Title: The next generation of metrics for multiple ecosystem conservation tenders

Authors: Stuart M. Whitten\textsuperscript{a,c}, Charlie Zammit\textsuperscript{b}, Veronica Doerr\textsuperscript{a}, Erik Doerr\textsuperscript{a}, Emma Burns\textsuperscript{b}, Simon Attwood\textsuperscript{b} and Art Langston\textsuperscript{a}.

\textsuperscript{a} CSIRO Ecosystem Sciences
\textsuperscript{b} Australian Government Department of Environment, Water and Heritage
\textsuperscript{c} Corresponding author: stuart.whitten@csiro.au; Ph: 02 62421683; Address: GPO Box 284, Canberra, ACT 2601.

Abstract
Conservation tenders are structured markets in which land managers are invited to submit bids offering specified management and their required payment (bid price) for undertaking the activities. These tenders specify a particular set of conservation outcomes and require a credible ecological framework for calibrating them and a metric which can describe the relative outcome or return on investment to be expected from each bid. In this paper we describe the design of a new Multiple Ecological Communities (MEC) metric applied in the 2010-11 round of the Australian Government’s Environmental Stewardship Program. The metric design incorporates a number of advances over existing biodiversity metrics including a state and transition model of ecological community dynamics, more explicit accounting of threats and available management actions, and extension of the investment focus beyond remnant habitats into the surrounding agricultural matrix. Metric design was integrated with data collection requirements in an effort to minimise costs and reduce data errors. The final metric form is consistent with both economic and ecological theory which allows for greater confidence in discriminating amongst the range of investment options available under the MEC project.

Keywords: conservation tenders, biodiversity metric, state and transition models, conservation value score, environmental stewardship.

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1. Introduction and background
Markets, and in particular conservation tenders, are important tools in delivering conservation outcomes from private land. At the national level the Australian Government has used conservation tenders as their preferred delivery mechanisms for the Environmental Stewardship Program, the Forest Conservation Fund, and Australia’s components of the Biodiversity Hotspots Program (Zammit & Boshier in press). Victoria and Queensland have led the use of conservation tenders at the state scale via the BushTender and Nature Assist programs respectively, and across Australia there are many small scale applications.

Conservation tenders are reverse auctions, usually designed as a first price, sealed bid, single round, discriminatory price auctions of the form described by Latacz-Lohman and Van der Hamsvoort (1997) and in additional detail by Stoneham et al. (2003). Landholder bids are ranked via some form of benefits index or conservation value score (CVS) which is then divided by the bid price to estimate a comparable per cost unit of biodiversity benefit. Contracts are generally offered to landholders until a stopping rule such as aggregate budget, reserve price or ecological target is reached. There is a growing body of applied research on the design of conservation tenders (see Stoneham et al. 2003; Latacz-Lohmann and Schlizzi 2005; Connor et al. 2008) and on the construction of environmental benefit indices (see Parkes et al. 2003; Hajkowicz et al. 2009).

Here we link these two areas of research with application to a new form of metric underpinning the current Multiple Ecological Communities (MEC) round of the Australian Government’s Environmental Stewardship Program. Our emphasis is in four areas:

• the role of ecological dynamics in forming purchase objectives, measuring progress and in describing the ecological relationships;
• the construction of a metric which accommodates more systematic consideration of management interventions while ensuring the metric is consistent with both ecological and economic theory;
• methods to include the range of on-farm management interventions within the agricultural matrix surrounding the remnant vegetation; and
• practical implementation considerations within a conservation tender including data veracity and transaction cost tradeoffs.

The role of the metric in conservation tender is to facilitate the efficient allocation of public funds. The metric is the quantitative measure of the conservation payoff from alternative investment options within program constraints. Efficient allocation requires that the metric is able to accurately describe the relative investment value of two different bids, and not just which provides a higher biodiversity outcome. To this end, we must be confident that a bid that scores twice as high as another bid is in fact desired twice as much, and that we would be ambivalent between the two bids if the higher scoring bid was also twice as expensive (i.e. they must be ratio-scale full comparable per Ebert and Welsch 2004).

