a surrogate for assessing and monitoring biodiversity, existing definitions of native vegetation condition, development of a conceptual framework for assessing vegetation condition, indicators of vegetation condition, development of a framework for monitoring and evaluating vegetation condition, and a brief discussion of the history of the development of vegetation condition assessment and monitoring and evaluation approaches, with particular attention to the current approaches used in Australia.

The purpose of this review is to provide background information to develop a definition of native vegetation condition for the *Resource Condition Monitoring – Native Vegetation Integrity* Project:

> ***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 in disturbed;
  - A realistically desired functional State (virtual benchmark);
- Baseline being the current state; and
- Predicted state what management goals aim for.

2 Scope of Document

This paper reviews:

- The use of vegetation data as a surrogate for biodiversity;
- Current definitions of vegetation condition;
- The importance of vegetation condition assessment and monitoring and evaluation to effective conservation (including the basic drivers of vegetation condition assessment and monitoring and evaluation) and the difficulties in assessing vegetation condition;
- Methods used to assess vegetation condition at different spatial scales
- The use of indicators to assess vegetation condition
- The development of a conceptual framework to assess vegetation condition
- The development of a framework to monitor and evaluate the assessment of vegetation condition
- Historical and current approaches to vegetation condition assessment and monitoring and evaluation used in Australia; and
- Definition of vegetation condition for the *Resource Condition Monitoring – Native Vegetation Integrity* Project.

This paper does not cover the following:

- Methods of benchmarking;
- An adequate assessment of methods used in the Rangelands
- A technical review of current remote sensing
- Specific actions to alleviate the impact of natural and human-induced threatening processes; and
- Data management protocols for storage and retrieval of monitoring data.

3 Introduction

Historically, one of the strongest drivers in conservation planning has been the need to gain information on the 'extent' and 'type' of remnant vegetation, as well as the depletion of this vegetation, in order to manage and protect biodiversity assets (Newell *et al.* 2006). More recently, however, another driver is the need to gain information on the 'condition' (sometimes termed 'quality') of native vegetation, and the need to monitor changes in vegetation condition over time (Newell *et al.* 2006). Gathering information about the condition of vegetation is becoming an integral part of natural resource management and conservation programs in order to help manage, maintain, or improve the current condition of vegetation. Despite the growing popularity of this approach to biodiversity conservation, a standard definition of 'vegetation condition' does not exist.

The aim of this review paper is to provide background information to develop a definition of native vegetation condition for the *Resource Condition Monitoring – Native Vegetation Integrity* Project.

In addition, this paper examines the use of vegetation data as a surrogate for assessing and monitoring biodiversity, existing definitions of native vegetation condition, development of a conceptual framework for assessing vegetation condition, indicators of vegetation condition, development of a framework for monitoring and evaluating vegetation condition, and a brief discussion of the history of the development of vegetation condition assessment and monitoring and evaluation approaches, with particular attention to the current approaches used in Australia.

The 'integrity' of native vegetation communities is defined as (i) the extent and distribution of vegetation communities; and (ii) their condition, for designated purposes (e.g. provision of habitat) (National Natural Resource Management Monitoring and Evaluation Framework 2003).

For the purpose of the *Resource Condition Monitoring – Native Vegetation Integrity* Project (hereafter referred to as '*RCM – NVI Project*'), vegetation 'integrity' is defined as both the extent and condition of native vegetation. Information on both the extent and the condition of native vegetation will ultimately be incorporated into the Project's evaluation of native vegetation integrity in Western Australia. This review will explore only monitoring and evaluating methods regarding the **condition** of native vegetation. A review of vegetation extent and the current status of a vegetation extent map for Western Australia will be discussed in other *RCM – NVI Project* documents.

4 Vegetation Condition

In Australia, there has been significant loss of, and changes to, native vegetation since European settlement. Consequently, a strong driver in conservation planning and management has been the need to gain information on the extent (quantity) of remnant native vegetation and the condition (quality) of the remaining native vegetation. Consequently, many regional, state and federal government agencies have instituted policies and requirements to monitor and evaluate native vegetation condition over time E.g. Regional Forest Agreements, Victoria's Native Vegetation Management Framework for Action (DNRE 2002, Newell *et al.* 2006).

The Australian Government recognises that measuring the extent and condition of native vegetation are important surrogates for indigenous biodiversity (e.g. Hill 2001). (See Section 6 for a discussion on the use of vegetation data as a surrogate for biodiversity). It requires both extent and condition to be used as two of the indicators of regional biodiversity status in order to evaluate Commonwealth investments in regional biodiversity conservation (Higgins 2006).

Monitoring vegetation condition is important for several reasons. Examples include: (1) vegetation condition assessment and monitoring is integral in the adaptive management process (see Section 9); and (2) monitoring vegetation condition can be used to detect the impact of threatening processes, such as fire, climate change and disease.

4.1 Definition of Vegetation Condition

Vegetation extent is defined as all plant life in a given area (Thackway and Lesslie 2005, 2006). More generally it is referred to as distribution and abundance of vegetation. The meaning of 'condition' is less clear, despite the concept of vegetation condition becoming more prevalent in recent land management policy in Australia. In the literature and policy, several definitions of vegetation condition are being used for different purposes and at difference scales and will largely depend on the management objectives.

Keith and Gorrod (2006) define condition as a state of being or health. In biological terms, condition at an individual scale refers to the fitness of that individual (Keith and Gorrod 2006), or rather a measure of the individual's reproductive success (Kimball 1994). At higher biological scales, for example communities, ecosystems and landscapes, the concept of condition becomes less clear (Keith and Gorrod 2006).

Keith and Gorrod (2006) identified intrinsic values of vegetation condition, derived from three concepts:

- Aesthetics: human perspectives about what makes a ‘good’ patch of vegetation; subjective; varies between people and landscapes.
- Production: derive from the ability of native vegetation to deliver resources for human consumption.
- Biodiversity: in part relates to the capacity of native vegetation to sustain local populations of native plants and animals (as well as their genetic diversity and ecological interactions).

Assessment of vegetation condition is a context-dependent concept and includes economic drivers such as sustainable production capability, and environmental drivers such as ecological function and biodiversity conservation (Oliver *et al.* 2002). Indicators include the capacity for economic goods, the degree of land cover or degradation, the presence of different plant species, important habitat for wildlife, ecological productivity and regeneration capacity, and the extent and type of past disturbance (Thackway *et al.* 2006). Different perspectives in which vegetation condition is assessed will determine what information is collected and may lead to different results. From one perspective vegetation may be in good condition, but may be in poor condition from another perspective (Thackway *et al.* 2006). For example from a production perspective a rangeland may be in optimal condition but from a biodiversity perspective it may be in poor condition (Tongway & Ludwig 1997).

Thackway *et al.* (2006) suggest that a definition of condition should ideally include:

- A statement of perspective and values to which the condition applies (which should be captured in the management goal or its elaboration);
- Consideration of the long term stability of the vegetation under current management conditions to deliver on the management goal (which itself should be spatially and temporally defined);
- Attributes of the vegetation to be assessed – that is, those attributes that best indicate the vegetation’s capacity to deliver the goal within the specified timeframe;
- Attributes of the vegetation’s environment (e.g. grazers, fire regimes, soil and water, etc.) – that is, those attributes that best indicate the likelihood that the vegetation will to deliver the goal within the specified timeframe. By measuring how vegetation condition changes in reference to threats, one can better choose the appropriate management actions that aim to alleviate these threats;
- A clearly defined or documented method of assessing the attributes;
- Reference to a level disturbance (also mentioned in Keighery 1994)

Vegetation condition assessment can also be measured within the context of threatening processes that impact on the quality and presence of sensitive and vulnerable plant species. The consideration of threats and disturbances in the assessment of the condition of native vegetation is important for identifying the management changes that should be focused on.

The *RCM – NVI Project* considers vegetation condition in the context of biodiversity values as recommended by the National NRM M&E Framework (ESCAVI 2003). The Department of Environment and Conservation’s corporate goal for biodiversity is to protect, conserve and, where necessary and possible, restore Western Australia’s biodiversity (DEC Corporate Plan 2006). The commitment to the maintenance or improvement of the State’s biodiversity ‘condition’ is a relatively new concept to be incorporated into conservation planning than the measurement of extent and the representativeness.

At a national level the drivers for condition assessment and reporting are the need to support and inform target-based approaches to regional planning for native vegetation management, and to provide a basis for ongoing reporting against targets. Although there is general agreement across the states and territories on the need for a nationally consistent approach it is critical that this compliments the states policy and legislative requirements (Lyon and Parkes 2006).

Parkes and Lyon (2006) have defined condition at a State or regional scale in an inherently comparative concept; requiring an agreed frame of reference or context. This reference state is often expressed as a 'benchmark' that represents the "characteristics of mature and apparently long-undisturbed stands of the same vegetation type". Even within this definition, however, the terms 'mature' and 'long-undisturbed' are both relative and will be different depending on the vegetation type. This presets a definition which does not focus on the management goal. It may not even know what processes are instigating the change.

4.2 Previous Definitions

Different definitions of vegetation condition, quality or health that have been used globally and in Australia have been tabulated by Gibbons and Freudenberger (2006) (Table 1). Additional definitions are included (after row 5). An attempt has been made to assign a level of scale.

The 'extent' of vegetation refers to the abundance and distribution of vegetation types (Reference to add). In addition, 'condition' and 'extent' both encompass 'composition', which refers to the types of vegetation that are in an area (Reference to add). A change in the composition alone, of a vegetation type or community does not give a measure of its condition.

Table 1: Definitions of vegetation condition, quality or health (modified from Gibbons and Freudenberger (2006).

Term Used	Definition	Reference	Scale
Habitat quality	The ability of key habitat components to supply the life requisites of selected species of wildlife	US Fish and Wildlife Service (1980)	Patch
Rangeland health	The sustained ability of land to produce forage from rainfall	Pickup *et al.* (1994)	Landscape/Region
Range condition	Has its own continuum…the position of a particular site along this continuum depends on a judgment of the value of the landscape for a given purpose	Tongway and Ludwig (1997)	Landscape/Region
Resilience	The predicted degree to which the ecosystem retains a capacity to recover after the removal of the source problem and application of restoration treatments	Perkins (2002)	Ecosystem
Vegetation quality	The degree to which the current vegetation differs from mature and apparently long undisturbed stands of the same vegetation community	Parkes *et al.* (2003)	State/ regional
Riparian condition	The degree to which human-altered ecosystems diverge from local seminatural ecosystems in their ability to support a community of organisms and perform ecological functions	Jansen *et al.* (2004)	Ecosystem
Condition	The capacity of a site to provide habitat for all the indigenous species that may reasonably be expected to use it	Gorrod (2006a)	Patch
Condition	the health or quality of vegetation or other ecosystem element, such as riparian areas”	Gibbons and Freudenberger (2006).	Ecosystem
Condition	A state of being or health. In biological terms, condition at an individual scale refers to the fitness of that individual.	Keith and Gorrod (2006)	
Condition	A measure of modification relative to a reference state defined according to: the requirements of one or more species; a desired functional state; sites relatively unmodified by	Zerger et al. (2008)	

	humans; and notional pre-European conditions

4.3 Assessing Vegetation Condition in Biodiversity Conservation Management

The assessment of vegetation condition is very complex and can be difficult to measure. The concept of vegetation condition is also difficult to measure and apply because it is univariate in nature – that is, it varies on a single scale from 'good' to 'poor' (Keith and Gorrod 2006). However vegetation condition that is commonly used to describe biodiversity is not univariate. If the management goal is couched in terms of multiple values, there may be multiple condition scores. Biodiversity encompasses many species with habitat requirements that may be poorly correlated or inversely correlated with one another (Keith and Gorrod 2006).

Gibbons and Freudenberger (2006) define vegetation condition as a "value-laden concept that requires data to be interpreted through a 'values prism' along a continuum of 'good' to 'bad'". In other words, one threat or change may be interpreted as 'bad' for one aspect of vegetation condition, but may also be interpreted as 'good' for another aspect. The authors give the example that high perennial weed cover may constitute 'bad' condition in terms of conserving native plant species richness, but it may constitute 'good' condition in terms of lowering the water table in a salinity-affected landscape.

Gibbons and Freudenberger (2006) therefore suggest that information on vegetation condition should only inform decision making when it is used alongside other information (e.g. management actions aimed to alleviate threats or aimed at reaching pre-determined vegetation states). Thus vegetation condition must be defined in the context of management objectives in order to plan effective conservation programs. In addition to collecting vital information and data on native vegetation condition and planning effective conservation programs, it is also important to make sure that a program fulfils its obligations to the government, the public or some other enforcement entity (Stem *et al.* 2005). Perhaps most important, however, is the need to assess whether a conservation program is effective in achieving its goals and outcomes (which should be consistent with obligations to government, etc.). The management body needs to be able to measure and report on whether the program's set goals and outcomes were met. This can only be accomplished if accurate information on native vegetation condition is collected. If the goals and outcomes were not met, then the information collected can be used to propose changes to the conservation program.

4.4 Scale

Table 2 demonstrates some of the terminology used at different scale (after Noss 1990 and Freudenberger and Harvey 2003). In the *RCM - NVI Project*, we will use the categories of scale listed in the last column.

Table 2: Terminology used in descriptions of scale.

Geomorphic / Geographic	Institutional / Jurisdictional	Biological	Vegetation NVIS	Terms Used in NVI project
Continental / Transcontinental	State & Commonwealth	Threatened Species	Class	State
Catchment (1000 – Millions km2)	DEC & NRM Regions, LGA	Bioregions	Formation	Region
Landscape / Subcatchment (100 – 1000 ha)	Landcare Group, Farms,	Communities	Association	Landscape
Slope (Catena) (1 – 1000 ha)	Land owner	Individuals	Species	Patch

Note that each scale level encompasses the ones below. Landscape is not a precise term. In this document the term is used in the general sense of Forman (1997) as "… a mosaic where the mix of local ecosystems or land uses is repeated in a similar form over a kilometres-wide area A landscape in agricultural areas is where this unit is repeated with a similar pattern of land use, including natural habitats. From a biodiversity perspective, the distances over which significant species turnover occurs should govern the upper size limit of a landscape (Wallace *et al*. 2003).

The spatial scale at which resource condition may be measured ranged from genes? Species to ecosystems to landscapes to biosphere? Each scale has the same requirement for predetermined targets and measurements of sensitive elements; one species for species-scale, to many species for landscape-scale.

4.5 *RCM – NVI Project* - Definition

The clear theme that is emerging from this review document is that vegetation condition should be defined according to the relevant goals and values.

Vegetation condition assessment must be measured within the context of threatening processes (that are also defined in terms of goals/values) that impact on the quality and presence of sensitive and vulnerable plant species. Only then can the appropriate management actions that aim to achieve pre-determined biodiversity targets be formulated. The vegetation parameters (such as species presence or ordinated[1] community groups) provide the base or benchmarked state of the flora, while spatial and temporal differences in treatments provide the test of management for threats.

[1] 'Ordination' is the collective term for multivariate techniques that analyse site x species matrix data; the techniques arrange site data along axes on the basis of data on species composition (ter Braak 1987).

Vegetation condition assessment is one 'layer' of point and spatial data that informs the overall biodiversity state. In the *RCM – NVI Project* the focus is on the measurement of vegetation indices; however, other elements of biodiversity would need to be considered for an all encompassing measurement of biodiversity condition. For the purposes of this review these other biodiversity elements are not addressed. In the context of the whole project, these elements will not be addressed.

In this project, vegetation condition primarily deals with the *in situ* conservation of biodiversity. In this context condition is framed in terms of an adaptive management model, the Pressure – State –Response model or State-and-transition models, all covering the measurement of management effectiveness for vegetation conservation (for a review of Pressure – State – Response and management effectiveness see Hockings *et al.* 2006 and Dumanski and Pieri 1997).

