Threatened Species Recovery Hub

National Environmental Science Programme

A general ecosystem model to guide conservation planning for diverse woodlands of southern australia

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Acknowledgement of Country

Much of this work was conducted on the unceded land of the Wathaurung, Boonwurrung and Woiwurrung peoples; we acknowledge the Traditional custodians of these lands and their long and enduring connection to Country. Field data were collected from across the south of the continent, including the Traditional Lands of the Taungurong, Yorta Yorta, Djadjawurung, Kamilaroi, Wiradjuri, Nyaki Nyaki, and Balardung peoples.

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Cover image:
Top left: A grassy woodland roadside remnant in an 'Exemplar' state. Image: Libby Rumpff
Top middle: A billabong in a remnant grey box woodland. Image: Megan Good
Top right: A 'transformed' woodland landscape. Image: Libby Rumpff
Bottom left: A 'thicket' woodland condition state. Image: Libby Rumpff
*Bottom middle: Obligate-seeder gimlet (*Eucalyptus salubris*) woodland, with a chenopod shrubby understorey. Image: Carl Gosper*
*Bottom right: Obligate-seeder gimlet (*Eucalyptus salubris*) woodland, with a sclerophyll shrubby understorey. Image: Carl Gosperr*

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Executive summary

There are 24 southern Australian eucalypt woodland communities listed as threatened under the Environment Protection and Biodiversity Conservation Act (EPBC Act; 16 Critically Endangered, 8 Endangered) but just 5 of these communities currently have national recovery plans. Under the EPBC Act, listed communities are not necessarily required to have recovery plans, but many have recommendations (in the 'Conservation Advice') that indicate they are required. Conservation planning information is also contained in the Conservation Advice document, which is required for all listed communities.

This work seeks to document expert understanding of where we can generalise and transfer understanding from one system to another to aid effective conservation management, without losing critical aspects of what defines each distinct woodland type. We used State Transition Models (STMs) to articulate the different starting and end points for restoration, clarify the key threats impeding recovery, and explore and justify which interventions can be harnessed to best target threats. By providing a basis to transfer understanding from one woodland type to another, the outcomes from this project will inform recovery planning for listed woodlands.

Experts were grouped according to expertise in three distinct woodland types (floodplains, grassy and shrubby/obligate seeder woodlands). Through a series of online surveys and face-to-face workshops, experts estimated commonness of condition states in each woodland type, the likelihood of transitions occurring between individual states, as well as the factors and drivers required for these transitions to occur. We used this information to explore generalities and deviations among woodland types in terms of threats and opportunities for woodlands in southern Australia.

The following are some of the key findings from the project:

- Woodland experts were able to define a series of 8 condition states that were based on measurable vegetation attributes.
- Overall, there was a high level of consensus among experts and among woodland types. Livestock grazing, rainfall and tree clearing were all major drivers of transitions among condition states in all three woodland types. Notable differences in the drivers of change in the woodland types tended to be due to differences in their basic ecology and reliance on resource pulses and disturbance regimes. For example, only floodplain woodlands rely on appropriate flood regimes for tree recruitment, and similarly, fire played a more important role in grassy and shrubby woodland transitions.
- The results from the expert elicitation process were used to create decision trees and a Guide to advise on the recovery of woodlands in different conditions states, across the different woodland types. The Guide includes important information about how to avoid threats, how to improve degraded states, as well as how to 'stay the same' when woodlands are already in desirable conditions states.
- The decision trees highlighted where specific advice is warranted, based on the expert data. However, many of the management recommendations are relevant to the three woodland types, indicating that despite differences in the composition, structure and function of the three woodland types, management advice is likely to be relatively consistent. This provides excellent justification for the development of a genersalised STM for southern Australian woodlands, to support a multi-community recovery plan.
- We collated and analysed field data from different condition states and woodland types across southern Australia. Drawing general conclusions was difficult due to the lack of replication across woodland types and geographic space, and the different sampling methods utilised. However, we were able to explore each dataset to determine whether certain attributes are useful for distinguishing between condition states (highlighted in the Guide), and thus might be useful in targeted monitoring strategies. The four most selected attributes irrespective of condition state pair were: (1) Tree density; (2) Exotic cover; (3) Native understorey diversity/richness; and (4) Native understorey cover.
- Though the decision trees are currently focused on managing for vegetation condition, we collaborated with fauna experts to identify how the general model could be updated to incorporate any threats and management specific to fauna. In the interim, a decision tree to support habitat attributes was developed and incorporated into the Guide.
- More broadly, in this project we have developed and demonstrated i) a robust and transparent process for eliciting general models to support recovery planning; ii) a structured analytical framework for assessing which monitoring attributes best distinguish condition states, and the thresholds that could be used to evaluate progress toward conservation (condition state) objectives; and iii) a framework for developing a Guide to support conservation planning of ecological communities, underpinned by STMs and decision trees to guide management.