There are a number of reasons why existing metric frameworks in Australia, such as those applied in BioMetric (Gibbons et al. 2009), BushTender (Parkes et al. 2003), or
that underpinning Nature Assist (Hajkowicz et al. 2009) are not ratio scale full comparable.\textsuperscript{1} BioMetric and BushTender employ modified condition index approaches to estimate the change in ecological condition for a particular area of native vegetation; partially adjusted for presence of native vegetation in the surrounding landscape. BioMetric applies an additive functional form while BushTender applies a multiplicative form (not a weighted geometric mean). The Nature Assist metric applies a multi-criteria approach to estimate change in utility using an additive functional form. In all cases management actions only apply on the habitat offered.

The theoretical and practical problem is similar for each of these metrics: they do not adequately represent the ecological dynamics and responses to management; are not ratio-scale comparable (or full comparable); and inadequately consider opportunities for on-site management, management in the surrounding agricultural matrix and landscape connectivity. The question is not whether these metrics are wrong, because all metrics represent a simplification of reality, but rather whether we can design an improved metric which can be practicably implemented.

In this paper we first set out a framework for a new metric form that is compatible with ecological dynamics, is ratio-scale comparable and which accommodates opportunities for connectivity and management in the surrounding landscape. We then describe the steps taken to integrate the metric design with the delivery of the current round of the Australian Government Environmental Stewardship program. The paper concludes by discussing some of the advantages of the new approach alongside opportunities for future research.

2. Methodological framework for a new biodiversity metric design

The CVS constructed for the Australian Government’s Environmental Stewardship program (hereafter CVS) must meet a range of specific design needs. The overarching goal is a CVS that satisfactorily scores across the range of eligible investment options and ecological communities under the relevant program. In this instance the CVS framework must be able to accommodate the ecological dynamics and opportunities for management across five nationally endangered ecological communities:\textsuperscript{2}

- Box Gum Grassy Woodlands including derived grasslands in NSW (BGGW);
- Natural Grasslands on Basalt and Fine-textured Alluvial Plains of Northern NSW and Southern Queensland (BAG);
- Weeping Myall Woodlands in NSW (WMW);
- Peppermint Box Grassy Woodland of SA (PBGW); and
- Iron-grass Natural Temperate Grassland of SA (IGG).

The CVS described in this paper was designed to estimate total asset value at a specific point in time (15 years from assessment which is the maximum contract length) but it is relatively easy to convert it to estimate net gain over that time period.

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\textsuperscript{1} Other metric forms have also been used but we are not aware of any which differ substantively in functional form from either of these approaches with the exception of complementarity approaches.

\textsuperscript{2} For more information on these communities and the Australian Government Environmental Stewardship program see: \url{http://www.nrm.gov.au/stewardship/index.html}
Representing ecological dynamics and relative values: state and transition models

S&TMs were originally developed to reflect what were believed to be approximate threshold dynamics in ecological systems. Thus, rather than arbitrarily categorising something that varies continuously S&TMs propose that at least some processes create step-like changes with broadly stable states in between these ‘transitions’. According to these models, areas within a single stable ‘state’ may vary in their ecological condition or value, but they will be more similar to each other in terms of function than they will be to areas in other states. Transitions between states can occur due to a specific action or process (like a particular threat, management action, or natural episodic event) which may be different for each state. State and transition models (S&TMs) play two roles in the CVS framework. First, they provide a simplified model of the ecological dynamics for each target ecological community. Second, the states are surrogates for ranked values within each ecological community.

Incorporating S&TMs into the CVS framework has three specific consequences. First, it assumes that small changes in ecological condition of the asset within the same state are not as important as the transitions between states. The difference between ecological states therefore represents a step change in relative values and the potential marginal gains from investment. Second, the appropriate management actions to prevent a downward transition (loss of state) and to facilitate an upward transition (gain of state) may be specific to the current ecological state rather than universal across a given ecological community. Hence, the CVS framework is structured around the initial state a Primary Management Unit (PMU; the nominated remnant habitat in a bid) is in and the expected ecological state of that habitat in 15 years given the threats present and management actions chosen by the land manager that are specific to that state. Finally, the state attribute definitions identify the specific quantitative thresholds that ecological condition must be distinguished in the field assessment.