The aim of the *RCM – NVI Project* is to develop a long-term, large-scale, strategic approach to assess and monitor and evaluate native vegetation condition in Western Australia, with the overall aim to conserve the State's biodiversity. Similar to Freudenberger and Harvey (2003), Noss (1990) and Thackway 2005, the *RCM – NVI Project* will use compositional, structural and functional attributes of vegetation condition as a surrogate to assess and monitor Western Australia's biodiversity.

The definition of vegetation condition in the Resource Condition Monitoring – Native Vegetation Integrity Project is:

> ***A measure, for the purpose of biodiversity conservation, of indicators 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 in disturbed
  - A realistically desired functional State (virtual benchmark)
- Baseline Current state
- Predicted state what management goals aim for.

5 Methods to Assess Vegetation Condition

Measuring the condition of vegetation is an important part of conservation programs around the world. For example, in North America the United States Environmental Protection Agency uses an additive scoring method (a rapid assessment site-scale index of vegetation) called Index of Biotic Integrity (IBI) (Andreasen *et al.* 2001). A similar method, the Environmental Benefits Index, is used by the US Conservation Reserve Program (Ribaudo *et al.* 2001). Another global example is a vegetation condition assessment of upland semi-natural vegetation used in the English Uplands (Jerram and Drewitt 1998). This method uses a relatively rapid and repeatable method that uses criteria (or a benchmark) for assessing 'favourable' (or 'optimal') vegetation condition for each of the four principle habitats in the Uplands.

In Australia, measuring the condition of vegetation has also become an important part of conservation programs. Methods to assess vegetation condition have been developed on a national level (Vegetation Assets, States, and Transitions (VAST) classification (Thackway and Lesslie 2005)) as well as for several states and territories. These include: Assessing Farm Bushland module in the Save the Bush Toolkit (Goldney & Wakefield 1997); Habitat Complexity Score (Catling & Burt 1995); Habitat Hectares - Victoria (Parkes *et al.* 2003); Biodiversity Benefits Index (Oliver & Parkes 2003); Rapid Appraisal of Riparian Condition (Jansen *et al*. 2004); BioMetric – New South Wales (Gibbons *et al.* 2005); and BioCondition assessment toolkit – Queensland (Eyre *et al.* 2006). These methods will be discussed below in more detail in Section 10.

5.1 Historical and Current Methods

Monitoring and evaluation approaches for assessing the condition or status of a conservation entity, such as the quality of a particular habitat have been used in conservation since the late 1800s (Stem *et al.* 2005). Methods include population monitoring (1890s), rapid assessment (early 1990s), and state-of-the-environment monitoring (mid 1980s) (Stem *et al.* 2005).

Oliver *et al*. (2002) stated that past approaches to condition assessment have tended to be taxon driven rather than all-species driven. These past approaches have often used the structural complexity of vegetation as a key predictor of condition (e.g. Catling and Burt 1995; Freudenberger 1999). As a result, structurally complex vegetation has become synonymous with vegetation in 'good' condition. However structural attributes alone are unlikely to be sufficient predictors of condition (Oliver 2002a; Oliver 2002b).

Methods for scoring vegetation condition or habitat value range from relatively generic scores of habitat structural complexity (e.g. Newsome and Catling 1979) to intricate scoring and modeling approaches applicable to single species, for example the United States Fish and Wildlife Service Habitat Suitability Indices (USFWS 1981). More recent methods provide rapidly obtained indices of native vegetation condition by using comparisons to reference condition states, or 'benchmarks' and are intended to provide a simple measure of vegetation condition (e.g. Habitat Hectares, Parkes *et al.* 2003).

Vegetation condition assessment methods are tools that have been developed to quantify one value of a patch of vegetation for biodiversity, which are based on the assumption that vegetation structural attributes act as surrogates for the habitat requirements of all indigenous plant and animal species (Gorrod, 2006b). A vegetation condition monitoring program measures any possible change in vegetation condition on a temporal or spatial scale. The term 'condition' can equate 'quality'.

Vegetation condition can be assessed at a range of spatial scales from site to regional to National scales, and from species to ecosystem to landscape scales, depending on the desired conservation goals (Briggs and Freudenberger 2006). While rapid, on-ground assessments of vegetation condition at the scale of individual sites (e.g. stand, paddock or remnant) have been used historically (Gibbons and Freudenberger 2006), landscape-scale and regional-scale assessments of the status and change in vegetation condition are a relatively new field for ecologists and government (Parkes and Lyon 2006). These more recent methods use remote sensing spatial modelling. Assessments of vegetation condition aim to provide an indication of the state of vegetation, and its capacity to continue to provide goods and services such as ecological productivity or production capacity for economic goods (Thackway *et al.* 2006). The assessment of vegetation condition at a national scale was based on how much of something exists (see VAST assessment by Thackway and Lesslie (2006), and is usually done in a defined area. The spatial assessment of vegetation condition is often represented by mapping and provides a snapshot in time (Briggs and Freudenberger 2006).

Gibbons and Freudenberger (2006) discussed two levels of vegetation condition assessment methods: on-ground site assessment or site-scale assessment and landscape scale using spatial modelling;

1. <u>On-ground (site-scale) assessment</u> – rapid, on-ground assessments of vegetation condition are based on easily measured biophysical attributes (Gibbons and Freudenberger 2006). These assessments can be accurate at fine scales, but can be impractical for assessment and monitoring across broad scales (Gibbons *et al.* 2006).

   Biophysical attributes are a measurable form for an individual plant that can be measured and used an indicator of vegetation condition. Attribute examples include plant height, canopy height, the number of trees with hollows, presence/abundance of problematic weed species, biomass and longevity. If a conservation program wanted to investigate the sensitivity to fire of a particular species, it would use indicators such as presence/absence of the species or the reproductive response of the species to fire. These indicators would be made up of certain measurable attributes, such as number of seeds produced or flowering rate or longevity. (Indicators (biodiversity indicators) are discussed more in depth in Section 8.)

2. <u>Landscape scale assessment using spatial modelling</u> – on-ground assessment of vegetation condition undertaken at individual sites can be spatially interpolated at a coarse scale over large areas using expert knowledge, environmental predictors, or a combination of environmental predictors and data from remote sensing platforms (Gibbons *et al.* 2006).

From the U. S. National Academy of Science symposium in 1986, Franklin (1988) noted that the growing concern over compositional diversity (e.g. species) was not accompanied by an adequate awareness of structural and functional diversity. Noss (1990) also recognised the limitations of focusing just on the compositional attributes of biodiversity, and developed a simple conceptual framework for identifying specific and measurable indicators (or attributes) of biodiversity. He recognised that biodiversity is not simply the number of genes, species or ecosystems in a defined area. Just knowing how many species are in an area does not indicate how these species are arranged (i.e. structure) or what they do (i.e. function) (Noss 1990). In comparison to Gibbons and Freudenberger (2006), Noss (1990) discussed three levels of scale: (i) regional landscape; (ii) community – ecosystem; and (iii) population – species at three levels of organisation: (a) composition; (b) structure; and (c) function (Table 3).

Table 3: Indicator variables for inventorying, monitoring and assessing terrestrial biodiversity at three levels of organisation, including a sampling of inventory and monitoring tools and techniques (adapted from Noss (1990)).

Indicators				
	Composition	**Structure**	**Function**	**Inventory and Monitoring Tools**
Regional Landscape	Identity, distribution, richness, and proportions of patch (habitat) types and multipatch landscape types; collective patterns of species distributions (richness, endemism)	Heterogeneity; connectivity; spatial linkages, patchiness; porosity; contrast; grain size; fragmentation; configuration; juxtaposition; patch size frequency distribution; perimeter-area ratio; pattern of habitat layer distribution	Disturbance processes (areal extent, frequency or return interval, rotation period, predictability, intensity, severity, seasonality); nutrient cycling rates; energy flow rates; patch persistence and turnover rates; rates of erosion and geomorphic and hydrologic processes; human land-use trends	Aerial photographs (satellite and conventional aircraft) and other remote sensing data; Geographic Information System (GIS) technology; time series analysis; spatial statistics; mathematical indices (of pattern, heterogeneity, connectivity, layering, diversity, edge, morphology, autocorrelation, fractal dimension)
Community – Ecosystem	Identity, relative abundance, frequency, richness, evenness, and diversity of species and guilds; proportions of endemic, exotic, threatened, and endangered species; dominance-diversity curves; life-form proportions; similarity coefficients; C4:C3 plant species ratios	Substrate and soil variables; slope and aspect; vegetation biomass and physiognomy; foliage density and layering; horizontal patchiness; canopy openness and gap proportions; abundance, density, and distribution of key physical features (e.g. cliffs, outcrops, sinks) and structural elements (snags, down logs); water and resource (e.g. mast) availability; snow cover	Biomass and resource productivity; herbivory, parasitism, and predation rates; colonization and local extinction rates; patch dynamics (fine-scale disturbance processes), nutrient cycling rates; human intrusion rates and intensities	Aerial photographs and other remote sensing data; ground-level photo stations; time series analysis; physical habitat measures and resource inventories; habitat suitability indices (HIS, multispeices); observation, censuses and inventories, captures, and other sampling methodologies; mathematical indices (e.g. of diversity, heterogeneity, layering dispersion, biotic integrity)
Population – Species	Absolute or relative abundance; frequency; importance or cover	Dispersion (microdistribution); range (macrodistribution);	Demographic processes (fertility, recruitment rate, survivorship, mortality);	Censuses (observations, counts, captures, signs, radio-tracking); remote sensing; habitat suitability

	value; biomass; density	population structure (sex ratio, age ratio); habitat variables (see community-ecosystem structure, above); within-individual morphological variability	metapopulation dymanics; population genetics (see below); population fluctuations; physiology; life history; phenology; growth rate (of individuals); acclimation; adaptation	index (HIS); species-habitat modelling; population viability analysis

Assessment of vegetation condition incorporate the above categories, each of which is effective at a different scale. Effective biodiversity conservation progress requires information on vegetation condition at multiple scales. As such, no single method is suited to undertaking such assessments across these scales and consideration of the different types of assessments is often required (Gibbons *et al.* 2006).

5.2 Remote Sensing Tools

Traditionally, information about vegetation condition has been collected using on-ground assessment methods conducted at the scale of individual sites (Gibbon and Freudenberger 2006). Spatial modelling and remote sensing are newer tools that can increase the accuracy and value of assessing vegetation condition in conjunction with more commonly used site-scale on-ground assessment methods (Briggs and Freudenberger 2006). An example is the use of Landsat imagery, which uses both spatial resolution and a historical archive of data to provide information on spectral signals over time to possibly help with monitoring changes in vegetation condition (Wallace *et al.* 2006). Satellite platforms, such as Landsat, SPOT, IKONOS, may be suitable for assessment of woody cover over large areas and for monitoring over time. However, these platforms can be limited in the characteristics of vegetation that they can detect. Instruments mounted on aircraft (such as multispectral and hyperspectral sensors and airborne laser scanners) can detect more features of vegetation than satellite-mounted sensors because of higher resolutions; however they are often suited to smaller areas because they are expensive (Gibbons *et al.* 2006). Table 3 presents the remote sensing tools available at different scales.

Vegetation condition can be assessed and mapped at regional scales with reasonable accuracy using remote sensing and/or abiotic variables, as shown by Drielsma and Ferrier (2006), Higgins (2006), Newell *et al.* (2006), Thackway and Lesslie (2006), Wallace *et al.* (2006) and Zerger *et al.* (2006). Higgins (2006) and Newell *et al*. (2006) investigated the development and use of vegetation condition maps in Victoria to support NRM activities on a landscape scale (Newell *et al*. 2006) and on a catchment scale (Higgins 2006). Thackway and Lesslie (2006) describe the Vegetation Assets, States and Transitions (VAST) framework that classifies vegetation by degree of human modification as a series of states. This framework is designed to assist in describing and accounting for human-induced modification to vegetation, and is discussed in more detail in Section 10. Zerger *et al.* (2006) describes a methodology for converting plot-based data on site condition into maps of vegetation condition across entire regions. This methodology does this by using a predictive statistical modelling framework (Generalized Additive Modelling) combined with a GIS.

Drielsma and Ferrier (2006): investigated the importance of scenario modelling of vegetation condition as an aid to land use decision making in the context of biodiversity. They described three approaches to compare the effects of different landscape scenarios on vegetation condition (listed in order or increasing refinement and complexity and data requirement):

(i) A simple land-use-condition approach, where vegetation condition is determined solely by land use. By using the vegetation condition values associated with each land use option, changes to land use are used to predict the changes in vegetation condition.

(ii) A land-use-regeneration approach, which uses a transition function (where each land use has a separate function for regeneration and degradation) to describe the dynamics of vegetation condition changes associated with changes in land use.

(iii) A threat-regeneration approach, which is based on the interaction between regeneration and a range of mapped threats. The information needed for this approach includes the likelihood of threats on a spatial scale, and the consequence of each threat on vegetation condition.

Spatial models or maps of vegetation condition should be related to vegetation condition data from on-ground assessments (i.e. ground-truthing), which in turn should be related to benchmarks for desirable states of vegetation condition (Ayers *et al.* 2005; Gibbons and Freudenberger 2006; Parkes and Lyon 2006).

The links between plot-based and spatially-based data are critical to the development of landscape-scale models of vegetation condition. Remote sensed data are varied and all require validation for application within vegetation communities. However, from a useful ecological context, the maximum scale of measurement (pixel size) appears to be 25 metres. This is equivalent to data generated by Landsat TM, and has been used widely in Western Australia to measure fire impacts on vegetation, grass productivity, rangelands management and tree declines. Smaller pixel airborne instruments (e.g. near infra-red videography, hyperspectral data) are also regularly used to better measure smaller-scale effects of threatening processes such as *Phytophthora* dieback (J. Wallace, pers. comm.) and species occurrences (Gibson *et al.* 2004; Coops and Catling 2002).

6 Vegetation Integrity as a Surrogate for Monitoring Biodiversity

6.1 Biodiversity

Biodiversity can be defined as the total of all the organisms that make up life on Earth, and contains all of the different life-forms (micro-organisms to plants and animals) from terrestrial to aquatic ecosystems (Wilson, 2003). It can be further defined at three levels:

- Genetic diversity: all the genetic information of individuals;
- Species diversity: all the estimated 30 – 50 million species on Earth; and
- Ecosystem diversity: the various habitats and communities, together with the ecological processes that support them.

There are many benefits of monitoring and conserving biodiversity, including the desire to preserve aesthetic and cultural values, ensure the significant economic and practical benefits that biodiversity provides to humans (e.g. food, medicines, wood, paper, honey, and dyes), and protect and research the unknown value of natural products for future generations (Wilson, 2003).

The Western Australian State Sustainability Strategy (2003) states several objectives relating to biodiversity, including:

- To continue to improve our knowledge and understanding of Western Australia's biodiversity and the processes that threaten biodiversity;
- To ensure the effective management of conservation reserves and other recognised special biodiversity conservation areas; and
- To conserve landscape / seascape scale ecological systems (integrating reserve and off-reserve conservation).

Surrogates for biodiversity are variables or attributes that are used to represent the distribution and abundance of species and communities. In conservation planning (and reserve design) surrogates need to be used because it is not possible to measure and document the complete biodiversity of an area. Examples of surrogates for biodiversity include maps of ecological communities and distributions of taxa, taken from records from biological surveys and museum and herbarium records (Burgman and Lindenmayer 1998).

6.2 Vegetation Data as a Surrogate for Biodiversity

Vegetation type and condition are widely used as surrogates of biodiversity (e.g. *State of Environment* reporting (Saunders *et al*. 1998)). An example of its use as a surrogate is the CAR system. The Australian Federal Government developed the Commonwealth Proposed Criteria for National Forest Conservation Reserves (Anon 1995) based on the objective of developing a comprehensive, adequate and representative network of nature conservation reserves (Burgman and Lindenmayer 1998). Design of CAR reserves depend on the reliability of surrogates to predict the distribution of various characteristics of biodiversity that are difficult to measure. Biological surveys cannot be used to assess all kinds or all levels of biodiversity because, for example they may not cover all taxa and communities, ecosystems are not static and surveys are expensive. Instead, the species and biological communities that are targets of reservation criteria act as surrogates for all other forms of biodiversity. Soil and vegetation maps and a few opportunistic taxonomic collections may be all that is available to guide the design of reserves in some areas (Burgman and Lindenmayer 1998).