General introduction

- There is a need for streamlined conservation planning for listed woodland communities.
- Broader ecosystem management models that clearly describe existing information and indicate the generality or specificity among the full suite of ecosystems can be useful, or indeed critical, for guiding future management
- Expert elicitation was used to build a general ecosystem model, using a state-transition model framework
- The model was validated with field data to explore targeted monitoring attributes, and refined further with input from fauna experts about habitat requirements to create a interactive management guide

Building the woodland ecosystem model: vegetation expert elicitation

- Experts described:
  - general condition states and their key attributes
  - likely transitions between pairs of condition states
  - the key threats and management interventions driving transitions
- General woodland STMs were developed for floodplain, grassy and shrubby/obligate seeder woodlands
- Decision trees were developed to guide management

2. Validating the general ecosystem model using field data

- Woodland ecologists from across southern Australia contributed vegetation survey data; allocating each site to a condition state
- To aid targeted monitoring programs
  - Classification regression tree analysis was used to identify key attributes that distinguish states.
  - Logistic regression was used to identify (monitoring) threshold values for attributes between pairs of states.

3. Building on the woodland ecosystem model: fauna expert elicitation

- Participants with expertise in a range of woodland fauna groups completed a survey and attended a 1-day virtual workshop.
- They identified a number of key habitat attributes to add to the model.
- Experts highlighted the importance of fauna as ecosystem engineers, the need to set ambitious restoration targets that include fauna, and the challenges of developing integrated STMs (e.g. landscape vs site scale models).

4. A general guide for conservation planning in eucalypt dominated woodlands of southern Australia

An interactive series of fact sheets aimed at policy makers and on-ground managers to provide:

- summaries of the key threats, management interventions, and key monitoring variables for each woodland condition state
- decision trees for each positive state-transition, to guide management decisions based on site-scale conditions

Figure 1. *The outline of the project. Each part (1-4) is described within this report.*

General introduction

Australian woodlands constitute some of the most extensive and yet exploited ecosystems in Australia. Occupying vast areas of Australia, they coincide with some of the most productive land in the country, resulting in extensive historical and ongoing land clearing, degradation due to grazing, and alteration to flooding and fire regimes (Yates and Hobbs 1997; Vesk and McNally 2006). As a result, many woodland communities and woodland dependant species are now listed as threatened under national and state legislation.

Listing under legislation does not necessarily lead to positive conservation outcomes, without regulation and continued management. Within Australia, management plans created through state and federal government programs aim to provide guidance for conserving and protecting threatened and endangered species and ecological communities. There are 24 eucalypt woodland communities listed as threatened under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (16 Critically Endangered, 8 Endangered), but only 5 of these currently have a recovery plan in place (Commonwealth of Australia, 2021). Under the EPBC Act, listed communities are not necessarily required to have recovery plans, but many have recommendations (in the 'Conservation Advice') that indicate they are required. Conservation planning information is also contained in the Conservation Advice document, which is required for all listed communities.

Resource and time constraints are considerable impediments for the development and implementation of well-researched management plans. Incomplete or ill-informed plans can lead to poor decision-making, wasted resources, and potential decline or loss of species or communities. Obtaining the relevant information from the scientific literature or from other resources can be difficult even for well-studied ecosystems. For less well studied ecosystems, it is difficult to find relevant information or determine what knowledge can be transferred from other ecosystems. Broader ecosystem management models that clearly describe existing information and indicate the generality or specificity among the full suite of ecosystems can be useful, or indeed critical, for guiding future management.

Conservation and recovery plans are typically developed one at a time, and resources for conservation assessment and recovery planning are scarce. As such, there is a critical need for a more cost-efficient approach to the recovery planning process, which can expedite the provision of guidance on appropriate woodland management interventions for land managers. The question is, can we generalize to aid effective conservation management without losing critical specifics of floristically or geographically distant woodlands?

The ecology, conservation and management of woodland communities is variable across southern Australia. Yet commonalities exist in ecosystem and community structure, ecosystem functions and demographic processes. In addition, although there are different land use histories, woodlands have been subject to pressure from pastoralism and cropping across their range. While woodlands comprise diverse ecological communities, scientists and mangers need to be able to determine whether idiosyncratic ecologies exist, and where different management strategies are needed.

Under the National Environmental Science Programme (NESP) Threatened Species Hub Projects 1.2.5 and 7.2, we worked with scientists and land managers from the Department of Agriculture, Water and the Environment (DAWE), state agencies, research institutions, and not-for-profit organisations to identify whether there is a place for an overarching classification of southern Australian eucalypt woodlands that can aid the EPBC listing and recovery planning process. Project collaborators have expertise in floodplain, temperate, subtropical and obligate seeder eucalypt woodlands, predominantly from southern Australia. Most of these woodland types have associated EPBC listed (or nominated) communities.