The stepwise changes in relative values induced by the S&TM approach mean that the resultant metric design is substantively different to approaches using a continuous condition index. The CVS framework comprises a set of ecological states and with stepwise changes in relative values between these. To invest across several communities using a single conservation tender, the distribution of scores must represent the relative values (or benefits) associated with investment in different ecological communities, and in different condition states in the S&TM within a single community. Therefore we require a methodology for directly comparing the values of ecological states across communities as well as within each community.

The listing statements and status of endangered ecological communities under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) were used to develop a conceptual structure of the policy relationship between values (see Table 1). Rank orderings across the ecological communities were derived from listing statements and the emerging practice of identifying condition classes within the EPBC Act provides a conceptual framework for assembling a rank order of condition states across different ecological communities. Sometimes, but not always, Listed

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3 The S&TMs applied in the MEC were modified from those described in Wall (2010).

4 Whether policy values are appropriate surrogates for community values is not the focus of this paper.
Condition Classes are described as A and B (for example, PBGW and IGG) or Best Quality and Good Quality (as in BAG). In Table 1 the ecological states are defined by the condition of the vegetation (See Appendix A1 for an illustration of the S&TM s using PBGW). A set of final relative values for each ecological state in each target community was set by the Australian Government (not shown in Table 1 for confidentiality reasons).

### Table 1: Relationship between values for each target ecological community and state

<table>
<thead>
<tr>
<th>EPBC Listing status</th>
<th>Score</th>
<th>BGGW</th>
<th>WMW</th>
<th>PBGW</th>
<th>IGG</th>
<th>BAG</th>
</tr>
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<tr>
<td>Listed</td>
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<td>1A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Listed</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5a, 1.5b</td>
</tr>
<tr>
<td>Listed</td>
<td>?</td>
<td>1B</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2.5a, 2.5b</td>
</tr>
<tr>
<td>Listed</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
<td>2A</td>
<td>3</td>
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<tr>
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<td>?</td>
<td>2B</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listed or Unlisted</td>
<td>?</td>
<td>3A</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Listed or Unlisted</td>
<td>?</td>
<td>3B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>4</td>
<td>4</td>
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</tr>
<tr>
<td>Unlisted</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: BGGW states designated as B are commonly referred to as BGGW derived grasslands.

**CVS functional form and conceptual structure**

The next step in constructing an appropriate metric is to determine a form to capture the potential transitions between the ecological states in the S&TM. The resultant score should be ratio-scale full comparable in order to deliver unambiguous estimates of the relative values from investment. The S&TM approach aids this goal because we are interested in the probability of the ecological condition transitioning stepwise within the S&TM rather than directly estimating the detailed ecological condition of the asset. Probability estimates are comparable ratio scales and can be combined into a ratio-scale full comparable CVS. This approach overcomes the problem of interval data and non-comparable ratio-scale data.

The resultant CVS framework is illustrated in Figure 1. The approach involves estimating a score per hectare, which is then adjusted for the total area of the asset offered, the duration of the contract and additional investment security (conservation covenant or similar). The metric applies a multiplicative form \( PMU_{15} \) bounded between zero and 100). The success of management of threats and opportunities for enhanced outcomes are expressly taken into account via the probability of their impact on the ecological state.
A simplified equation form is (the more complex, detailed form is explained in steps below):

\[ CVS = PMU_{15} \times A_{PMU} \times D \times S \]  \hspace{1cm} (1)

And

\[ PMU_{15} = f(PMU_i, P_{loss}, P_{gain}) \]

Where:

- \( PMU_{15} \) = Expected final score for offered remnant in 15 years.
- \( PMU_i \) = Initial remnant score assessed as S&TM state.
- \( P_{loss/gain} \) = Probability of degradation/improvement to a lower/higher S&TM state.
- \( A_{PMU} \) = Area of the PMU in hectares.
- \( D \) and \( S \) are duration of contract and security.

If there are multiple remnants offered then the CVS formula becomes:

\[ CVS = \left[ \sum_{i=1}^{n} (PMU_{i15} \times A_{PMU_i}) \right] \times D \times S \]  \hspace{1cm} (2)

Where the additional subscript \( i \) denotes the relevant PMU (\( i = 1, \ldots, n \)).