Native vegetation is also used in a number of State-based tools for assessing biodiversity, such the Biodiversity Benefits Index (developed as part of the *NSW Environmental Services Scheme* (Department of Land and Water Conservation 2004)). Vegetation maps are perhaps the most frequently used surrogates for biodiversity since these may be the only useful information available for a catchment or region where few or no biological surveys have been undertaken (Williams 2005).

Although vegetation maps are frequently used, the ability of vegetation maps to act as surrogates for biodiversity is not often validated (Burgman and Lindenmayer 1998). This is because it is assumed that the protection of a proportion of each vegetation type will automatically protect sufficient proportions of other organisms (Burgman and Lindenmayer 1998). Vegetation maps may fail as surrogates because the distributions of flora assemblages are not related to the distribution and abundance of other species. An example of this is when sets of species are dependent on particular successional stages within a vegetation community, such as the old growth stage of a particular type of forest (Burgman and Lindenmayer 1998).

Native vegetation is also often used as a surrogate for biodiversity where a target (e.g. 10-20% of area of remaining vegetation type) is set in a catchment to protect the vegetation of that catchment and its biodiversity. This approach may be adequate *if* the species composition found in the overall vegetation ecosystem are well represented in the portion of this ecosystem chosen for protection, and if the portion set aside can fulfil the habitat requirements of these species (Williams 2005). However, it is often the case that these requirements may not be met (Ferrier and Watson 1997). Therefore, this approach to biodiversity management may be best served by basing decisions on a more diverse range of biological information about the catchment and the vegetation systems (Williams 2005).

Furthermore, when implementing strategies to conserve all biodiversity in a given area, managers should be aware that the extent, type and condition of native vegetation may not be a suitable surrogate (Williams 2005). Doherty *et al*. (2000) and Mac Nally *et al*. (2002) found that using measures of vegetation type and condition capture only a subset of the diversity of plants and animals that occur in a region. Miller (2000) stated that vegetation is often used synonymously with habitat, yet they are not the same – habitat is more complex, and describes an area with a combination of resources (e.g. food, cover and water) and environmental condition (e.g. temperature, precipitation, presence and absence of predators / competitors) that allows a given species or population to survive and reproduce. In addition, work undertaken in the rangeland regions, and reported at the *Biodiversity Monitoring Workshop*, demonstrated that native vegetation is a poor surrogate for patterns of invertebrate biodiversity and that these must be monitored directly (Crisp *et al*. 1998; Jonsson and Jonsell 1999; Eyre and Luff 2002, Andersen *et al*. 2003).

Despite these shortcomings, several studies and toolkits have used vegetation data as a surrogate for the biodiversity status of remnant vegetation in Australia, such as Save the Bush Toolkit (Goldney and Wakefield 1997) and the Biodiversity Benefits Index (Oliver *et al*. 2005). Jenkins et al. (2000) used vegetation data to help them select remnants for protection by fencing using a two-step process. First, identify the most suitable bush remnants for fencing by using a rapid assessment technique to assess the vegetation condition, habitat quality, floristic information and land use history of a site, as well as to record a species list, including threatening weed species. Second, a selection panel uses several ‘decision trees' to interpret the vegetation data in order to assign a funding priority to each assessment.

Other studies include Oliver *et al*. (2007) determined a set of ecosystem attributes – drawn from vegetation condition data and landscape context attribute pools – to use as surrogates for patch-level species biodiversity, Habitat Hectares (Parkes *et al*. 2003) provides an index of habitat quality for use as a surrogate for the status of patch-level species biodiversity. The index is based on combining assessments of three landscape context attributes (patch size, distance to nearest large patch, and the amount of native vegetation within 5 km of the site), and seven vegetation condition attributes (weed cover, native tree cover and health, native understorey cover and richness, litter cover, woody plant recruitment, wood load and the density of large trees). This index is used to rationalise the allocation of government funds to landholders in order to manage and restore native vegetation remnants in Victoria.

Ferrier (2002) expresses some caution about relying too heavily on the use of remotely sensed data to interpret the spatial distribution of selected taxa to represent biodiversity as a whole. While this method can be cost-effective and rapid, vast gaps in this available information may pose a major challenge for regional conservation planning. This approach is less effective in regions where little data is available but where there may be little choice but to base conservation planning on some form of remote mapping, which may be derived from interpretation of satellite imagery or from numerical classification of abiotic environmental layers (Ferrier 2002).

Three strategies have been put forward by Ferrier (2002) for making more effective use of available biological data and knowledge to alleviate such problems by:

(1) more closely integrating biological and environmental data through predictive modelling, with increased emphasis on modelling collective properties of biodiversity rather than individual entities;

(2) making more rigorous use of remotely mapped surrogates in conservation planning by incorporating knowledge of heterogeneity within land-classes, and of varying levels of distinctiveness between classes, into measures of conservation priority and achievement; and

(3) using relatively data-rich regions as test-beds for evaluating the performance of surrogates that can be readily applied across data-poor regions.

6.3 *RCM – NVI Project* - Vegetation as a Surrogate for Biodiversity

Freudenberger and Harvey (2003) stated that biodiversity is not a quantity that can be measured in its entirety; rather it is a similarity or difference in measurable characteristics or attributes from one place to the next. In a biodiverse landscape, the compositional, structural and functional attributes of biodiversity is maintained. Freudenberger and Harvey (2003) used the term 'attribute' to mean some measurable characteristic of biodiversity. Any attribute used as a surrogate for biodiversity is complex, including vegetation (Table 5). Despite this, it is assumed that native vegetation is a crude but useful surrogate for some attributes of biodiversity. Fundamental to the use of native vegetation as a surrogate (or other surrogates) is a correlation or link between the surrogate and biological diversity.

All surrogate measures of biodiversity are imperfect, and no one surrogate can adequately capture all of the compositional, structural and functional attributes of biodiversity. Many of the structural attributes listed in Table 4 contribute to habitat requirements of vertebrate and invertebrate fauna.

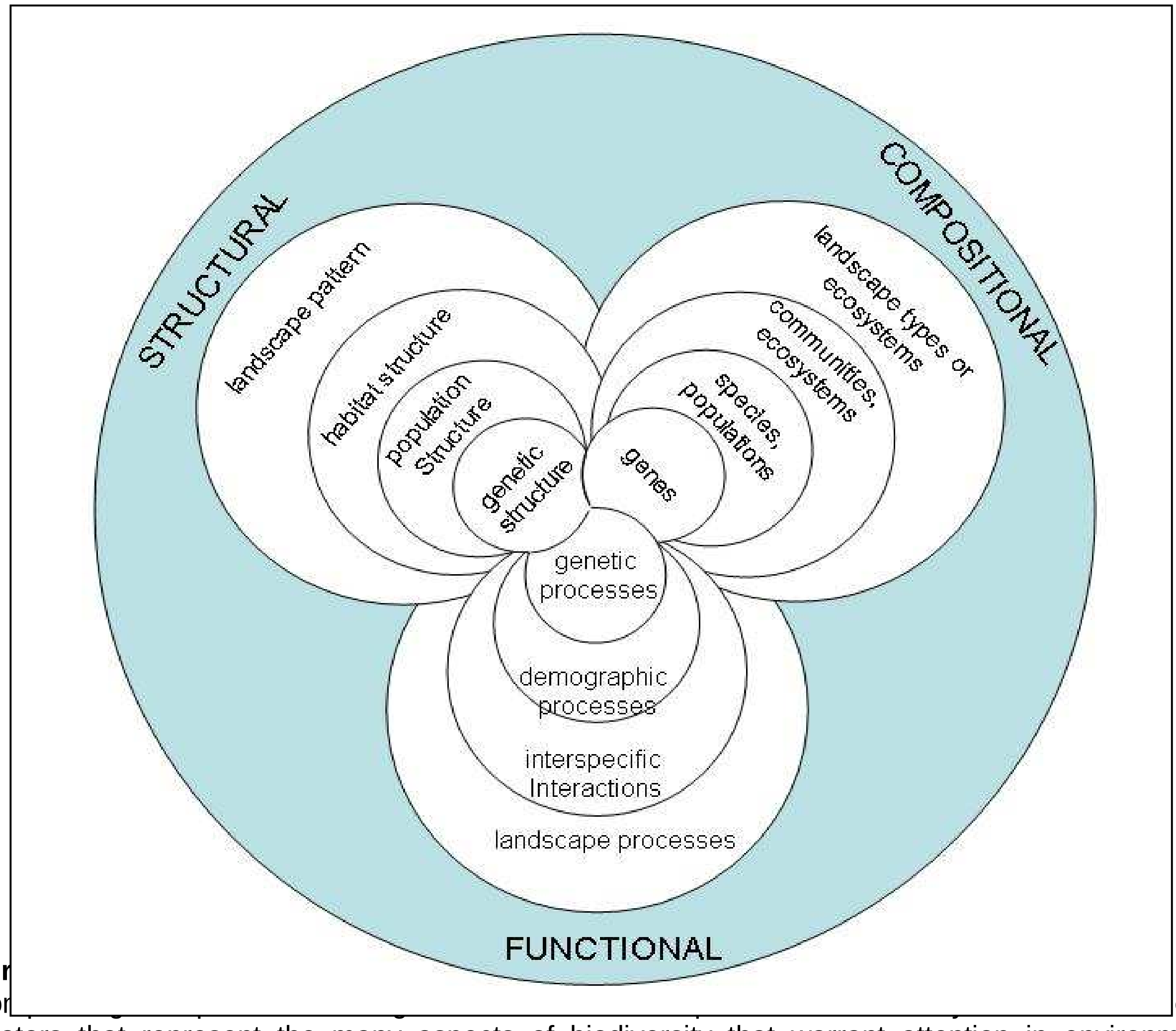
Table 4: Potential vegetation condition surrogates which may be used for assessing biodiversity. (sources: Noss 1990; Oliver 2002; Jansen *et al*. 2004; Perkins 2002; Tongway and Hindley 2004.)

Composition	**Structure**	**Function**
• Native plant species richness • Native plant species richness by life form • Cover of exotic species • Presence/abundance of problematic weed species • Presence/abundance of threatened plant species • Presence/abundance of increasers and/or decliners • Presence/abundance of nectar or seed resources • Mistletoe abundance • Evidence of introduced animals (e.g. rabbits, foxes)	• Cover by plant life form • Cover by vertical stratum • Number of vegetation strata • Tree diameter distribution • Number of trees with hollows • Volume (or other measure of abundance) of coarse woody debris • Tree growth stage • Basal area of overstorey stems • Canopy height • Abundance of large, dead trees • Litter cover (or other measure of abundance) • Rock cover	• Presence of regeneration • Cover of bare ground • Cryptogam cover • Soil surface stability • Rate of infiltration • Soil compaction • Adjacent land use • Dieback • Soil salinity • Presence/abundance of salt-tolerant plant species • Presence/abundance of plant functional types • Grazing, fire, or logging regimes • Time since clearing • Degree of soil modification • Mistletoe abundance • Perennial plan basal cover • Bioturbation

7 Developing a Conceptual Framework for Assessing Vegetation Condition

As discussed above, vegetation is an integral part of assessing biodiversity, and vegetation condition can be assessed at a range of spatial scales from site/patch-scale to landscape-scale to regional scale. When developing a conceptual framework, it is important to consider the assessment of vegetation condition at each of these spatial scales. In this section, advice found in the literature for developing frameworks to assess vegetation condition at these different scales is presented.

Noss (1990) presented a simple conceptual framework for identifying specific and measurable attributes of biodiversity, as shown in Figure 1 below, with three levels of organisation: (a) composition; (b) structure; and (c) function. This framework includes attributes of vegetation as well as other aspects of biodiversity; however, the *RCM – NVI Project* and its framework will concentrate on vegetation aspects only.



Figur each enco on of indicators that represent the many aspects of biodiversity that warrant attention in environmental monitoring and assessment programs (Adapted from Noss (1990)).

7.1 Patch Scale Assessment

On overview of rapid, on-ground methods used to assess vegetation condition at the scale of site was conducted by Gibbons and Freudenberger (2006). The authors discussed four steps that those developing new approaches for assessing vegetation condition should work through. The four steps are: (1) define management objectives and operational constraints; (2) develop an appropriate conceptual framework for the ecosystems under consideration; (3) select an appropriate suite of indicators; and (4) consider the options available for combining these into an index. These are briefly described in point form below.

1. Define management or policy objectives and operational constraints:

   The availability of time and resources, and the objectives of the assessment can all heavily influence the methods chosen to assess vegetation condition. It is essential that management objectives, time, other resources available are matched with the proposed vegetation condition assessment methods.

2. Develop an appropriate conceptual framework for the ecological system under consideration:

   Toolkits or indices that are developed to assess vegetation condition represent predictive models of ecosystems. Therefore they should be based on a conceptual framework that accurately reflects and describes the ecological system under consideration. Such frameworks include:

   - Succession: the orderly development of plant communities through a series of stages as a function of time. Assessment methods based on the theory of succession should be avoided in ecosystems that: (a) do not revert to their previous condition after a disturbance is removed; or (b) can develop into different states depending on the nature, or timing, of the disturbance;

   - State and Transition: a conceptual framework that reflects how the same ecosystem can occur in a range of alternative stable states (Westoby *et al.* 1989). Disturbance triggers the transition between these states, but the transitions do not necessarily occur in both directions (unlike sucession);

   - Resilience: resilience is the capacity of a community to recover after the removal of disturbances or stresses (Westman 1978);

     Resilience: The amount of change a system can undergo (its capacity to absorb disturbance) and remain within the same regime – essentially retaining the same function, structure and feedbacks (Walker and Salt 2006).

     Resilience: A measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (Hollings 1973).

   - Trigger, transfer, reserve, pulse: this framework is based on the idea that rainfall triggers biological, physical and chemical activities, and the products of these activities are transferred across the landscape by water and wind, which collect in different parts of the landscape and produces a pulse in the vegetation (Ludwig and Tongway 1997). An example assessment toolkit based on these concepts is Landscape Function Analysis (LFA); and

- Reference conditions: this method compares a particular site with sites of comparable ecosystem types that are in relatively unmodified pristine or functional condition.

3. Select an appropriate suite of indicators or vegetation attributes:

   There are many different biophysical attributes that can be measured as indicators of vegetation condition. These include canopy height, number of trees with hollows, presence/abundance of problematic weed species, fire regimes and grazing regimes. Attributes or indicators used to assess vegetation condition should meet the following criteria (Noss 1990; McElhinny *et al.* 2005):

- Demonstrated ecological basis (i.e. significantly associated with the biota and processes of interest);
- Applicable over the range of ecosystems and ecosystem states under consideration;
- Sufficiently sensitive to discriminate between the range of sites and states under consideration;
- Simple, cost-effective and repeatable to measure;
- Robust to seasonal or climatic variation;
- Instructive or helpful for assessors and managers with respect to interpreting and managing a site; and
- Not highly correlated with other attributes being measured.

4. Consider available options for combining these vegetation attributes into an index of condition:

   A common characteristic of methods developed to assess vegetation condition is that they combine data from multiple attributes into a simple index. These indices can combine multiple attributes and are conceptually easier to understand and compare than multiple attributes measured on different scales. Several approaches exist that combine raw data on vegetation attributes on sites into an index of vegetation condition. These include:

- *Additive scoring systems*: this method combines multiple attributes into a metric, score or index for a site to standardise the data for each attribute. This is done either: (i) as present or absent (0 or 1); (ii) as a score (e.g. 0, 1, 2, or 3); or (iii) by dividing the observed value by an expected value and summing th scores across all attributes (Gibbons and Freudenberger 2006). These scoring systems underpin many rapid assessment protocols around the world, such as the Index of Biotic Integrity (IBI) that is used by the US Environmental Protection Agency (Andreasen *et al*. 2001). Australian examples include Save the Bush Toolkit (Goldney and Wakefield 1997), Habitat Complexity Score (Catling and Burt 1995), Habitat Hectares (Parkes *et al*. 2003), and the Biodiversity Benefits Index (Oliver and Parkes 2003).