Our overall aim was to synthesize the ecological knowledge base necessary to support the conservation and recovery planning process for threatened woodlands. This project sought to evaluate the use of generalised State Transition Models (STMs) for the provision of conservation advice and recovery planning for EPBC-listed communities, using the test-case of the inland Eucalypt woodlands in southern Australia.

The benefit of state-and-transition models in this context is that they can be used to represent different motivations for management, by articulating the different 'states' of condition (structure, function and composition) of a community that might be targeted for restoration or protection. These models can thus provide a more nuanced platform for discussing the threats and drivers influencing pathways for restoration, and justifying the management interventions necessary to achieve a transition or avoid degradation.

Giving advice on what management is required for a recovery plan first requires an understanding of the management objective for the relevant community or landscape. We will use STMs to articulate the different starting and end points for restoration, clarify the key threats impeding recovery, and explore and justify which interventions can be harnessed to best target threats. By providing a basis to transfer understanding from one woodland type to another, this project will mean that recovery plans can be more rapidly developed within the constraints on the process.

Australian woodlands are an excellent test-case for the development of a general ecosystem model because although the ecology, conservation and management of woodland communities is variable across southern Australia, commonalities exist in ecosystem and community structure, and ecosystem functions and demographic processes. While woodlands comprise diverse ecological communities, scientists and mangers need to determine whether idiosyncratic ecologies exist, and where different management strategies are needed. In this study, we asked:

- Can we build a general ecosystem model for southern Australian woodlands while maintaining measurable and testable management information?
- Can we use this hypothetical model to create conservation plans, recovery plans and other policy instruments to achieve measurable outcomes?

The project ran over several years and involved the following steps (Figure 1):

1. Expert elicitation: Woodland experts from across southern Australia participated in a series of online surveys and in-person workshops to create a general State and Transition Model that can be used as a template for the management of temperate Australian eucalypt woodlands. This involved defining the general condition states, describing possible transitions between condition states and identifying possible threats and management interventions as well as vegetation attributes that might indicate transitions had occurred.
2. Exploring the model with field data: Following the expert elicitation phase, we gathered field datasets and asked dataset contributors to assign each of their field sites to one of the eight condition states. We used the vegetation attributes collected in each of datasets to explore differences in the way field ecologists interpreted the condition states, and how the vegetation attributes varied among condition states within datasets. We also identified vegetation attributes that are best able to distinguish between pairs of condition states.
3. Expert elicitation – fauna: We invited woodland fauna experts to participate in a survey and virtual workshop to elicit feedback and ideas for how to increase the relevance of our vegetation focused Woodland Ecosystem Model. Experts listed threats, management options, habitat attributes and indicator species for each condition state.
4. Condensing the project into a user-friendly Guide: The Guide is an attempt to bring together the expert knowledge and field data to create an interactive and practical framework to streamline the process of building recovery plans and designing robust monitoring and ecosystem management projects for listed woodland communities.

Definitions

We refer to several terms throughout this report, which are defined in Table 1.

***Table 1** Key terms used in this report with their meanings and any relevant literature.*

Term	Meaning
Ecological community (EC)	"a group of native plants, animals and other organisms that naturally occur together and interact in a unique habitat" (http://www.environment.gov.au/biodiversity/threatened/communities)
Woodland	A term generally used in Australia to describe ecosystems which contain widely spaced trees, the crowns of which do not touch (Yates and Hobbs 1997; https://www.environment.gov.au/land/woodlands)
Woodland types	Representative of temperate woodlands from the Australian Ecosystem Models Framework (Richards et al; Figure 1), with the exception of temperate sedgy-shrubby woodlands. The temperate woodland types referred to in this report include 'Floodplain woodlands', 'Shrubby/Obligate-seeder woodlands' (which combine obligate-seeder and dryland temperate shrubby woodlands from Figure 1) and 'Grassy' woodlands (i.e. dryland temperate grassy woodlands from Figure 1).
Woodlands of southern Australia	These include grassy, shrubby, floodplain or obligate-seeder woodlands from the following Australian bioregions below the Queensland border: MUL - Mulga Lands, SEQ - South Eastern Queensland, COP - Cobar Peneplain, DRP - Darling Riverine Plains, MDD - Murray Darling Depression, NAN - Nandewar , NET - New England Tablelands, NNC - New South Wales North Coast, NSS - New South Wales South Western Slopes, RIV – Riverina, SCP - South East Coastal Plain, SEC - South East Corner, SEH - South Eastern Highlands, SYB - Sydney Basin, VIM - Victorian Midlands, BEL - Ben Lomond, FUR – Furneaux, KIN – King, TCH - Tasmanian Central Highlands, TNM - Tasmanian Northern Midlands, TNS - Tasmanian Northern Slopes, TSE - Tasmanian South East, TSR - Tasmanian Southern Ranges, TWE - Tasmanian West, EYB - Eyre Yorke Block, FLB - Eyre Yorke Block, KAN - Kanmantoo, NCP - Naracoorte Coastal Plain, GAW - Gawler, AVW - Avon Wheatbelt, COO - Coolgardie, ESP - Esperance Plains, GES - Geraldton Sandplains, HAM - Hampton, JAF - Jarrah Forest, MAL - Mallee, WAR - Warren, YAL - Yalgoo, SWA - Swan Coastal Plain.
States and state attributes	States can be defined in relation to various structural, functional and compositional attributes, which we refer to in this report as state attributes. A state is recognised as distinct if recovery of the state is dependent on "unacceptably long recovery times, active restoration, extreme events, or a reversal of climatic change that occurs over several decades or never occurs" (Bestelmeyer et al 2017). That is, a change from one state to another does not necessarily imply that threshold values in the state attributes have been reached (i.e. Bestelmeyer 2006).
Transitions	*Transitions* can be classed as *direct* or *indirect*, and are triggered by *drivers*. Direct transitions are those that do not necessitate a move through any other state within the time period specified.
Drivers	A driver is external to the system and can cause a gradual or abrupt change in controlling variables (e.g. processes), which affect state attributes. Drivers can be a positive driver of change (i.e. a management intervention), or a threatening process (threat).