The expanded \( PMU_{15} \) detailed in Equation (1) is:

\[ PMU_{15} = PMU_{i-1} \times (P_{loss}) + PMU_i \times (1 - P_{loss}) \times (1 - P_{gain}) + PMU_{i+1} \times (1 - P_{loss}) \times (P_{gain}) \]  \hspace{1cm} (3)

Where:

- \( PMU_{15}, PMU_i, P_{loss} \) and \( P_{gain} \) are all as defined above.
- \( PMU_{i-1}, PMU_{i+1} \) = State score of next lower/higher state.
- \( 1 - P_{loss/gain} \) = Probability that PMU does NOT degrade/improve to lower/higher S&TM state.

S&TM values provide a functional structure for interpreting the likelihood and trajectory of ecological change represented in Equation (3). Potential improvement or loss is limited to a single ecological state. Probabilities of improvements or loss are directly linked to the ecological asset and condition state and more explicit accounting of threats and available management actions. This is a major advance over previous metrics. The probability of state loss is therefore the consequences threats occurring within the PMU estimated as:

\[ P_{loss} = P_{threat} \times P_{degrade} \times (1 - P_{abate}) \]  \hspace{1cm} (4)

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\(^5\) Except for the revised S&TM for BAG.
Where:
P_{\text{threat}} = \text{Probability that threats will be present (0/1 depending on presence absence).}
P_{\text{degrade}} = \text{Probability that threats will be severe enough to degrade PMU to a lower state.}
P_{\text{abate}} = \text{Probability that threat abatement will succeed (0/1 no management/management).}

Where numerous different threats are simultaneously present a cumulative $P_{\text{lossAll}}$ for all the threats combined is calculated:

$$P_{\text{lossAll}} = 1 - [(1 - P_{\text{loss1}})*(1 - P_{\text{loss2}})*(1 - P_{\text{loss3}})*...*(1 - P_{\text{lossN}})] \quad (5)$$

Where: $P_{\text{loss1}}, P_{\text{loss2}}, \text{etc} = \text{Probability that PMU will degrade to lower state due to each relevant threat.}$

We achieve some simplification by ignoring threats that must be managed compulsorily in the Program and those required by law. These threats do not need to be considered in the $P_{\text{loss}}$ equations because they will not help distinguish between the investment values of different land manager bids. $P_{\text{gain}}$ and a cumulative $P_{\text{gainAll}}$ is estimated in a similar way to $P_{\text{loss}}$ (Equations (4) and (5)) based on the probabilities that various management actions will improve the PMU sufficiently that it will make the transition to a higher state (and score). $P_{\text{gain}}$ is conditional on threats being managed effectively (i.e. no degradation to lower state). Assets in best condition (where $P_{\text{gainAll}}$ becomes zero) are not disadvantaged because only management of threats is required to retain the maximum score.

**Including management and impacts from the surrounding agricultural matrix**

An important goal of the current round of Environmental Stewardship funding is expanding the range of on-farm management interventions to include actions within the agricultural matrix surrounding the remnant vegetation. These activities can be described in the metric framework as posing a threat to state from beyond the remnant; i.e. an external threat. Similarly, the threat of ecological isolation will occur if the remnant is too small or too distant from other similar vegetation to support self sustaining populations within the ecological community.

External threats from adjacent land uses such as deposition of nutrients and other chemicals, invasion of weeds, and root damage from cropping are conceptualised as edge effects. These external threats to the remnant can be abated by additional management actions in a buffer directly adjacent to the offered remnant. Buffering actions are only considered to abate threats, not enhance the remnant (hence no $P_{\text{gain}}$). The edge effect concept means that damage is dependent on the area subjected to the threat. For example, physical damage from edges exposed to cropping, may extend 20 metres into a remnant (hence require a 20 metre buffer), while enhanced nutrient impacts may penetrate more than 150 metres (see Lovell & Sullivan 2006). $P_{\text{loss}}$ for external threats and their associated buffering management actions:

$$P_{\text{loss}} = P_{\text{threat}} * P_{\text{degrade}} * [(W_{\text{EE}} * (\text{Perimeter} - 4 * W_{\text{EE}}) / 10,000) / A_{\text{PMU}}] * [1- (P_{\text{abate}} * BP / \text{Perimeter})] \quad (6)$$

Where:
$P_{\text{threat}}, P_{\text{degrade}}, P_{\text{abate}}, A_{\text{PMU}}$ are defined as above.