- *Multiplicative scoring systems*: this method is similar to above, but combines multiple attributes together by multiplying the values of each attribute. This method recognises that the condition of the site is defined by the co-occurrence of more than one attribute and the loss of one attribute cannot be directly compensated by the addition of another (Burgman *et al*. 2001). Gibbons and Freudenberger (2006) give the example that in order for many species to have suitable habitat, they must have adequate feeding, shelter and nesting resources must co-occur. Therefore, if one required attribute is missing – and therefore is assigned a zero – then the site has no value.

- *Statistical approaches (e.g. ordination, regression models)*: Gibbons and Freudenberger (2006) state that statistical methods represent a more objective alternative to additive and multiplicative scoring systems. One example is pattern-based statistics (e.g. ordination and classification) can be used to determine the difference between sites – for example the difference between a reference/benchmark site and another measured site – for many attributes simultaneously. This measure of dissimilarity becomes the condition 'score' (Gibbons and Freudenberger 2006).

- *Probability of persistence*: this method gives an estimate of the gain of biodiversity representation or persistence when a site is added to a network of areas managed for conservation. Spatial data for each attribute across the entire region is necessary so that the change from adding, improving or removing attributes from sites can be calculated. Spatial datasets alone are often too coarse for making predication about an individual site, and need to be linked with site assessment methods. (Gibbons and Freudenberger 2006).

Gibbons and Freudenberger (2006) presented an argument that, in order to make effective decisions about the condition of individual sites, information must be gained from scales that are broader than the scale of site. Methods used at broader scales include spatial modelling and remote sensing, which may be more appropriate than on-ground assessment methods for obtaining vegetation condition information. However, Gibbons and Freudenberger (2006) also state that spatial modelling and remote sensing should add value to, not replace, on-ground vegetation condition assessment methods. This is because current techniques for spatially predicting vegetation condition cannot capture as accurately and as completely as can on-ground assessment methods.

7.2 Landscape Scale Assessment

Landscape-scale assessments of vegetation condition require an analysis of ground-truthed, or reference attributes at the plot-scale, that are then interpolated at larger-scales to provide spatial models of condition indices. Vegetation condition can be assessed in the context of threatening processes that affect condition and the plot-based information must provide categorical or continuous metrics that quantify the level of impact of threats for each plot, in conjunction with the elements of vegetation that define its condition.

This procedure is now used to set management targets for biodiversity conservation in New South Wales (Ferrier *et al.* 2002a, Ferrier *et al.* 2002b), Victoria (Gibson *et al.* 2004) and New Zealand (Overton *et al.* 2002, Stephens *et al.* 2002).

The step-wise process is similar in each of the above cases, and is outlined in point form below:

- Survey of plot-based attributes with sufficient replication to allow combination of redundant data through clustering procedures.

- Collection of environmental attributes from plot-based sample sites, including measures of threats to vegetation condition.

- Data exploration and validation through removal of extreme outliers and statistical examination of correlated environmental variable.

- Determination of environmental predictors of condition and predominant threats that determine degradation.

- Spatial prediction of the condition indices. The combination analysis of the environmental predictors through techniques of regression (e.g. Generalised Additive Models) with spatial prediction is termed ‘Generalised Regression Analyses and Spatial Prediction’ (GRASP) (Overton *et al.* 2002) and is defined in specific application in programming tools, such as S-plus (Lehmann *et al.* 2002a, 2002b).

A full description of the techniques is provided in Ferrier *et al.* (2002a, 2002b) and in Lehmann *et al.* (2002a, 2002b), with application for management described in Stephens *et al.* (2002).

7.3 Regional Scale Assessment

In comparison to the use of site-based vegetation condition assessments, creating and using maps of native vegetation condition on a regional scale is relatively new. However, they can be an important tool to complement site-based assessments (Zerger *et al*. 2008). Regional groups (e.g. catchment management authorities) require information on vegetation condition – to set regional vegetation management targets, undertake on-ground actions in the context of these targets, and to monitor and report achievement towards these targets – which cannot be met by measuring vegetation condition only at the site-scale (Zerger *et al*. 2008).

For measuring vegetation condition at a regional scale, methods can be divided into two main areas: (i) methods that rely on remote sensing; and (ii) methods that use modelling with GIS surrogates. Methods that use remote sensing map the compositional, structural and functional surrogates of vegetation condition using a variety of methods, such as aerial photographic interpretation, videography, airborne laser scanning, hyperspectral imagery and multispectral imagery. These techniques have not been adopted routinely for broad-scale vegetation condition mapping, partly because they rely on technologies that are costly to be applied at a regional scale (Zerger *et al*. 2008). There are few examples in the literature that focus specifically on native vegetation condition using modelling methods. These methods are typically conducted at regional or national scales due to the scale of commonly available GIS data (Zerger *et al*. 2008).

At the 2007 Future for Native Vegetation Condition Research in Tasmania and Victoria Workshop, Zerger and Jones (2007) stated that it is important to ask what the purpose is behind ‘scaling-up’ and assessing vegetation condition at a regional scale rather than a site-based scale. There are trade-offs between accuracy and precision and scale – i.e. the larger the scale the lower the accuracy and precision. Depending on the purpose of measuring vegetation condition, whether it is for property vegetation planning or spatial priority setting, the optimal scale of measurement and level of accuracy and precision will vary. Deciding where the sites will be located and what will be measured at the site are key question to be answered, and scaling up may not be required for all vegetation condition assessments (Zerger and Jones 2007). Therefore, it is important to use regional expertise when assessing vegetation condition at a regional scale.

8 Vegetation Condition Indicators

Vegetation condition indicators are a way of presenting and managing complex information sets in a simple and clear manner. However, in many conservation projects, managers and scientists have a difficult time determining what they should be monitoring. In most instances, people attempt to measure a long list of indicators, which involves gathering extremely large and unfocused amounts of data (Salafsky *et al.* 2001). In the absence of monitoring objectives or questions, which align to policy or management questions, undertaking monitoring or single sampling of indicators amounts to collecting data for the sake of it and a wasted use of resources. Gathering data that remains unanalysed and unreported, and without a clear management or policy question, will lead to failure in knowing whether management intervention is making a difference, and as consequence conservation effort can be wasted.

Indicators of vegetation condition serve five different functions:

- Simplification – summarize complex sets of data in order to simplify information;
- Representation – provides indirect measurements, often indicative of larger, more complex processes and components of a system, based on a number of assumptions;
- Quantification – provide comparable scientific observations;
- Standardisation – of methodology; and
- Communication – provide a clear message to decision makers and the general public.

8.1 Selecting Vegetation Condition Indicators

Indicators are important measurement tools for monitoring vegetation condition and are a prerequisite for measuring and evaluating management effectiveness of monitoring vegetation condition. However, selection of appropriate indicators that are useful in evaluating management effectiveness requires a step-by-step approach for each program, region or site.

The points below outline the rules and criteria for selecting vegetation condition indicators:

- Choosing indicators should be a cooperative exercise between policy makers, managers and scientists, guaranteeing that indicators are policy and management relevant (aligning with conservation targets and determining baseline choice), affordable, easy to monitor and reliable.

- Many assumptions have to be made about indicators. These assumptions need to be outlined along with their limitations and a consensus formed as to their validity.

- Indicators and monitoring should be designed to detect changes in time frames and on the spatial scales that are relevant to policy objectives and management actions. It is important to detect change before it is too late to correct any observed problems. There needs to be careful analysis of the issues and the scales they occur before selecting indicators and an analysis to determine ‘acceptable’ change and an analysis to ensure such changes can be detected by the monitoring program proposed.

- Appropriate indicators should be SMART (specific, measurable, achievable, relevant and timely).

- To assess improvement or deterioration in the status of vegetation condition, baseline and policy objectives are required against which current and expected future states can be compared. The baseline may be the earliest repeated measure of the indicators of vegetation condition, or may be a scientifically reconstruction of historical conditions, for example pre-industrial state. The baseline provides a context for the assessment of change and gives meaning to an indicator. It should be emphasized that the baseline is not the target vegetation condition state.

- In addition, vegetation condition indicators should meet a number of overarching criteria:

- Policy relevant and meaningful – Indicators should send a clear message and provide information at a level appropriate for policy and management decision-making by assessing change in status of vegetation condition related to baselines and agreed policy targets.

- Biodiversity relevant – indicators should address key properties of biodiversity or related issues such as state, pressure, response, use or capacity.

- Scientifically sound – indicators must be based on clearly defined, verifiable and scientifically acceptable data, which are collected using standard methods with known accuracy and precision.

- Broad acceptance – the power of an indicator is in its broad acceptance and understanding.

- Cost-effective and involve an appropriate level of effort – indicators should be measurable in an accurate and affordable way using determinable baselines and targets for the assessment of improvements and declines. An initial burst of expenditure when setting up the program is often worthwhile.

- Affordable modelling – information on cause-effect relationships should be achievable and quantifiable in order to link pressure, state and response indicators.

- Sensitive or responsive to on-going change – indicators should be sensitive to show trends (both negative and positive), and where possible distinction between human-induced and natural changes. Thus, indicators should be able to detect changes in condition in timeframes and on scales that are relevant to decisions but also robust so measuring errors do not affect interpretation of results.

- Representative – a set of indicators provides a representative picture of the pressures, vegetation condition state, responses, and uses. A small number of indicators are often more communicable to policy makers and the public.

- Aggregation and flexibility – Indicators should be designed in a manner that facilitates aggregation at a range of scales for different purposes.

Once an appropriate set of indicators are selected, a series of protocols or parameters to undertake measurements are essential to ensure appropriate sampling design and minimise biases in data collection.

8.1 Indicators for Native Vegetation Communities' Integrity Matter for Target

Under the National NRM Monitoring and Evaluation Framework, the Native Vegetation Communities' Integrity Matter for Target has been assigned a set of indicators as detailed in Table 5. These national-level indicators (and associated protocols) have been developed by the Executive Steering Committee for Australian Vegetation Information (ESCAVI). They are designed to set a standard approach to the gathering of data and information to underpin regional target setting, and thus allow collation at higher levels. There are also existing and on-going requirements for monitoring the status of native vegetation within Western Australia.

Table 5: National Indicator Heading and Indicators for Native Vegetation Communities' Integrity and related indicators specific to Western Australia *(from the RCM-NVI Project Implementation Plan with the State indicators being proposed by DEC).*

Indicator Heading	Recommended National Indicators	Proposed State Indicators
Native vegetation extent and distribution	• The extent of each priority native vegetation type by IBRA subregion measured in hectares. • The extent of each present native vegetation type by IBRA subregion measured in hectares. • The proportion remaining of each native vegetation type by IBRA subregion measured as a percentage of the pre-European extent.	• Change in extent of vegetation communities.
Native vegetation condition Measure A	• The proportion of each native vegetation type in each IBRA subregion that is estimated to be in specified condition classes based on a selected set of attributes.	• Changes in the vegetation structure and floristic composition of a set of representative sample sites, linked to measures of ecosystem processes. • Broad scale changes in extent and nature of ecosystem processes (remote sensing linked to on-ground sites).
Management Action Indicator Measure B	• The proportion of each output from Measure A where management practices are being implemented which are improving, or reversing the decline of, the condition of native vegetation.	

At this national scale and indicators attributes of vegetation condition include the distribution of remaining vegetation (Measure A), tenure, history of land use, current management practices, knowledge of key threats and existing site observations and/or data for condition attributes (ESCAVI 2004).

9 Developing a Framework for Monitoring and Evaluating Vegetation Condition

Monitoring is the repeated measurement of a factor or range of factors over time to determine change, while evaluation is the analysis of information gathered by monitoring to determine whether management activities have been effective in achieving the objectives of the project. Evaluation and monitoring must always go together, with monitoring providing the raw information to answer questions about project progress and evaluation analysing that information and drawing conclusions (Coote *et al*. 2001).

Monitoring and evaluation attempts to ask five questions (Coote *et al*. 2001):
1. Did we do what we set out to do?
2. Did it work?
3. How did it work?
4. If it didn't work, why not?
5. What will we repeat or do differently next time?

In comparison to assessing vegetation condition, monitoring vegetation condition determines a change or trend in something, usually over time. The goals of vegetation condition monitoring are often to determine any trends in condition with changes in management, for example grazing and fire, as well as changes in weather, such as rainfall (Briggs and Freudenberger 2006). Hand in hand with monitoring is the need to evaluate how effective the assessment and monitoring is of the vegetation condition program. There is growing demand to use information on vegetation condition in a broader regional context and to monitor achievement, and to report on progress towards regional, state and national targets of vegetation condition (Parkes and Lyon 2006; Neldner 2006). Even if much data is collected on trends in the condition of a particular vegetation type or community, it is of no use without these trends being analysed and the reported on.

Monitoring of vegetation condition is traditionally done using fixed plots on the ground where condition variables are measured at regular intervals to determine changes over time (Briggs and Freudenberger 2006). As mentioned above, the goal of monitoring vegetation condition is usually to examine trends in condition of vegetation in response to changes in management (e.g. fire regimes or grazing regimes). Depending on the goal, the fixed plots may be in a stratified random design, or located in areas subject to different grazing levels or different grazing regimes (Briggs and Freudenberger 2006).

After data is collected from monitoring activities, it must be evaluated in order to assess whether the goals and expected outcomes of the program are being met. Monitoring and evaluation activities are inseparable from each other and need to form part of an integrated conservation program. Even if the correct assessment method is determined for measuring the condition of a particular type of native vegetation, the repeated measurement of this condition is of no use without the data and trends in data being analysed, and then reported on. Many biodiversity-related monitoring programs are ineffective because they collect large amounts of data on a long list of pre-determined 'indicators'.

An effective biodiversity-related program on native vegetation condition (or any conservation-related program) should have a clear question that defines the program and specific goals and outcomes, an appropriate method for assessing condition, as well as a framework for being able to evaluate whether the question is being answered and the goals and outcomes are being met.

Briggs and Freudenberger (2006) discussed elements that a monitoring and evaluation program for vegetation condition should include:

- Defining the objectives;
- Designing the program at spatial and temporal scales that meet the objectives;
- Collecting data rigorously at the correct scales;
- Analysing and interpreting the data; and
- Undertaking management and policy actions using the results of the monitoring and/or assessment program.

9.1 Impact Assessment and Adaptive Management

In addition to ensuring that the correct plot or experimental design suits the desired goal of the vegetation condition assessment and monitoring program, flexibility is also needed to allow for the ongoing review, development and improvement of the program (Parkes and Lyon 2006).

Recent monitoring and evaluation approaches have focused on measuring the effectiveness of conservation actions. These approaches can be divided into: (i) impact assessment, and (ii) adaptive management (Stem *et al.* 2005).

Impact assessments are usually one-time assessments to determine how well a project has performed. An example of an impact assessment approach is environmental impact assessment (EIA), which ensures that environmental impacts are considered prior to development projects.

Adaptive management is a systematic process that involves the integration of project design, management and monitoring to examine interventions to adapt and learn (Salafsky *et al.* 2001). The ultimate goal of adaptive management is to adapt and learn to improve an ongoing project or conservation management action (Stem *et al.* 2005) to achieve better outcomes. In the mid to late 1990s, some conservation organisations began to use a 'project-cycle management' approach to monitoring and evaluation. This adaptive management approach helped the conservation organisations understand whether the interventions they were making in their conservation programs were having the intended impact, and to use these results to improve their programs (Stem *et al.* 2005). The main principles of this approach is that monitoring and evaluation should be fully integrated into the management cycle - not added on as an afterthought - and that indicators of success should be clearly linked to the goals, objectives and activities of the conservation program (Herweg *et al.* 1998; Margoluis and Salafsky 1998; Stem *et al.* 2005).

Managers and practitioners must have a clear understanding of their monitoring needs in order to determine which monitoring and evaluation approach or tool is most appropriate to their program. If the goal is to understand and improve specific conservation interventions, both the status of biodiversity (and potential threats to biodiversity) and approaches for measuring effectiveness are needed (Stem *et al.* 2005).