1. Part One: Building the woodland ecosystem model

1.1 Summary

- We attempt to use generalised woodland knowledge to inform recovery plans and other policy instruments for vegetation communities that have been less well studied.
- We used an expert elicitation process to create general State Transition Models (STM) for southern Australian woodlands.
- Woodland experts agreed upon the existence of 8 condition states across different woodland types. When asked to consider the drivers and threats associated with transitions among states and the likelihood of transitions occurring between states, responses varied among woodland types. However, a remarkable level of consensus was reached among experts both within and among three broad woodland types. Livestock grazing, rainfall and tree clearing were all major drivers of transitions among condition states in all three woodland types. Differences among woodland types tended to reflect differences in their basic ecology and reliance on resource pulses and disturbance regimes. For example, only floodplain woodlands rely on appropriate flood regimes for tree recruitment, and similarly, fire played a more important role in grassy and shrubby woodland transitions.
- Synthesis and applications: The STM framework allowed a group of woodland experts with a diversity of experience in woodland research and management to articulate the different starting and end points for restoration, clarify the key threats impeding recovery, and explore and justify which interventions can be harnessed to best target threats. The results from the expert elicitation process were used to create decision trees to advise on recovery of woodlands in different conditions states, across the different woodland types.

1.2 Introduction and approach

Over a two-year period from 2016-2018, two expert workshops and a series of online surveys were undertaken to develop and compare state-and-transition models from diverse woodland types across southern Australia to identify and describe:

- The range of states and transitional pathways that commonly occur in southern Australian woodlands
- The key threatening processes that are most influential in enacting transitions across the spectrum of woodlands, and
- The management interventions that drive transitions between condition states.

1.2.1 Step 1: Selecting a group of Australian woodland experts

Woodland experts were chosen based on their knowledge of different woodland types, across a large geographic area. Many of the woodland experts involved in this research were not comfortable linking their expertise to the individual listed communities (Table 2) but could share their knowledge in relation to the different woodland types. Thus, the workshop focused on looking at similarities and differences for 3 types of woodlands from the CSIRO Australian Ecosystem Models Framework (Richards et al. 2020; Figure 2): Grassy, Floodplain, and Shrubby and Obligate seeder (combined).

1.2.2 Step 2: Identifying and describing states

Defining and describing the condition states was an iterative process spanning two workshops and two online surveys and incorporating knowledge from 35 experts. The first workshop in 2016, involved a discussion among 17 Australian woodland experts identified a generalised set of woodland states relevant to southern Australia. These states were described in relation to key structural, compositional and functional vegetation attributes and were based on the woodland condition states described in Rumpff et al 2011. All states were described without reference to land management history (i.e. only in relation to vegetation attributes) and did not include attributes specifically used by fauna (i.e. hollows, logs).

These woodland states were used in the first online survey sent to a larger group of participants in preparation for the second workshop. This survey gave participants the opportunity to consider the proposed states and their attributes so that they could participate in the further refinement of the states at the workshop. Indeed, we spent time at the beginning of the second workshop clarifying and improving the state definitions to reduce linguistic ambiguity as much as possible. We also spent time clarifying state names to ensure there were no land-uses associated with the names, to increase the generalisability of the model (Figure 3; Table 4).