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Note a correction factor $4*W_{\text{EE}}^2$ is applied to $P_{\text{degrade}}$ to ensure that corners are not double-counted which when simplified produces the form shown in Equation (6).
**Perimeter** = Perimeter distance around PMU offered in metres

**WEE** = Width of edge effect is the depth to which threat penetrates the PMU for each relevant threat in metres

**BP** = Buffered perimeter as proportion of total (thus allowing partial abatement)

\[ W_{EE} \times \left( \frac{\text{Perimeter} - 4 \times W_{EE}}{10,000} \right) / A_{PMU} \text{ to a maximum of 1.} \]

Functional ecological isolation of a remnant prevents the flow of native individuals and their genetic material into a remnant thus creating an isolation threat (Debinski & Holt 2000; Lindenmayer & Fischer 2006). The seriousness of the isolation \( P_{\text{degrade}} \) depends the patch size. Very small patches will have a high likelihood of losing state while patches above a certain threshold size will have essentially no chance of losing state due to isolation effects (within 15 years). Isolation threats are abated by fostering connectivity in the surrounding landscape. The practical application of the isolation concept in MEC is limited to woodland communities (BGGW, PBGW, WMW) because it has not been possible to develop a suitable remote assessment technique for grassland communities. The isolation threat is somewhat different from all other threats because management actions influence \( P_{\text{degrade}} \) rather than \( P_{\text{abate}} \). Thus, for isolation threats \( P_{\text{loss}} \) is:

\[ P_{\text{loss}} \text{ (Isolation)} = P_{\text{threat}} \times P_{\text{degradeI}} \]

And

\[ P_{\text{degradeI}} = \left[ \left( 1 - \frac{A_{CP}}{A_{NIT}} \right)^3 \right] / 2 \]

Where:

- \( P_{\text{threat}} = 1 \) for isolation (because it is always assumed to be a potential threat)
- \( P_{\text{degradeI}} = \) Probability that isolation will lower state after including the effects of connectivity management (if any undertaken) to increase the effective size of the patch
- \( A_{CP} = \) Area of connected patches up to a maximum of \( A_{NIT} \) (\( A_{CP} \geq A_{NIT} \) Then \( P_{\text{degradeI}} = 0 \))
- \( A_{NIT} = \) Patch area at which no isolation threat (NIT) is considered present

Equation (8) is based on a pragmatic application of broad ecological theory and expert ecological opinion (see e.g., Soulé 1987).

Treating isolation as a threat ignores the possibility that the remnant may offer critical positive benefits to the surrounding landscape as a connectivity node or anchoring patch. Reeson et al. (2009) discuss the practical impossibility of capturing all landscape values in a site oriented metric such as that described here.

### 3. Integrating data needs and implementation

Collecting and processing the data necessary to construct the CVS is likely to be the largest single transaction cost in program implementation. However previous metrics have been criticised for accuracy in data collection (Gorrod and Keith 2009, Whitten et al. 2009). Therefore an important aspect of integrating metric design with implementation requires development of processes that seek to jointly minimise cost and errors in data collection.

Three sequential steps are used in the MEC tender to reduce potential transaction costs and minimise data collection errors: eligibility; data collection; and data capture checks. First, prior to field assessment incurring costs, additional attention has been given to landholders understanding the eligibility and tender process. This step is

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designed to minimise the possibility of ineligible sites being visited or landholders deciding not to proceed after field assessment.

Second, the use of S&TM models mean that the emphasis is on distinguishing between ecological state rather than on fine scale measurements of ecological condition. Collection of ecological data is therefore focused on collection of condition attributes which change markedly across ecological states and which differ depending on which ecological community and state transition is being considered. Though less data is collected within the remnant, greater attention must be paid to which data is collected in which community. Data must also be collected to identify the presence/absence of threats within and beyond the remnant. Thus, there are a range of different and highly specific data collection tasks. A Rapid Assessment Protocol (RAP) was developed to specify all stages of data collection. As an example of the level of detail considered, the on-ground vegetation data were designed to focus on variables that could be assessed rapidly on a 50m x 20m plot thus minimising field assessment time and cost.