In Western Australia, two draft documents are currently being finalised that address adaptive management:

1. The Draft Biodiversity Conservation Appraisal System (2008), Department of Environment and Conservation (DEC), which has been drafted to improve DEC's delivery of biodiversity conservation. The document provides a framework to:

> (a) measure and report on biodiversity conservation outcomes and on management effectiveness to alleviate threats to biodiversity; and
>
> (b) plan and implement priority conservation programs and activities using an active adaptive management approach to deliver on-ground outcomes and to improve knowledge

2. The (Draft) National Natural Resource Management Monitoring, Evaluation, Reporting and Improvement (MERI) Framework (Australian Government NRM 2008), which provides a generic national framework for monitoring, evaluating, reporting on and improving Australia's approaches to managing key assets

These documents are discussed in more detail in the RCM – NVI Project document on the Review of NRM Regional Resource Condition Targets and the RCM – NVI Project Framework.

9.1.2 IUCN Guidelines for Evaluating Management Effectiveness of Protected Areas

In the document IUCN Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas (Hockings *et al.* 2006), guidelines for evaluating management effectiveness of protected areas are discussed. A synthesis of this discussion follows.

Evaluation is part of an effective management cycle

Effective evaluation needs a high level of support and commitment from protected area management agencies as well as from other parties involved. Evaluation of management effectiveness should be incorporated into the core business of protected area agencies.

Assessments can benefit from being based on a credible and tested Framework

- A consistent and accepted approach such as the IUCN-WCPA Framework provides a solid theoretical and practical basis for developing management effectiveness assessment systems, and improves the capacity to harmonise information across different systems.
- Evaluation exercises that assess each of the six elements in the Framework and the links between them are most desirable, as these build up a relatively comprehensive picture of management effectiveness. This kind of evaluation is regarded as having greater ‘explanatory power’.

Management objectives and standards are needed

- It is critical that the key values, management goals and objectives for the protected area have been spelt out clearly. Standards against which inputs, processes and outputs can be judged are also important.

Evaluation works best with a clear plan

- A clear purpose, scope and objectives for the assessment are needed. It is important at the beginning of an evaluation project to know exactly what it is expected to achieve, and to understand the levels of resourcing and support that can be expected. Agreement among all partners on criteria, assessment objectives and broad questions is important before a more detailed methodology is selected or developed.

The methodology needs to suit the purpose

- We should learn from others and use or adapt existing methodologies if possible. Methodologies should be as compatible as possible.
- Tools need to be appropriate and responsive to needs. Flexibility should be retained – an iterative approach is helpful. Methodologies should be improved over time.

Indicators need to be carefully chosen

- Indicators need to be as cost-effective as possible. It is desirable for indicators to have some explanatory power, or be able to link with other indicators to explain causes and effects. Social, economic and cultural indicators as well as those related to natural systems are needed.
- The limitations of indicators need to be understood. There is a danger that evaluations can over-simplify reality by interpreting indicators to mean more than they really do.

Good communication, team-building and stakeholder involvement is essential in all phases of the project.

- Gaining approval, trust and cooperation of stakeholders, especially the managers of the protected areas to be evaluated, is critical and must be ensured throughout the assessment. Assessment systems should be established with a non-threatening stance to overcome mutual suspicion. If the evaluation is perceived to be likely to 'punish' participants or to reduce their resources, they are unlikely to be helpful to the process.
- Care needs to be taken to ensure all stakeholders have an opportunity to express their viewpoints.

A long-term evaluation plan with a good monitoring programme is preferable

- For all except special-purpose single-event evaluations, it is desirable to repeat similar measures at intervals. Standardized reporting allows comparisons across sites, across time, and to meet multiple reporting requirements. The system should be capable of showing changes through time.
- Evaluation of management effectiveness is best if it is backed up by robust, long-term monitoring.
- Evaluation must make the most of what information is available (where necessary, interpreting qualitative and anecdotal information), and should drive the establishment of a future monitoring programme, which is targeted to find out the most critical information.

Evaluation findings must be communicated and used positively

- Advice from evaluation needs to be clear and specific enough to improve conservation practices and it needs to be realistic, addressing priority topics and feasible solutions.
- Adaptive management and action learning approaches work on the philosophy that the assessment process itself it is vital learning experience, which enhances and transforms management. Evaluation often has impacts on management well before a formal report is prepared.
- Short-term benefits of evaluation should be demonstrated clearly wherever possible.
- Assessment planning should include an early consideration of communication and of the evaluation audiences.
- The way that findings are reported must suit the intended audiences. Timeliness of reporting is critical to making it useful.
- Evaluations should spell out need for planned change or should encourage reinforcement of what is going well at site or organizational level.
- Recommendations should include short-term actions, which are clear, concrete, achievable within time and resource constraints and prioritised; as well as long-term and other recommendations that enable managers to take advantage of potential increased resources and opportunities.
- Evaluation findings, wherever possible, should be positive, identifying challenges rather than apportioning blame.
- Findings and recommendations of evaluation need to feed back into management systems to influence future plans, resource allocations and management actions. Evaluations that are integrated into the managing agency's culture and processes are more successful and effective in improving management performance in the long term.
- Two key factors that determine whether evaluation findings will 'make a difference' are:
    - a high level of commitment to the evaluation by managers and owners of the protected areas; and

- o adequate mechanisms, capacity and resources to address the findings and recommendations.

IUCN Framework Case Study: Enhancing our Heritage Project

In Hockings *et al*. (2006), several case studies have been presented from around the world that have drawn upon the IUCN Framework while these projects have developed their assessment systems of protected areas. Case Study IV: "Enhancing our Heritage: Monitoring for success in Natural World Heritage sites is an example of a detailed site-level assessment, aimed at building monitoring systems and long-term understanding of management in individual protected areas. The Enhancing our Heritage (EoH) project aims to develop and test management assessment methods in many World Heritage sites including Uganda (Bwindi Impenetrable National Park), Tanzania (Serengeti National Park), India (Keoladeo National Park), Nepal (Royal Chitwan National Park), Honduras (Río Plátano Biosphere Reserve) and Venezuela (Canaima National Park).

Using the IUCN Framework, the EoH project is developing and testing a toolkit of methodologies that will help managers and stakeholders assess current activities, identify gaps and discuss how problems might be addressed. Indicators and tools for assessing each component of the IUCN Framework were suggested to build up a picture of the adequacy and appropriateness of management and the extent to which objectives are being achieved. The EoH workbook includes 11 tools, which are based on a variety of best practices in protected area assessment (Table 6). The EoH project assessment and evaluation methodology is shown in Figure 2.

Table 6: Workbook methodologies from the Enhancing our Heritage Project (adapted from Hockings *et al*. 2006)**.**

Context	Identifying management values and objectives
	Identifying threats
	Relationships with stakeholders/partners
	Review of national context
Planning	Assessment of management planning
	Design assessment
Inputs	Assessment of management needs and input processes
	Assessment of management processes
Outputs	Assessment of management plan implementation
	Assessment of work/site output indicators
Outcomes	Monitoring and assessing the outcomes of management

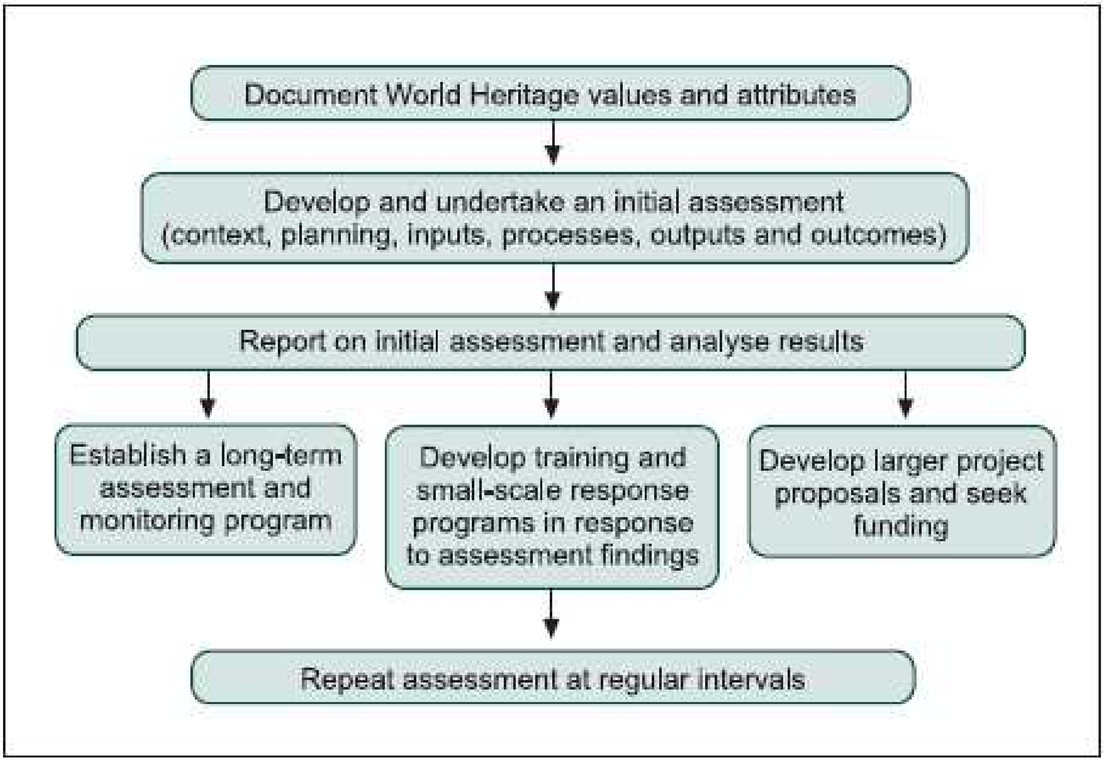


Figure 2: The Enhancing our Heritage project assessment and evaluation methodology (from Hockings *et al.* 2006)**.**

10 Vegetation Condition Assessment and Monitoring & Evaluation Methods in Australia

The Vegetation Assets, States and Transitions (VAST) framework was developed at a national scale, and has been applied at various scales by various organisations (see Northern Territory, Section 10.2). It classifies vegetation by the degree of human modification as a series of states (Thackway and Lesslie 2005, 2006). Table 7 outlines this framework.

In Sections 10.1 to 10.7 below, an example methodology is discussed for each State and Territory. A table comparing these methodologies and toolkits used by each State and Territory, including definitions of benchmarks, can be found in Appendix 1.

10.1 Western Australia

Keighery (1994) developed a vegetation condition scale (Table 8) that is widely used in rapid assessment techniques of vegetation condition in Western Australia, including such projects as Bush Forever (Government of Western Australia 2000) and the Perth Biodiversity Project. The Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region (Del Marco *et al.* 2004), assesses vegetation condition by using a rating given to vegetated natural areas (both uplands and wetlands) to categorise disturbance related to human activities. This rating refers to the degree of change in the structure, density and species present in native vegetation in relation to undisturbed 'pristine' native vegetation of the same type (adapted from Government of Western Australia 2000). In addition to Keighery's (1994) scale, another vegetation condition scale by Kaesehagen (1994) is used.

The Perth Biodiversity Project has developed a web-based Natural Area Initial Assessment (NAIA) Database was designed to collate, analyse data collected on their Natural Area Initial Assessment Templates. This has also been adopted by the South West Biodiversity Project). These templates consist of 1) Initial Desktop Assessment 2) Field Assessment A Template 3) Field Assessment B – Significant Species and Communities Template and 4) Assessment Summary Template. The NAIA Templates are used to assess the biodiversity values (including a condition rating) of natural areas on Local Government managed lands, lands subject to development proposals, or lands to be targeted for the offering of incentives to landholders to encourage biodiversity protection and management. Data is in early stages of compilation. This data will incorporate descriptions of benchmark reference sites for major vegetation unit on the Swan Coastal plain.
(http://www.walga.asn.au/about/policy/pbp/na_templates.)

The Monitoring and Evaluation Biodiversity Conservation Project Manual (Coote 2001) was designed as a guide for managers and technical advisors to plan and design a monitoring and evaluation program for native vegetation and biodiversity management projects. Vegetation condition is rated using four categories: (1) pristine to slightly degraded; (2) degraded; (3) erosion prone to eroded; and (4) eroding ditch to weed infested drain. Other factors assessed include presence / absence of understorey and groundcover, ages of vegetation present, dead trees and dead branches present in the canopy.

Table 7: VAST VEGETATION ASSETS, STATES AND TRANSITIONS

		Native Vegetation Cover Dominant structuring plant species indigenous to the locality and spontaneous in occurrence – i.e. a vegetation community described using definitive vegetation types relative to estimated pre-1750 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		**Type 1: RESIDUAL** Native vegetation community structure, composition, and regenerative capacity intact - no significant perturbation from land use / land management practice	**Type II: MODIFIED** Native vegetation community structure, composition and regenerative capacity intact – perturbed by land use / land management practice	**Type III: TRANSFORMED** Native vegetation community structure, composition and regenerative capacity significantly altered by land use / land management practice	**Type IV: REPLACED – ADVENTIVE** Native vegetation replacement – species alien to the locality and spontaneous in occurrence	**Type V: REPLACED – MANAGED** Native vegetation with cultivated vegetation	**Type VI: REMOVED** Vegetation removal
Diagnostic Criteria	**Current Regenerative Capacity**	Natural regenerative capacity unmodified	Natural regeneration tolerates / endures under past &/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. Limited potential for restoration	Regeneration of native vegetation community lost of suppressed by intensive land management. Limited potential for restoration	Nil or minimal
	Vegetation Structure	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 classes	Dominant structuring species of native vegetation community significantly altered, e.g. a layer / strata frequently &	Dominant structuring species of native vegetation community removed or predominantly	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental

			removed.	repeatedly removed	cleared or extremely degraded		
	Vegetation Composition	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	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; Isolate native tree / shrubs / grass species in the above examples	Forest plantation; 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 scaled areas

Table 8: Examples of vegetation condition scales used in Western Australia by Bush Forever and the Perth Biodiversity Project (*compared with those developed by Kaesegan 1994)*.

Keighery Condition Scale **(Keighery 1994)**	**Kaesehagen Condition Scale** **(Kaesehagen 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 to Excellent** • 80% to 100% native flora composition • Vegetation structure intact or nearly so • Cover/abundance of weeds <5% • No or minimal signs of disturbance
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.	**Fair to Good** • 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 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.	**Poor** • 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
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.	**Very Poor** • 0% to 20% Native flora composition • Vegetation structure disappeared • Cover/abundance of weeds 60% to 100%, any number of individuals • Disturbance incidence very high

10.2 Northern Territory

A recent approach to measuring vegetation condition in the Northern Territory applied the Vegetation Assets, States and Transitions (VAST) classification framework (Thackway & Lesslie 2005). The VAST framework orders vegetation by degree of anthropogenic modification as a series of states, from a residual or base-line condition through to total removal. States and transitions in the classification are defined by breakpoints in vegetation composition, structure and regenerative capacity in relation to an identified base-line condition. A number of Northern Territory data sets were attributed with the VAST criteria to test an approach for condition assessment at a landscape scale.

VAST categories (Residual Bare, Residual, Modified, Transformed, Replaced Native, Removed) where assigned subjectively to three data sets.

Data sets included:

- Land Use (NT Lump) dataset (spatial scale 1:1000,000 for most of Northern Territory) - used to assess possible land management effects;
- Fire Frequency Mapping of Northern Territory from 1997-2003 (spatial scale 1:250,000) –gives an estimate of the severity of fire as a habitat modifier; and
- Biological Naturalness layer from Department of Environment and Heritage (circa 1999) – gives some indication of grazing pressure, particularly along water points.

These were then spatially overlaid and the VAST categories where reassigned based on the combinations of all three (Thackway *et al.* 2006).

10.3 South Australia

Under the Pastoral Land Management and Conservation Act [1989] a pastoral lease cannot be granted or extended without an assessment of the condition of the land (Lange *et al.* 1994). As a result South Australia has a comprehensive and integrated program of resource inventory, resource condition assessment, range monitoring and lease inspection (Gould *et al.* 2001).