We also asked experts (in a survey, with follow-up discussion at Workshop 2) to specify which vegetation attributes could be used to best distinguish between different states. A list of 10 state attributes was produced: native understorey richness, native understorey cover, exotic understorey cover, midstorey (shrub) density (per hectare), sapling tree density (per hectare), mature tree density (per hectare), level of Colwell phosphorus (Colwell P, mg/kg), available nitrogen/nitrates (mg/kg), pH and the presence or absence of grazing sensitive species. We designed a second structured elicitation survey to obtain quantitative values for each of these attributes (Supplementary Material S1.2)

We considered the results of the second survey preliminary as we only obtained responses from 2 experts for Floodplain/Riparian woodlands, 2 for Grassy woodlands and 1 for Shrubby/Obligate Seeder woodlands. In addition, a best-practice elicitation protocol would include the opportunities for experts to discuss and revise their estimates if desired, before calculating a group average (Hanea et al 2016). We expect the quantification in states to be an important potential source of variation between woodland types , and across southern Australia. This is further investigated using field data in Part 2 of this report.

1.2.3 Step 3: Which transitions are plausible among woodland types?

In order to elucidate which transitions were possible between pairs of states, we circulated an online survey that asked experts to i) identify which woodland types they were familiar with, and; ii) specify which transitions they expected to see for each of the woodland condition states. The aim was to determine whether there was a consensus model structure among woodland types, and if not, where the differences in transitional pathways occurred. The survey results provided us with 32 responses (from 18 experts, for three woodland types) for each of the possible transitions, and from this data we built Directed Acyclic Graphs (DAG) describing transitions for each woodland type. During the subsequent workshop, we divided experts into three groups, corresponding to three woodland types: Floodplain/Riparian, Grassy, and Shrubby/Obligate seeder. The groups were provided with the DAGs that summarized all survey responses (irrespective of which woodland type they were from), as well as those relevant to the groups' specific woodland type. We asked groups to review and compare the set of DAGS and discuss which transitions are plausible for their relevant woodland type, before sharing findings with the broader group. Our aim for the discussion was to gain a shared understanding of whether an overarching consensus model for woodlands in southern Australia exists, and if not, where the main differences occurred between woodland types.