The third step is the construction and use of a standard data capture tool (the MEC CVM Tool)\(^8\) which captures and then processes each data item required to calculate the CVS. The CVM Tool aids in quality control of data via limiting data that can be entered to appropriate values. Interactive elements are also included by determining which management actions are appropriate for a given remnant and what their relative priorities are (i.e., high, medium, etc.), to help the land manager decide which management actions to undertake. Different access permissions allow the MEC CVM Tool to simultaneously support field assessment via data capture and management advice, and to calculate CVS for transfer to bid evaluation.

4. Discussion and conclusions

Government investment in biodiversity conservation has traditionally focused on the acquisition and management of public protected areas. Threats to biodiversity are unlikely to be adequately addressed without a stronger emphasis on landscape scale conservation that straddles public and private land, and that incorporate incentives that operate through competitive markets (Zammit et al 2010). The Environment Stewardship MEC project represents a significant improvement over previous metrics by applying a functional form that is more consistent with both economic and ecological theory. In particular the approach:

- more accurately captures ecological dynamics by incorporating S&TM into metric design;
- fosters systematic incorporation of management interventions responding to threats and opportunities to enhance ecological condition;
- expands the range of on-farm management interventions to include actions within the agricultural matrix surrounding the remnant vegetation; and
- integrates implementation with metric design via a more efficient field assessment process and measures aimed at improving accuracy of assessment.

While these advances to conservation metrics have progressively improved the ability of investors to select the best value for money bids at the enterprise level, they do not

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\(^8\) The tool was assembled using Microsoft Access® software and rolled out using Access runtime.
yet incorporate a formal consideration of the spatial distribution of the target assets with a catchment or region. It is therefore likely that the optimal conservation outcomes for a landscape or region are not being fully realised through existing conservation tenders. Development of landscape oriented metrics such as those suggested by Reeson et al. (2009) would more accurately capture these benefits.

The Environmental Stewardship program only invests in nationally endangered communities under the EPBC Act and the MEC project reflects progression from previous tenders that targeted single assets such as box gum grassy woodlands. Even so, constraints imposed by limiting investment to co-occurring nationally endangered communities that are suitable for tenders mean that MEC-style approaches will remain inefficient. Future tenders may overcome this constraint in part by targeting both endangered species and/or ecological communities in a region. The associated metric design would need to capture anticipated improvements in habitat condition or extent for a potentially large mix of nationally endangered species and/or ecological communities and their spatial arrangement – a significantly more complex task than that described in this paper.

References


1.1


Appendix 1: Simplified State and Transition Model: Peppermint Box Grassy Woodland

**STATE 1**
- Mature or adult trees present, and saplings or seedlings present
- 5-70% canopy cover (pfc)
- > 30 native plant species
- > 75% nativeness of plant groundcover (herbaceous plants and small shrubs <1m tall)
- Never fertilised, or > 40 yrs since last fertilisation

**STATE 2**
- Mature or adult trees present, and saplings or seedlings present
- 5-70% canopy cover (pfc)
- 15-29 native plant species
- 50-74% nativeness of plant groundcover (herbaceous plants and small shrubs <1m tall)
- Fertilised <3 times, with last application between 1990-2005 or fertilised <5-6 times, with last application between 1965-90

**STATE 3**
- Mature or adult trees present, seedlings and saplings absent
- 5-70% canopy cover (pfc)
- 5-14 native plant species
- 10-49% nativeness of plant groundcover (herbaceous plants and small shrubs <1m tall)
- Fertilised 3-6 times, with last application between 2005-10 or fertilised 4-10 times, with last application between 1990-2005

**STATE 4**
- No or very few mature or adult trees present, seedlings absent
- <5% canopy cover (pfc)
- 1-4 native plant species
- <10% nativeness of plant groundcover (herbaceous plants and small shrubs <1m tall)
- Fertilised > 10 times with last application between 2005-10

**STATE 5**
- No tree age classes present
- 0% canopy cover (pfc)
- No native plants (crops or sown exotic pasture)
- Fertilised > 10 times with last application between 2005-10

**Source:** Modified from Wall (2010)