As part of the State Government's Pastoral Lease Assessment Program from 1990-2000, over 5500 permanent photopoint monitoring sites and 20,000 land condition sample points were established in the pastoral zone. These were set up to provide a baseline to monitor the condition of soil and vegetation resources over time. A Land Condition Index (LCI) score for each lease is calculated using data collected from these sample points.

The assessment of land condition using the LCI approach has been carried out on most leases inside the dog fence where sheep have traditionally been run. On the more extensive cattle properties outside of this fence, the LCI has not been used, but photopoint monitoring has been complemented by assessments of land cover changes using Landsat imagery.

The LCI is based on the condition rating of about 80-100 sample sites within each lease. Assessments are made into one of the following classes: 1) high disturbance; 2) moderate disturbance; and 3) low disturbance. These classes are precisely specified for each component of each pasture type within a district. The disturbance categories are based on the presence, absence and abundance of perennial plant species, the level of grazing and browsing of palatable species and soil surface condition. Condition classes therefore provide an assessment of the likelihood of the vegetation community returning to its pre-disturbed condition.

A weighted average condition index is determined for each lease by multiplying the percentage of sample points for each condition rating by the rating. This gives a value for each lease of between 100 (all sample points severely disturbed) and 300 (all sample points assessed as low disturbance, Gould *et al.* 2001).

<u>Attributes recorded at each photopoint:</u>

- Station Name
- Paddock Name
- Site Number
- Last Assessment Date
- Site Location Description
- Easting / Northing
- Waterpoint Name
- Land System Name
- Dominant Species
- Geological formation
- Rock Type
- Landform
- Soil Textures
- Site Comments
- Site Vegetation
- Site Condition Estimate
- Erosion Type and severity
- Crown Separation Ratio (CSR)
- Shrub Count

<u>Attributes used for Site Condition Estimate:</u>

- Plant species composition
- Plant productivity
- Soil erosion status

Two other methodologies used in South Australia include the Guide to a Native Vegetation Survey using the Biological Survey of South Australia Guide and the Mount Lofty Bushland Condition Monitoring manual.

The former provides brief guidelines to the standard vegetation survey methods and uses four main factors to assess vegetation condition:

- Number of vegetation layers;
- Range of habitats;
- Regeneration; and
- Size and shape of the patch.

The Mount Lofty Bushland Condition Monitoring manual was created to provide bushland owners and managers with a tool that can accurately measure change in the condition of their bushland. Ten key environmental indicators of bushland health are given a score for each patch of bushland. These scores then provide a measure of the bushland's condition. The ten key indicators are:

- Plant species diversity;
- Weed abundance and threat;
- Structural diversity A and B;
- Tree habitat features;
- Regeneration;
- Tree and shrub health;
- Feral animals;
- Total grazing pressure;
- Fauna species diversity; and
- Bushland degradation risk.

10.4 New South Wales

In New South Wales 'BioMetric' is a tool used for assessing terrestrial biodiversity at the scale of the patch, paddock or property. It assesses loss of biodiversity from proposed clearing, gains in biodiversity from proposed offsets, as well as gains in biodiversity from management actions proposed for incentives (Gibbons *et al.* 2005). The development of the BioMetric tool resulted in the development of three new underpinning datasets across the State of NSW, including a vegetation condition benchmarks database.

Gibbons *et al.* (2005) defines vegetation condition benchmarks as quantitative measures of the range of variability in condition in vegetation with relatively little evidence of alteration, disturbance or modification by humans since European settlement. Vegetation condition benchmarks are used in BioMetric as yardsticks against which to assess the current and predicted future condition of native vegetation for clearing, offset and incentive proposals. Benchmarks are available by vegetation class for the ten vegetation condition variables used to calculate a Site Value (condition at the stand or patch-scale) in the biodiversity score in BioMetric. Each vegetation class encompasses one to many vegetation types within each Catchment Management Authority area.

Site Value is assessed for each zone by measuring ten condition variables in plots and comparing the measured values with benchmarks. Each condition variable is allocated a score from 0 to 3 (0 = low, 1 = moderate, 2 = high, 3 = very high) based on the difference between its measured value and its benchmark (Gibbons *et al.* 2005).

Site Value variables measured when assessing vegetation condition:

- Indigenous plant species richness
- Native over-storey cover
- Native mid-storey cover
- Native ground cover (grasses)
- Native ground cover (shrubs)
- Native ground cover (other)
- Number of tree hollows
- Exotic plant cover
- Regeneration
- Total length of fallen logs
- Number of stems in specified diameter classes

10.5 Victoria

In Victoria the 'Habitat Hectares' method for assessing vegetation quality or condition involves the assessment of a number of site-based habitat and landscape components against a pre-determined 'benchmark' relevant to the vegetation type being assessed (DSE 2004).

The Vegetation Quality Assessment Manual for Habitat Hectares defines vegetation quality or condition "as a measure of the intactness and viability of vegetation in relation to its site condition and landscape context" (DSE 2004). The 'benchmark' represents the average characteristics of a mature and apparently long-undisturbed state for the same vegetation type (Parkes *et al.* 2003).

The Habitat Hectares method involves identifying and assessing habitat zones that consist of a single Ecological Vegetation Classes (EVC) with an assumed similar averaged quality or condition (DSE 2004). EVCs are aggregations of floristic communities that are defined by a combination of floristics, life form and position in the landscape which exist under a common regime of ecological processes within particular environments (Parkes *et al.* 2003).

Each unique Ecological Vegetation Class/quality combination is referred to as a habitat zone and a patch of native vegetation may contain one or more habitat zones. The number and size of habitat zones assessed will be dependent on a number of factors including the size of the patch, the variability of the vegetation and the context of the assessment (DSE 2004).

The Habitat Hectares assessment approach involves assigning a habitat score to a habitat zone that indicates the quality of the vegetation relative to the EVC benchmark. The final habitat score out of 100 for the habitat zone is determined by summing all the scores from each site condition and landscape context component. This score represents the proportion of complete habitat present at the site (Parkes *et al.* 2004).

<u>Components and weightings of the habitat score:</u>

Site Condition

- Large Trees **10**
- Tree Canopy Cover **5**
- Understorey **25**
- Lack of weeds **15**
- Recruitment **10**
- Organic Litter **5**
- Logs **5**

Landscape Context

- Patch Size * **10**
- Neighbourhood * **10**
- Distance to Core Area * **5**

Total 100

* (these components can be derived on-site or with the assistance of maps and other information e.g. GIS)

10.6 Tasmania

In Tasmania, the TASVEG toolkit is used to assess vegetation condition, which is based on the 'Habitat Hectares' method of assessing the condition of native vegetation developed by Parkes *et al*. (2003) in Victoria.

This method enables vegetation condition to be accounted for in planning, monitoring and decision-making processes. The assessed vegetation condition score is not a measure of conservation significance itself but it is critical to determine the conservation value of native vegetation in combination with other assessed biodiversity attributes (e.g. threatened ecological communities). The TASVEG toolkit has been designed to assist in the process of ensuring decisions concerning native vegetation management are made in an appropriate and consistent manner by ensuring vegetation condition assessments are applied consistently (Michaels 2006).

In order to determine the condition of a site, this approach involves assessing site-based and landscape components of the vegetation against a defined 'benchmark' for the same vegetation community. Benchmarks were generated using TASVEG vegetation community descriptions, existing literature, site data and input from vegetation scientists with expert knowledge of particular communities (Michaels 2006).

Both a vegetation condition score and a landscape context score are added to produce a single condition score for a zone (a discrete area of native vegetation consisting of a single vegetation community with an assumed similar average condition. Zones are the spatial units within a site in which vegetation condition is measured) (Michaels 2006).

The components and weighting of the overall site condition score for forest and non-forest vegetation condition assessments are:

	Forest		**Non-Forest**	
Site Condition	Component	Score	Component	Score
	Large Trees	10	Dominant Life Form Cover	15
	Tree Canopy Cover	5		
	Understorey Life Forms	25	Understorey Life Forms	25
	Lack of Weeds	15	Lack of Weeds	15
	Recruitment	10	Persistence Potential	10
	Organic Litter	5	Organic Litter	5
	Logs	5		
Landscape Context	Sub-Total	75	Sub-Total	70
			Multiply sub-total by 1.07	75
	Patch Size	10	Patch Size	10
	Neighbourhood	10	Neighbourhood	10
	Distance to Core Area	5	Distance to Core Area	5
SCORE	**Total**	**100**	**Total**	**100**

Another method used in Tasmania is A Land Manager's Guide for Assessing and Monitoring the Health of Tasmania's Forested Bush, which uses checklists to measure and assess the health or condition of forested bush by assessing three main landscape features (Barnes & McCoull 2002):

- Plants – types, structure and health;
- Habitats – areas where animals and plants can live and grow; and
- Disturbances – processes that damage the health of plants and habitats: erosion, pest invasion, firewood collection and land clearing.

The guide states there are four main factors which are indicative of vegetation health or condition: number of vegetation layers; range of habitats; regeneration; and the size and shape of the patch (Barnes & McCoull 2002).

There are seven checklists included in the guide and the total score of each checklist provides an indication of the health of the component being measured. Checklist 1 and 7 are not scored because they bring together information about the site that cannot be easily scored, including rock type (geology), landscape position, land use history, and the bush type(s) present. Checklists 2 to 6 are scored and measure different components of bush health (Barnes & McCoull 2002).

Checklists include assessment of the following attributes:

- Checklist 2: Site Features (size, shape, connectivity and position of the site in the surrounding landscape).
- Checklist 3: Plant Diversity Audit quadrat and a Plant Diversity Tally.
- Checklist 4: Bush Health (bush structure, weed invasion, native plant regeneration, dieback, native and feral animals).
- Checklist 5: Habitat Features (areas of dense native shrubs, tree hollows, dead standing trees, fallen logs, litter and fallen branches, areas with native grasses, ferns and mosses, rocks and boulder fields, caves, wet areas and rivers, streams and creeklines).
- Checklist 6: Disturbances (stock grazing, weeds, wood hooking and firewood collecting, dumping of garden waste, gravel and soil, nutrient-rich seepage and off-road vehicle use).

Bush Health Checklist Summary

Checklist	**Overall Bush Health Category**		
	Poor	**Okay**	**Good**
1. Site Features	-4 to 1	2 to 7	8 to 12
2. Plan Diversity Audit	-2 to 1	2 to 4	5 to 6
3. Bush Health	-10 to -1	0 to 6	7 to 10
4. Habitat Features	0 to 6	7 to 13	14 to 20
5. Disturbances	-12 to -7	-4 to -4	-3 to 0

10.7 Queensland

In Queensland the BioCondition assessment toolkit provides a protocol for vegetation condition assessment at the patch, paddock or property scale. It outlines a framework to measure how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values (Eyre *et al.* 2006).

In the BioCondition Field Assessment Manual vegetation condition has been defined as "…the structural, compositional and functional aspects of a mature and relatively undisturbed regional ecosystem important for the maintenance of biodiversity values". This definition is based on two key assumptions: (i) a suite of attributes exist that reflect the structural, compositional and functional aspects of a regional ecosystem; and (ii) a reference condition exists for each regional ecosystem (Eyre *et al.* 2006).

BioCondition is a site-based, quantitative, repeatable assessment procedure that provides a numeric score or condition rating of 1, 2, 3 or 4. Benchmarks are a quantitative value for each site condition attribute assessed in BioCondition, and are used as a reference value for comparison purposes. They are specific to each Regional Ecosystem (RE), and are based on the average value of a mature and long undisturbed reference sites, or from Best on Offer (BOO) reference sites, given few ecosystems are totally free of impacts of threatening impacts (Landsberg and Crowley 2004).

<u>The assessable attributes and weightings for deriving the final BioCondition score</u>

Attribute Weighting (%)

- Recruitment of woody perennial species **5**
- Native plant species richness **10**
- Tree canopy cover (%) **5**
- Tree canopy height **5**
- Shrub layer cover (%) **5**
- Native perennial grass cover (%) **5**
- Native perennial forb and non-grass cover (%) **5**
- Native annual grass, forb and non-grass cover (%) **5**
- Large trees **15**
- Fallen woody material **5**
- Weed cover **10**

Site-based Condition Attributes

- Litter cover **5**
- Size of patch **10**
- Context **5**

Landscape Attributes (fragmented subregions)

- Connection **5**

Landscape Attributes (intact subregions)

- Distance to water **20**

TOTAL **100**

11 Summary and Future Directions

〉 This review of the current literature on vegetation condition assessment, monitoring and evaluation discussed the following:

- The history of the development of the concept of vegetation condition;
- Existing definitions of native vegetation condition;
- The use of vegetation data as a surrogate for assessing and monitoring biodiversity;
- Development of a conceptual framework for assessing vegetation condition;
- Indicators of vegetation condition;
- Development of a framework for monitoring and evaluating vegetation condition; and
- Monitoring and evaluation approaches currently in used in Australia.

〉 The purpose of this literature review was to provide background and develop definitions for the *Resource Condition Monitoring – Native Vegetation Integrity Project*.

Vegetation **'integrity',** as defined by the executive Steering committee for Australian Vegetation Information (ESCAVI) and adopted by the *Resource Condition Monitoring – Native Vegetation Integrity Project*, comprises of both 'extent' and 'condition'. Vegetation **extent** is defined as all plant life in a given area or distribution and type of vegetation as presented in maps. In Western Australia this has been calculated as the pre-European extent of vegetation intersected with the current extent layers prepared by the Department of Agriculture and Food WA.

Past approaches to defining vegetation condition tended to be taxon-driven (e.g. sensitive species). Later approaches used structural complexity, which became synonymous with 'good' condition in terms of habitat complexity. More recent methods provide rapidly obtained indices of native vegetation condition by using comparisons to reference condition states, or 'benchmarks', and are intended to provide a simple measure of vegetation condition.

The definition of vegetation **condition** is complex and needs to:

- Incorporate the purpose of assessing and monitoring vegetation condition – i.e. for biodiversity conservation, rather then for production or aesthetics;
- Be driven by the management goals that may be specific to a management action or may be general for the setting up of benchmarks and reference sites;
- Be driven by key threatening processes (which also are the focus of the management goal);
- Be applicable at a range of scales – the National indicator for vegetation condition is bases on remaining vegetation types and associated with tenure and land use. Site indicators may be more subjective; for example, use of the Keighery (1994) ratings for vegetation condition requires specific training;
- Be measured by specific indicators based on selected attributes of composition, structure and function. (A functional attribute may be made up of compositional and structural attributes such as weediness or regeneration or it may be associated with the threatening process erosion, soil salinity or water quality.);
- Incorporate measures of modification resulting from disturbance;
- Be assessed against a benchmark or reference state;
- Incorporate the concept of long-term stability or resilience – i.e. the rate and direction of change (improvement or deterioration). How well can it recover and how long will it take to recover (from natural, intentional and non intentional man made disturbances)?; and

- Consider the quality or health of a community or ecosystem.

〉 The definition proposed for the *Resource Condition Monitoring – Native Vegetation Integrity Project* is:

A measure, for the purpose of biodiversity conservation, of vegetation composition, structure and function relative to a benchmark state (i.e. within the context of management goals driven by the presence or absence of threatening processes) at a patch or landscape (community or ecosystem) scale.

〉 Vegetation and vegetation condition are often regarded as surrogates for biodiversity but this assumption has its limitations as it is only one component of biodiversity.

〉 From an assessment of various toolkits developed across Australia, the following attributes of condition include:

- <u>Composition</u>: species; life-form; origin (native or introduced) richness; number of species per area; diversity; range of life form and how this changes across the landscape;

- <u>Structure</u> at different scales:
  - o Patch scale: height and cover of all strata present; and
  - o Landscape scale: horizontal patterns across the landscape.

- <u>Function</u>, which may be made up of compositional and structural aspects, for example the presence of weeds species, regeneration (species and age structure), litter and hollow logs.