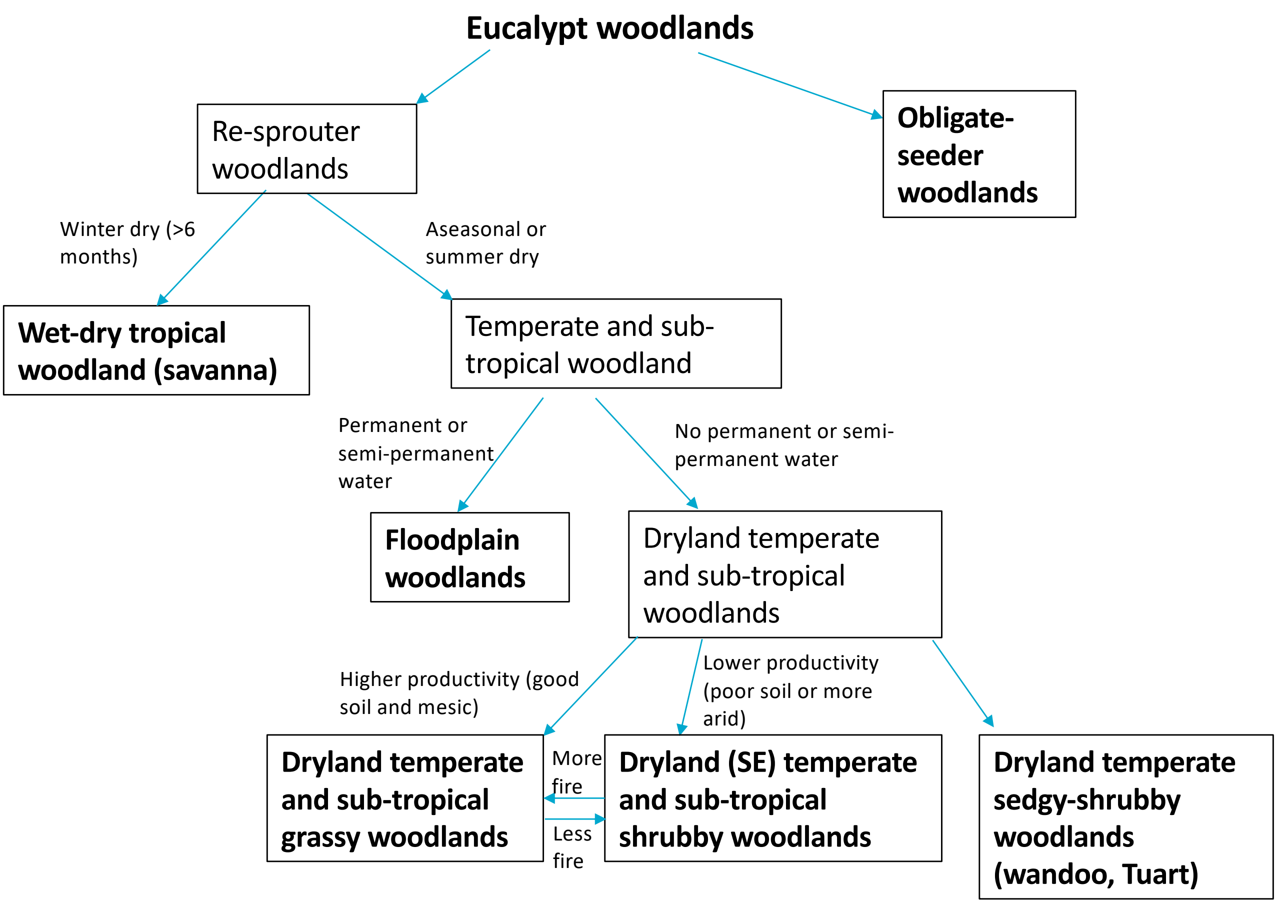


Figure 2. Australian Ecosystem Models Framework: Woodlands (image supplied by S. Prober and A. Richards, CSIRO). This project refers to temperate woodlands only, but does not include the sedgy-shrubby woodlands.

Table 2. *EPBC listed woodland communities of southern Australia examined in the 2018 workshop, with the associated woodland types used in this project.*

Community	State	Threat Status	Woodland types	Number of Experts
Grey Box (*Eucalyptus microcarpa*) Grassy Woodlands of South-eastern Australia	SA, VIC, NSW, ACT	Endangered	Grassy and Shrubby	14
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	SA, VIC, NSW, QLD, ACT	Critically Endangered	Grassy	11
Grassy Eucalypt Woodland of the Victorian Volcanic Plain	VIC	Critically Endangered	Grassy	7
Lowland Grassy Woodland in the South East Corner Bioregion	VIC, ACT, NSW	Critically Endangered	Grassy and Shrubby	4
Eucalypt Woodlands of the Western Australian Wheatbelt	WA	Critically Endangered	Obligate-seeder and Grassy	3
Gippsland Red Gum (*Eucalyptus tereticornis* subsp. *mediana*) Grassy Woodland and Associated Native Grassland	VIC	Critically Endangered	Floodplain and Grassy	3
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregion	NSW, QLD	Endangered	Floodplain and Grassy	2
New England Peppermint (*Eucalyptus nova-anglica*) Grassy Woodlands	NSW, QLD	Critically Endangered	Grassy and Shrubby	2
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest	NSW	Critically Endangered	Grassy and Shrubby	2
Illawarra and South Coast Lowland Forest and Woodland	NSW	Critically Endangered	Grassy and Shrubby	2
Eucalyptus ovata Forest and Woodland in Tasmania	TAS	Nominated	Grassy and Shrubby	2
Kangaroo Island Narrow-leaved Mallee (*Eucalyptus cneorifolia*) Woodland	SA	Critically Endangered	Shrubby	1
Peppermint Box (*Eucalyptus odorata*) Grassy Woodland of South Australia	SA	Critically Endangered	Grassy and Shrubby	1
Western Sydney Dry Rainforest and Moist Woodland on Shale	NSW	Critically Endangered	Shrubby	1

1.2.4 Step 4. What are the drivers of transitions?

Using the states and transitions that were deemed plausible by the three woodland groups in the workshop (Step 3), each group was asked to consider each individual transition, and create a series of plausible cause-and-effect pathways (see Supplementary Material S1.1). The cause-and-effect pathways identified drivers that need to occur together or in sequence, for the transition to take place. The drivers could be classified as either: environmental drivers (e.g. drought), land-use or management drivers (e.g. grazing), or ecological processes (e.g. nutrient cycling). Participants were asked to be as specific as possible regarding the nature and direction of the drivers, particularly for broad threats which encompass different threats, like 'climate change'. For example, instead of just specifying 'drought', participants were asked to write 'increasing drought frequency or duration'.

The workshop groups were also asked to identify which state attributes could be used to indicate that the transition has taken place (e.g. shrub cover or immature stems), and whether the transitions could occur over 20 or 100 years.

Finally, for each cause-and-effect pathway, the groups estimated the likelihood of this pathway/sequence of events occurring in their woodland type, using six qualitative categories (Table 3). Each likelihood category was assigned a quantitative score, so that the average likelihood for a transition (given all possible causal pathways) could be compared across woodland types.

Table 3. *Likelihood categories assigned to each casual chain by participants, and the quantitative scores assigned to each category for use in analysis.*

Likelihood	Likelihood Score
Almost_No_Chance	0.00
Very Unlikely	0.17
Unlikely	0.33
Neither_Likely_or_Unlikely	0.50
Likely	0.75
Very_likely	1.00

1.2.5 Step 5. Developing management recommendations

We used the causal-chain expert data from Step 4 to inform management recommendations for each woodland state. These recommendations are presented as decision trees, which step users through a series of if/then questions, based on observed outcomes from monitoring.