〉 At the landscape and patch scale indicators need to be specific to the management goal, time frame and disturbance mechanism, which can be selected from the set of attributes mentioned above (plus others).

More importantly these indicators need to relate to relevant environmental attributes, for example climate, soil nutrients, grazing pressure, hydrological influences, water quality and human impact. Data collected from these environmental factors are essential to analyse the causes of trends in vegetation condition.

The selection of indicators also need to take into account the time and effort required to collect and analyse data and how accurately can it be correlation with the relevant environmental variables.

〉 Condition can be measured and related to a benchmark, and is usually done through a scoring system (e.g. Habitat Hectares). Habitat Hectares was initially developed for a bush tendering system, and it has been further developed according to required purposes. In New South Wales for vegetation clearing offset calculation, and in Tasmania for assessing changes in biodiversity to enable vegetation condition to be accounted for in planning, monitoring and decision-making processes.

Subjective methods have been developed in Western Australia that incorporate elements of composition, structure and levels of disturbance. For example, the rating of **"**Very Good" refers to altered vegetation structure and obvious signs of disturbance (e.g. repeated fires, presence of aggressive weeds, dieback, logging and grazing).

〉 The methods discussed above are used in fragmented landscapes, and different methods have been developed for rangelands. The methods developed for use in the rangelands have focused on pasture condition and other aspects of biodiversity.

〉 Vegetation condition can be assessed and mapped at regional scales with reasonable accuracy using remote sensing and/or abiotic variables. Spatial models or maps of vegetation condition should be related to vegetation condition data from on-ground assessments (i.e. ground-truthing), which in turn should be related to benchmarks for desirable states of vegetation condition. Further investigation of up-to-date techniques is required as this was not covered in this document.

〉 Methods for developing a framework for patch scale assessment of condition include the following steps:

1. Define management or policy objectives and operational constraints;
2. Develop an appropriate conceptual framework for the ecological system under consideration;
3. Select an appropriate suite of indicators or vegetation attributes; and
4. Consider available options for combining these vegetation attributes into an index of condition.

At a Landscape scale the steps commonly used include:

1. Survey of plot-based attributes with sufficient replication to allow combination of redundant data through clustering procedures;
2. Collection of environmental attributes from plot-based sample sites, including measures of threats to vegetation condition;
3. Data exploration and validation through removal of extreme outliers and statistical examination of correlated environmental variable;
4. Determination of environmental predictors of condition and predominant threats that determine degradation; and
5. Spatial prediction of the condition indices. The combination analysis of the environmental predictors through techniques of generalised regression with spatial prediction and is defined in specific application in programming tools.

For measuring vegetation condition at a regional scale, methods can be divided into two main areas: (i) methods that rely on remote sensing; and (ii) methods that use modelling with GIS surrogates.

〉 In conclusion fit for purpose/context/range of approaches need to be explicit about the purpose for which native vegetation condition is being assessed and/or monitored. Native vegetation condition may be assessed and monitored for many different purposes and it is essential to be clear about the purpose as this will determine or strongly influence the field methods employed.

〉 There are different field methods used for assessing native vegetation condition. While flexibility in assessment methods is required to accommodate different management needs, there is a need to create the opportunity for greater integration of approaches. Currently, regional organisations in Victorian and Tasmania undertake the assessment and reporting of vegetation condition, but not monitoring.

〉 Future work of the *Resource Condition Monitoring – Native Vegetation Integrity Project* includes:

- Develop and select indicators and benchmarks to incorporate past and existing monitoring protocols;
- Investigate the use of remote sensing methods in the *Resource Condition Monitoring – Native Vegetation Integrity Project*;
- Review methods to assess vegetation condition in the Rangelands;
- Data management protocols for storage and retrieval of monitoring data

12 Glossary

(Please note: this glossary is currently in draft form, and the RCM –NVI Project team are in the process of compiling a Departmental database that includes origins of glossary terms and multiple definitions. Our final selection of definitions and terms will be made from this database at a later date.)

Adaptive management cycle
A management tool that describes a sequential order of management components that needs to occur to ensure continuous learning and improved outcomes are realised. *(from Jakowyna 2008)*

Aspirational targets
Statements about the desired future (~50 years) state or vision for an asset that reflect its values. *(from Jakowyna 2008)*

Asset
Refers to a physical environmental or natural resource object having some importance (eg. a waterway, a wetland, a native vegetation assemblage, an endangered native species, a threatened ecological community, a soil unit, a landscape, a national park, a coastal segment, a marine reserve, an airshed, a heritage icon, a landform, a landscape, a bioregion, etc). *(from Jakowyna 2008)*

Biodiversity
The total of all the organisms that make up life on Earth, and contains all of the different life-forms (micro-organisms to plants and animals) from terrestrial to aquatic ecosystems. It can be further defined at three levels: (i) genetic diversity: all the genetic information of individuals; (ii) species diversity: all the estimated 30 – 50 million species on Earth; and (iii) ecosystem diversity: the various habitats and communities, together with the ecological processes that support them. *(from Wilson (2003).)*

The variability among living organisms and the ecosystems and ecological complexes of which those organisms are a part. Includes: (i) diversity within native species and between native species; (ii) diversity of ecosystems; and (iii) diversity of other biodiversity components. *(from DEC (2006); Draft - A 100-year Biodiversity Conservation Strategy for Western Australia: Blueprint to the Bicentenary in 2029)*

Evaluation
Refers to a formal review process to systematically assess the appropriateness, effectiveness and efficiency of a policy, program, or project. *(from Jakowyna 2008)*

Goal
The higher order objective to which a program is intended to contribute (*from MERI Framework*)

Habitat
The biophysical medium or media (a) occupied by an organism; or (b) once occupied by an organism or group of organisms, an dinto which organisms of that kind have the potential to be reintroduced. *(from Williams (2005): Native Vegetation and Regional Management: A guide to research and resources.)*

The subset of physical environmental factors that permit an organism to survive and reproduce. Implicitly these factors are associated with a geographic location *(from Burgman and Lindenmayer (1998).)*

Indicator
A physical, chemical, biological, social or economic variable that can be measured and used to assess management performance or progress. *(from Jakowyna 2008)*

A quantitative or qualitative factor or variable that provides a simple and reliable basis for assessing achievement, change or performance. It is a unit of information measured over time that can help show changes in a specific condition. A given goal or objective can have multiple indicators (*from International Federation of Agricultural Development (IFAD))*

Intrinsic values
Ethical positions that place value on species and communities, independent of people (*from Burgman and Lindenmayer 1998*)

Immediate targets
Establishes a specific outcome or output for management actions or activities that occur over a very short timeframe (1-3 years). They are useful for reporting on the progress of immediate deliverables (ie. outputs) linked to management projects, actions and activities. *(from Jakowyna 2008)*

Intermediate targets
Establishes a specific outcome or output for management actions or activities that occur over the medium term (5-10 years). They are useful for measuring broadscale progress of management programs and projects that contribute to a long term improvement in asset condition, such as changing behaviours and attitudes (eg. management practices), addressing environmental threats and issues, and environmental rehabilitation / restoration activities). *(from Jakowyna 2008)*

Long term asset targets
A specific endpoint or desired outcome that contributes progress towards an aspirational target or objective. *(from Jakowyna 2008)*

Management Action Target (MATs)
Establishes a specific management outcome or output that (upon completion) will contribute towards achieving a Resource Condition Target. *(from Jakowyna 2008)*

Matters for targets
Mandatory indicators for developing RCTs for NRM regional strategies. *(from Jakowyna 2008)*

Outcome
An intended result, effect, or consequence (beneficial or otherwise) that occurs from carrying out a program or activity. *(from Jakowyna 2008)*

Outputs
The immediate products and services delivered from carrying out a program or activity. *(from Jakowyna 2008)*

Pressures
Represent environmental issues, problems or threats that impact the environment or natural resources (eg. greenhouse gas emissions; introduced animals; weeds; clearing of native vegetation; etc). *(from Jakowyna 2008)*

Resource Condition Targets (RCTs)

A specific endpoint or desired outcome that contributes progress towards an aspirational target. *(from Jakowyna 2008)*

SMART
An acronym for Specific, Measurable, Appropriate, Realistic and Timebound that represents a suite of principles that ensures managers will develop and use effective targets to deliver effective outcomes. *(from Jakowyna 2008)*

Target
The measurable or quantifiable component towards achieving desired policy visions, objectives and goals (which in themselves tend to be qualitative, conceptual or general statements of intent). *(from Jakowyna 2008)*

Threat
A potential pressure or problem that may cause impact to the environment or natural resources. *(from Jakowyna 2008)*

Vegetation composition
The percentage of each type of vegetation within a community, ecosystem or landscape. (*reference to add*.)

The types of vegetation that are present in an area.
(http://coweeta.ecology.uga.edu/webdocs/1/glossary.htm)

Vegetation extent
The range, magnitude or distance over which a vegetation type extends. (Ref).

13 References

Andersen, A., Fisher, A., Hoffman, B., Read, J., and Richards R (2003). The Use of Invertebrates for Biodiversity Monitoring in Australian Rangelands, With Particular Reference to Ants, In: *Biodiversity monitoring in the rangelands: a way forward*, *Final Report to the Environment Australia on an Expert Technical Workshop*. (Eds. A. Smyth, C. James and G. Whiteman). Alice Springs, CSIRO Sustainable Ecosystems, 29 October – 1 November 2002, Alice Springs NT, Environment Australia and CSIRO, Canberra.

Andreasen, J. K., O'Neill, R. V., Noss, R. and Slosser, N, C. (2001). Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators* **1**: 21-35.

Anon (1995). *National Forest Conservation Reserves, Commonwealth proposed criteria – a position paper*. Australian Government Publishing Service, Canberra. July 1995.

Australian Government NRM Team. (2008). Draft National Natural Resource Management Monitoring, Evaluation, Reporting and Improvement (MERI) Framework. Version 6 (April 1 2008).

Ayers, D., Seddon, J., Briggs, S., Doyle, S. and Gibbons, P. (2005). *Interim Benchmarks for the BioMetric Tool*. NSW Department of Environment and Conservation, Sydney.

Barnes, R. W. and McCoull, C. J. (2002). *A land manager's guide for assessing and monitoring the health of Tasmania's forested bush*. Nature Conservation Report 02/2. Nature Conservation Branch, Resource Management and Conservation, Department of Primary Industries, Water and Environment, Hobart.

Braithwaite, L. W., Turner, J. and Kelly, J. (1984). Studies on the arboreal marsupial fauna of Eucalypt forests being harvest for woodpulp at Eden, New South Wales, III: Relationships between faunal densities, Eucalypt occurrence and foliage nutrients and soil parent materials. *Australian Wildlife Research* **11**: 11-48.

Briggs, S. V. and Freudenberger, D. (2006). Assessment and monitoring of vegetation condition: Moving forward. *Ecological Management and Restoration* **7**(S1): S74-S76.

Burgman, M. A. and Lindenmayer, D. B. (1998). *Conservation Biology for the Australian Environment*. Surrey Beatty and Sons: NSW.

Burgman, M. A., Breininger, D. R., Duncan, B. W. and Ferson, S. (2001). Setting reliability bounds on habitat suitability indices. *Ecological Applications*, **11:** 70-78.

Catling, P. C. and Burt, R. J. (1995). Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the effect of habitat variables on distribution and abundance. *Wildlife Research* **22**: 271-288.

Coops, N.C. and Catling, P.C. (2002). Prediction of the spatial distribution and relative abundance of ground-dwelling mammals using remote sensing imagery and simulation models. *Landscape Ecology* **17**: 173-188.

Coote, M. (2001). Monitoring and Evaluating Biodiversity Conservation Projects: A guide for managers and technical advisers to planning and designing a monitoring and evaluation program for native vegetation and biodiversity management projects. Department of Conservation and Land Management and Bushcare.

Crisp, P. N., Dickinson, K. J. M. and Gibbs, G. W. (1998). Does native invertebrate diversity reflect native plant diversity? A case study from New Zealand and implications for conservation. *Biological Conservation* **83**: 209-220.

Del Marco, A., Taylor, R., Clarke, K., Savage, K., Cullity, J. and Miles, C. (2004). *Biodiversity Planning Guidelines for the Perth Metropolitan Region*. Western Australian Local Government Association and Perth Biodiversity Project, Perth.

Department of Environment and Conservation. (2008). *Biodiversity Conservation Appraisal System: A framework to measure and report on biodiversity conservation achievements and management effectiveness of the Western Australian Department of Environment and Conservation*. Draft, March 2008.

Department of Environment and Conservation. (2008). *Corporate Plan 2007 – 2009* *http://www.naturebase.net/content/view/76/278/*

Department of Land and Water Conservation. (2004). Environmental Services Scheme: Caring for our natural resources.

Department of Sustainability and Environment (DSE) (2004). *Vegetation Quality Assessment Manual– Guidelines for applying the habitat hectares scoring method*. Version 1.3. Victorian Government Department of Sustainability and Environment, Melbourne.

Doherty, M., Kearns, A. Barnett, G., Sarre, A., Hochuli, D., Gibb, H. and Dickman, C. (2000). *The Interaction Between Habitat Conditions, Ecosystem Processes And Terrestrial Biodiversity - A Review.* Australia: State of the Environment, Second Technical Paper Series (Biodiversity), Department of the Environment and Heritage, Canberra.

Drielsma, M. and Ferrier, S. (2006). Landscape scenario modeling of vegetation condition. *Ecological Management and Restoration* **7**(S1): S45-S52.

Dumanski, J. and Pieri, C. (1997). Application of the Pressure-State-Response framework for the Land Quality Indicators (LQI) programme. In *Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development* (1997). Proceedings of the Workshop organized by the Land and Water Development Division FAO Agriculture Department and the Research, Extension and Training Division FAO Sustainable Development Department, 25-26 January 1996. (http://www.fao.org/docrep/W4745E/w4745e08.htm)

ESCAVI (2003). An interim Approach to the Native Vegetation Indicator Executive Steering Committee for Australian Vegetation Information, Australian Government, Canberra. (http://nrm.gov.au/monitoring/vegetation-condition/index.html)

ESCAVI (2004). An interim approach to the native vegetation condition indicator (indicator status: for advice) (http://www.nrm.gov.au/publications/factsheets/me-indicators/native-veg/pubs/vegetation-condition.pdf)

Eyre, M. D. & Luff, M. L. (2002). The use of ground beetles (Coleoptera: Carabidae) in conservation assessments of exposed riverine sediment habitats in Scotland and northern England. *Journal of Insect Conservation* **6:** 25-38.

Eyre, T. J., Kelly, A. L. and Neldner, V. J. (2006). *BioCondition: A Terrestrial Vegetation Condition Assessment Tool for Biodiversity in Queensland*. Field Assessment Manual. Version 1.5. Environmental Protection Agency, Biodiversity Sciences unit, Brisbane.

Failing L. and Gregory R. (2003). Ten common mistakes in designing biodiversity indicators for forest policy. *Journal of Environmental Management* **68**: 121–32.

Ferrier, S. (2002). Mapping Spatial Pattern in Biodiversity for Regional Conservation Planning: Where to from here? *Systematic Biology* **51**: 331–363.

Ferrier, S. and Watson, G. (1997). *An Evaluation of the Effectiveness of Environmental Surrogates and Modelling Techniques in Predicting the Distribution of Biological Diversity*. Consultancy report prepared by S. Ferrier and G. Watson (NSW National Parks and Wildlife Service) for Department of Environment, Sport and Territories.
(http://live.greeningaustralia.org.au/nativevegetation/pages/pdf/Authors%20F/2_Ferrier.pdf)

Ferrier, S., Watson G., Pearce, J. and Drielsma, M. (2002a). Extended statistical approaches to modelling spatial pattern in biodiversity in northeast New South Wales. I. Species-level modelling. *Biodiversity and Conservation* **11**: 2275-2307.

Ferrier, S., Drielsma, M., Manion, G. and Watson, G. (2002b). Extended statistical approaches to modelling spatial pattern in biodiversity in northeast New South Wales. II. Community-level modelling. *Biodiversity and Conservation* **11**: 2309-2338.

Freudenberger, D. (1999). *Guidelines for Enhancing Grassy Woodlands for the Vegetation Investment Project*. Report to Greening Australia, ACT and South-East NSW. CSIRO Wildlife and Ecology, Canberra.

Freudenberger, D. and Harvey, J. (2003). Assessing the Benefits of Vegetation Enhancement for Biodiversity: A Draft Framework. (A report for Environment Australia and the Biodiversity Benefits Task Group). Commonwealth of Australia.

Gibbons, P., and Freudenberger, D. (2006). An overview of methods used to assess vegetation condition at the scale of site. *Ecological Management and Restoration* **7**(S1): S10-S17.

Gibbons, P., Ayers, D., Seddon, J., Doyle, S. and Briggs, S. (2005). *BioMetric*. Version 1.8. A Terrestrial Biodiversity Assessment Tool for the NSW Property Vegetation Plan Developer Operational Manual, Canberra.

Gibbons, P., Zerger, A., Jones, S. and Ryan, P. (2006). Mapping vegetation condition in the context of biodiversity conservation. *Ecological Management and Restoration* **7**(S1): S1-S2.

Gibson, L.A., Wilson, B.A. and Aberton, J.G. (2004). Landscape characteristics associated with species richness and occurrence of small native mammals inhabiting heathland: A spatial modelling approach. *Biological Conservation* **120**: 75-89.

Goldney, D. and Wakefield, S. (1997). Assessing farm Bushland. In: *Save the Bush Toolkit* (Charles Sturt University and Orange Agricultural College), pp. 1-12. Charles Sturt University, Bathurst, NSW.

Gorrod, E. (2006a). Evaluating the ecological and operational basis of vegetation condition assessments. *Ecological Management and Restoration* **7**(S1): S80.

Gorrod, E. (2006b). *Observer variation in vegetation condition assessments: Implications for biodiversity*. Ecological Society of Australia Conference, 28 August – 1 September 2006. Wellington, New Zealand.

Gould, P., Lay, B., Tynan, R. and Watson, I. (2001). *Rangeland monitoring, resource inventory, condition assessment and lease inspection activities in South Australia*, conducted by Primary Industries and Resources SA.

Goldney D. and Wakefield S. (1997). *Save the Bush Toolkit*. Charles Sturt University, Bathurst.

Government of Western Australia (2000). *Bush Forever. Vol. 2: Directory of Bush Forever Sites*. Department of Environmental Protection, Perth.

Herweg, K., Steiner, K. and Slaats, J. (1998). *Sustainable land management: guidelines for impact monitoring*. Centre for Development and Environment, Berne, Switzerland.

Hill, R. (2001). Native Vegetation Policy Reversing the Decline in the Quality and Extent of Australia's Native Vegetation Cover Statement by Senator the Honourable Robert Hill Minister for the Environment and Heritage September 2001
(http://www.environment.gov.au/land/publications/vegetation-policy.html)

Higgins, I. (2006). Vegetation condition mapping and catchment management: The North Central Victorian experience. *Ecological Management and Restoration* **7**(S1): S68-S71.

Hockings, M., Stolton, S., Leverington, F., Dudley, N. and Courrau, J. (2006). *Evaluating Effectiveness. A framework for assessing management effectiveness of protected areas*. 2nd edition. IUCN (The World Conservation Union), Gland, Switzerland and Cambridge U.K.

Hollings, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* **4**: 1-23.

Jakowyna, B. (2008). *Guidelines for Developing and Reviewing Long Term Asset Targets* (Draft, Version 1.3). Department of Environment and Conservation and Department of Agriculture and Food Western Australia.

Jansen, A., Robertson, A., Thompson, L. and Wilson, A. (2004). Development and application of a method for the rapid appraisal of riparian condition. *River and Riparian Land Management Technical Guideline* **4**: 1-14.

Jenkins, B., Andrews, S. and Morsley, R. (2000). Selecting native vegetation remnants for nature conservation on private land in north-west NSW with the assistance of four decision trees. *Ecological Management and Restoration* **1**: 228–30.

Jerram, R. and Drewitt. A. 1998. *Assessing vegetation condition in the English Uplands.* English Nature Research Reports, Number 264. English Nature, Northminster House, Peterborough.

(http://naturalengland.communisis.com/NaturalEnglandShop/product.aspx?ProductID=0efdea70-e25c-48c3-b5f5-39abaad9302e)

Jonsson, B. G. and Jonsell, M. (1999). Exploring potential biodiversity indicators in boreal forests. *Biodiversity and Conservation* **8**: 1417-1433.

Karfs, R., Applegate, R., Fisher, R., Lynch, D., Mullin, D., Novelly, P., Peel, L., Richardson, K., Thomas, P. and Wallace, J., 2000, *Regional land condition and trend assessment in tropical savannas: The Audit Rangeland Implementation Project Final Report*, National Land and Water Resources Audit, Canberra.

Kaesehagen, D. (1994). Bushland corridor mapping. In: *Invasive weeds and regenerating ecosystems in*
Western Australia. Proceedings of a conference held at Murdoch University (ed. G. Burke). Murdoch, Western Australia.

Keighery, B.J. (1994). *Bushland plant survey. A guide to plant community survey for the community*. Wildflower Society of WA (Inc.). Nedlands, Western Australia.

Keith, D. and Gorrod, E. (2006). The meanings of vegetation condition. *Ecological Management and Restoration* **7**(S1): S7-S9.

Kimball, J. W. (1994). *Biology*. W. C. Brown Publishing Company.

Landsberg, J. and Crowley, G. (2004). Monitoring rangeland biodiversity: Plants as indicators. *Austral Ecology* **29**: 59–77.

Lange, R. T., Lay, B. G. and Tynan, R.W. (1994). Evaluation of extensive arid rangelands: the Land Condition Index (LCI). *Transactions of the Royal Society of South Australia.* **118**: 125-131.

Lehmann, A., Leathwick, J.R. and Overton, J.McC. (2002a). Assessing New Zealand fern diversity from spatial predictions of species assemblages. *Biodiversity and Conservation* **11**: 2217 – 2238.

Lehmann, A., Overton, J.McC. and Leathwick, J.R. (2002b). GRASP: Generalised regression analysis and spatial predictions. *Ecological Modelling* **157**: 189-207.

Low Choy, S. J., Stewart-Koster, B., Kelly, A., Eyre, T. and Mengersen, K. M. (2005). Identifying good condition in native vegetation: A Bayesian regression and decision theoretic approach. MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005 (eds. Zerger, A. and Argent, R. M.).

Ludwig, J. A. and Tongway, D. J. (1997). A landscape approach to rangeland ecology. In: *Landscape Ecology Function and Management. Principles from Australia's Rangelands* (eds J. Ludwig, D. Tongway, D. Freudenberger, J. Noble and K. Hodgkinson), pp. 1-12. CSIRO Publishing, Collingwood, Victoria.

Mac Nally, R., Bennett, A. F., Brown, G. W., Lumsden, L. F., Yen A., Hinkley, S., Lillywhite, P. and Wards, D. (2002). How Well Do Ecosystem-Based Planning Units Represent Different Components of Biodiversity? *Ecological Applications* **12**(3): 900–912.

McElhinny, C., Gibbons, P., Brack, C. and Bauhus, J. (2005). Forest and woodland stand structural complexity: it's definition and measurement. *Forest Ecology and Management* **218**:1-24.

Margolius, R. and Salafsky, N. (1998). *Measures of success: designing, managing, and monitoring conservation and development projects*. Island Press, Washington, D.C.

Michaels, K. (2006). *A Manual for Assessing Vegetation Condition in Tasmania, Version 1.0.* Resource Management and Conservation, Department of Primary Industries, Water and Environment: Hobart.

Miller, C. (2000). Vegetation and Habitat Are Not Synonyms. *Ecological Management and Restoration* 1(2): 102–104.

Natural Resource Management Ministerial Council. (2003). *Monitoring and Evaluation Natural Resource Management Monitoring and Evaluation Framework*. Endorsed by the Natural Resource Management Ministerial Council, 3 May 2002 Meeting.

Neldner, J. (2006). Why is vegetation condition important to government? A case study from Queensland. *Ecological Management and Restoration* **7**(S1): S5-S7.

Newell, G. R., White, M. D., Griffioen, P., and Conroy, M. (2006). Vegetation condition mapping at a landscape-scale across Victoria. *Ecological Management and Restoration* **7**(S1): S65-S68.

Newsome, A. E. and Catling, P. C. (1979). Habitat preferences of vertebrates inhabiting Heathlands of coastal, montane and alpine regions of south-east Australia. In: *Ecosystems of the World*, Volume 9A. *Heathlands and Related Shrublands of the World* (ed. R. L. Specht), pp. 301-316. Elsevier, Amsterdam.

Noss, R. F. (1990). Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* **4**: 355-364.

Oliver, I. (2002a). An expert panel-based approach to the assessment of vegetation condition within the context of biodiversity conservation Stage 1: the identification of condition indicators. *Ecological Indicators* **2**(3): 223-237.

Oliver, I. (2002b). Introduction to an expert panel based approach for the assessment of vegetation condition within the context of biodiversity conservation. *Ecological Management and Restoration* **3**: 225-227.

Oliver, I., Smith, P. L., Lunt, I. and Parkes, D. (2002). Pre-1750 vegetation, naturalness and vegetation condition: What are the implications for biodiversity conservation? *Ecological Management and Restoration* **3** (3): 176-178.

Oliver, I. and Parkes, D. (2003). *A Prototype Toolkit for Scoring the Biodiversity Benefits (and Disbenefits) of Landuse Change*. Version 5. Department of Land and Water Conservation, Sydney.

Oliver, I., Ede, A., Hawes, W. and Grieve, A. (2005). The NSW Environmental Services Scheme: results for the biodiversity benefits index, lessons learned, and the way forward. *Ecological Management and Restoration* **6:** 197–205.

Overton, J. McC., Stephens, R. T. T., Leathwick, J. R. and Lehman, A. (2002). Information pyramids for informed biodiversity conservation. *Biodiversity and Conservation* **11**: 2093-2116.

Parkes, D. and Lyon, P. (2006). Towards a national approach to vegetation condition assessment that meets government investors' needs: A policy perspective. *Ecological Management and Restoration* **7**(S1): S3-S7.

Parkes, D., Newell, G. and Cheal, D. (2003). Assessing the quality of native vegetation: the 'habitat hectares' approach. *Ecological Management and Restoration* **4**: S29-S38.

Perkins, I. (2002). *Harrington Park Stage 2 Ecological Assessment Final Report*. Ian Perkins Consultancy Services and Aquila Ecological Surveys, Sydney.

Pickup, G., Bastin, B. N. and Chewings, V. H. (1994). Remote sensing-based condition assessment for non-equilibrium rangelands under large-scale commercial grazing. *Ecological Applications* **4**: 497-517.

Ribaudo, M. O., Hoag, D. L., Smith, M. E. and Heimlich, R. (2001). Environmental indices and the politics of the Conservation Reserve Program. *Ecological Indicators* **1**: 11-20.

Robinson, R. (2006). *ForestCheck: Monitoring Biodiversity in South-West Forests Operating Plan*. The Department of Environment and Conservation, Perth.

Salafsky, N., Margoluis, R. and Redford, K. (2001). *Adaptive management: a tool for conservation practitioners*. Biodiversity Support Program, Washington, D. C.
(available at: http://fosonline.org/resources/Publications/AdapManHTML/Adman_1.html)

Saunders, D. Margules, C. and Hill, B. (1998). Environmental Indicators for National State of the Environment Reporting: Biodiversity.

Stem, C., Margoluis, R., Salafsky, N. and Brown, M. (2005). Monitoring and Evaluation in Conservation: a Review of Trends and Approaches. *Conservation Biology* **19**(2): 295-309.

Stephens, R. T. T, Brown, D. J. and Thornley, N. J. (2002). Measuring Conservation Achievement: Concepts and their application over the Twizel Area. *Science for Conservation* **200**: 5-112.

ter Braak, C. J. F. (1987). Ordination. in *Data Analysis in Community Ecology*. Jongman, R.H., C.J.F. ter Braak and O.F.R. van Tongeren, editors. Pudoc, Wageningen, The Netherlands.

Thackway, R. and Lesslie, R. (2005). *Vegetation Assets, States, and Transitions: accounting for vegetation condition in the Australian landscape*. Technical Report, Bureau of Rural Sciences, Australian Government Department of Agriculture, Fisheries and Forestry. Canberra, A.C.T.

Thackway, R. and Lesslie, R. (2006). Reporting vegetation condition using the Vegetation Assets, States and Transitions (VAST) framework. *Ecological Management and Restoration* **7**(S1): S53-S62.

Thackway, R., Sonntag, S. and Keenan, R. J. (2006). *Assessment of Vegetation Condition: An Indicator of Sustainable, Productive Ecosystems*. Science for Decision Makers, Bureau of Rural Sciences, Australian Government Department of Agriculture, Fisheries and Forestry. Canberra, A.C.T.

Thackway, R., Lesslie, R. and Bricklenhurst P. *Accounting for vegetation condition in the Australian landscape: An approach in the Northern Territory using VAST criteria and GIS*. Bureau of Rural Sciences, Canberra, ACT (Thackway, R. and Lesslie, R.); Land & Vegetation, Department of Infrastructure, Planning and Environment, Northern Territory (Bricklenhurst P.). (http://www.nt.gov.au/nreta/natres/natveg/vegmapping/pdf/vast.pdf).

Tongway, D. and Hindley, N. (2004). Landscape function analysis: a system for monitoring rangeland function. *African Journal of Range and Forage Science*, **21**: 109-113.

Tongway, D. J. and Ludwig, J. A. (1997). The nature of landscape dysfunction in rangelands. In*:* *Landscape Ecology: Function and Management* (eds J. Ludwig, D. Tongway, D. Freudenberger, J. Noble and K. Hodgkinson), pp 49–61. CSIRO Publishing, Collingwood.

Walker, B. and Salt, D. (2006). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press: Washington DC.

Wallace K. J., Beecham, B. C. and Bone, B. H. (2003). Managing Natural Biodiversity in the Western Australian Wheatbelt. Department of Conservation and Land Management.

Wallace, J., Behn, G. and Furby, S. (2006). Vegetation condition assessment and monitoring from sequences of satellite imagery. *Ecological Management and Restoration* **7**(S1): S31-S36.

Westman. W. E. (1978). Measuring the inertia and resilience of ecosystems. *Bioscience* **28**: 705-710.

Westoby, M., Walker, B. and Noy-Meir, I. (1989). Opportunistic management for rangelands not at equilibrium. *Journal of Range Management* **42**: 266-274.

Williams, J. (2005). *Native Vegetation and Regional Management: A guide to research and resources*. Greening Australia Ltd, Yarralumla: ACT.

Wilson, B. Biodiversity, Extinction and Threats. (2003). In: *Ecology: An Australian Perspective* (eds. P. Attiwill and B. Wilson). 2003. Oxford University Press: Victoria.

US Fish and Wildlife Service. (1980). *Habitat Evaluation Procedures*. Us Fish and Wildlife Service, Department of the Interior, Washington, D.C.

USFWS (1981). *Standards for the Development of Habitat Suitability Index Models*. United States Fish and Wildlife Service, Washington, DC, USA.

Zerger, A., Gibbons, P., Jones, S., Doyle, S., Seddon, J., Briggs, S. V., and Freudenberger, D. (2006). Spatially modeling native vegetation condition. *Ecological Management and Restoration* **7**(S1): S37-S44.

Zerger, A. and Jones, S. (2007). *Scaling up: Challenges to the assessment and monitoring of vegetation condition at a landscape level*. Landscape Logic Workshop: Future for Native Vegetation Condition Research in Tasmania and Victoria Workshop, 18-19 October 2007, Cradle Coast Campus, University of Tasmania, Burnie.

Zerger, A., Gibbons, P., Seddon, J., Warren, G., Austin, M. and Ryan, P. (2008). Native Vegetation Condition: Site to Regional Assessments**:** pg 139-157. BOOK