These decision trees accounted for all the suggested management recommendations (from Step 4) aimed at making transitions to an improved state. Note that the recommendations provided assume that certain vegetation condition states are preferable to others. Last, if management actions were specific to a particular woodland type, this is reflected in the decision tree.

Accompanying the decision trees, we present summary information for each of the condition states, including:

i. A description of each condition state,

ii. How common each state is within each of the woodland types

iii. Recommendations for how to:

- maintain or increase the likelihood of transition to an improved state (decision trees)
- avoid degradation (or a negative transition)

1.3 Key Findings

1.3.1 How common are the woodland states?

The groups were asked to specify how common each condition state is for their respective woodland type, using five qualitative categories; (Table 5). Results were varied, but across all woodland types Transformed was the most common state, and the most intact vegetation condition states, Exemplar, Simplified 1 and Simplified 3, were scarce. Simplified 2, Simplified 4 and Overstorey Thicket were common in at least one woodland type only.

There were also differences among woodland types and this was likely due to the inherent differences in the 'arability' of the soil and tendency for certain vegetation types to be more impacted by agricultural transformations than others (i.e. floodplain and riparian woodlands are very fertile and grassy woodlands naturally provide more fodder for grazing animals, whereas shrubby woodlands tend to occur on less productive land and are less likely to be grazed or cropped). We assume that the experts rated the commonness based on the current extent of their woodland types, but this is an issue that may need to be resolved.

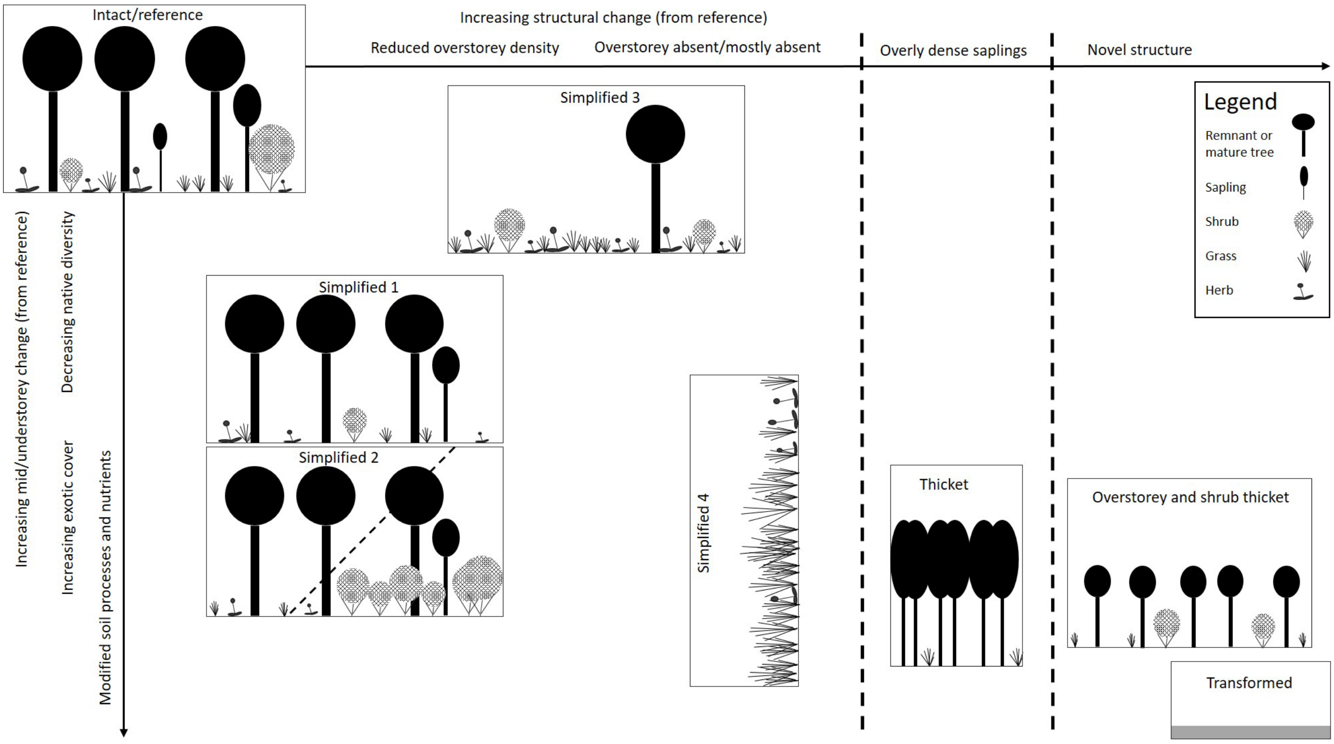


Figure 3. *Conceptual model describing the woodland condition states (developed by Carl Gosper and Megan Good). This figure was developed for communication purposes, and to accompany the descriptions in Table 4.*

Table 4. *Qualitative state descriptions, according to structural, compositional and functional attributes. Note, the land uses provided are not comprehensive, but provided to aid communication.*

Name	Example Land Use	Description
Exemplar	remnants or reserves	The best of the best, but not necessarily pre-1788. All vegetation strata are intact; understorey species richness is high and includes disturbance-sensitive species; low weed cover; soil is stable and has a natural nutrient balance
Simplified 1	travelling stock reserve	Overstorey is mostly intact; mid/understorey is depleted in both richness and cover; understorey flora is primarily native; soil nutrient levels are natural, or close to natural
Simplified 2	road reserve	Overstorey is mostly intact; mid/understorey is depleted in richness; midstorey can be elevated in cover; exotic annual herbs present and may be prevalent; altered soil processes
Simplified 3	derived native pasture	Overstorey mostly absent; midstorey depleted but understorey remains mostly intact
Simplified 4	native pasture, grazing land	Overstorey is depleted or absent; midstorey is absent or depleted; understorey is depleted in native species richness and cover
Overstorey Thicket	destocked pasture	Overly dense overstorey; very low understorey species richness, low under/mid storey cover; understorey may be dominated by natives of exotics; soil stability may be compromised
Overstorey and Midstorey Thicket	revegetated sites	Few to no mature trees; high density of shrubs and tree saplings; higher shrub and tree richness compared to Overstorey Thicket; understorey may be dominated by natives or exotics; low native understorey richness
Transformed	exotic pasture, salinized area, cropland	Very low to no vegetation cover in the mid and understorey; overstorey absent or low, dead or dying, no recruitment, soil is saline, acidic, or highly nutrified

Table 5. *Commonness of condition states in different woodland types*

	Woodland Type		
Condition State	Floodplain/Riparian	Grassy	Shrubby/Obligate-seeder
Exemplar	Very Uncommon	Very Uncommon	Uncommon
Simplified 1	Uncommon	Uncommon	Uncommon
Simplified 2	Uncommon	Common	Neither Common nor Uncommon
Simplified 3	Uncommon	Very Uncommon	Very Uncommon
Simplified 4	Uncommon	Common	Uncommon
Overstorey Thicket	Common	Uncommon	Very Uncommon
Overstorey and Midstorey Thicket	Very Uncommon	Common	Very Uncommon
Transformed	Very Common	Very Common	Very Common

1.3.2 Are there common transitions across woodland types?

Woodland experts from each of the three groups estimated the likelihood of transitions between each pair of states for their woodland type. Figure 4 presents a summary of the transitions that experts felt were likely to occur from each of the starting states, for each woodland type, over 20 years. Figure 5 presents the same data, but for a 100-year time frame.

The most striking, but perhaps expected result is the predicted difficulty in transitioning to the Exemplar state across all woodland types, even within 100 years. The exception is the transition from a Simplified 1 state, which is thought to occur from all woodland types, but appears to be most likely in floodplain woodlands. Similarly, experts felt it was unlikely that positive transitions to a Simplified 1 state would occur within 20 years, with the exception of the Simplified 2 state. Again, the likelihood increased when a longer timespan was considered (100 years, Figure 5). These results highlight the challenges associated with restoring degraded woodlands back to a more 'natural' state, under current management practices.

Experts also indicated that stability of states was common. This finding is regardless of condition, thus states seem to be resilient to change. Transitions to the more degraded, or more structurally altered states (Simplified 4, and Transformed) were also thought to be common among the three woodland types at both 20 and 100-year timescales. This suggests that degrading transitions or drivers are overwhelming positive changes, highlighting the importance of preventative threat management in these systems.

There were some transitions that were not consistent among woodland types. For example, transitions to the Thicket state are common in Grassy and Floodplain Woodlands only, as the transition is generally associated with woodlands dominated by episodically recruiting eucalypts (e.g. *E. microcarpa* and *E.camaldulensis*). The floodplain woodlands were unlikely to transition to the Overstorey/Midstorey thicket state, and this was probably due to the low proportion of shrubs or midstorey trees in these woodlands. In these cases, this likely reflects the individual ecology and structure of the different woodland types. In terms of persistence of the thicket state, experts deemed it likely that floodplain thickets would transition within the 100-year timeframe, whereas thickets in the other woodland types might persist beyond 100 years. Again, this may be due to ecology and stand structure, but expert beliefs about the magnitude and frequency of drivers of change acting in these systems (i.e. floods etc) should be accounted for (Figure 7).

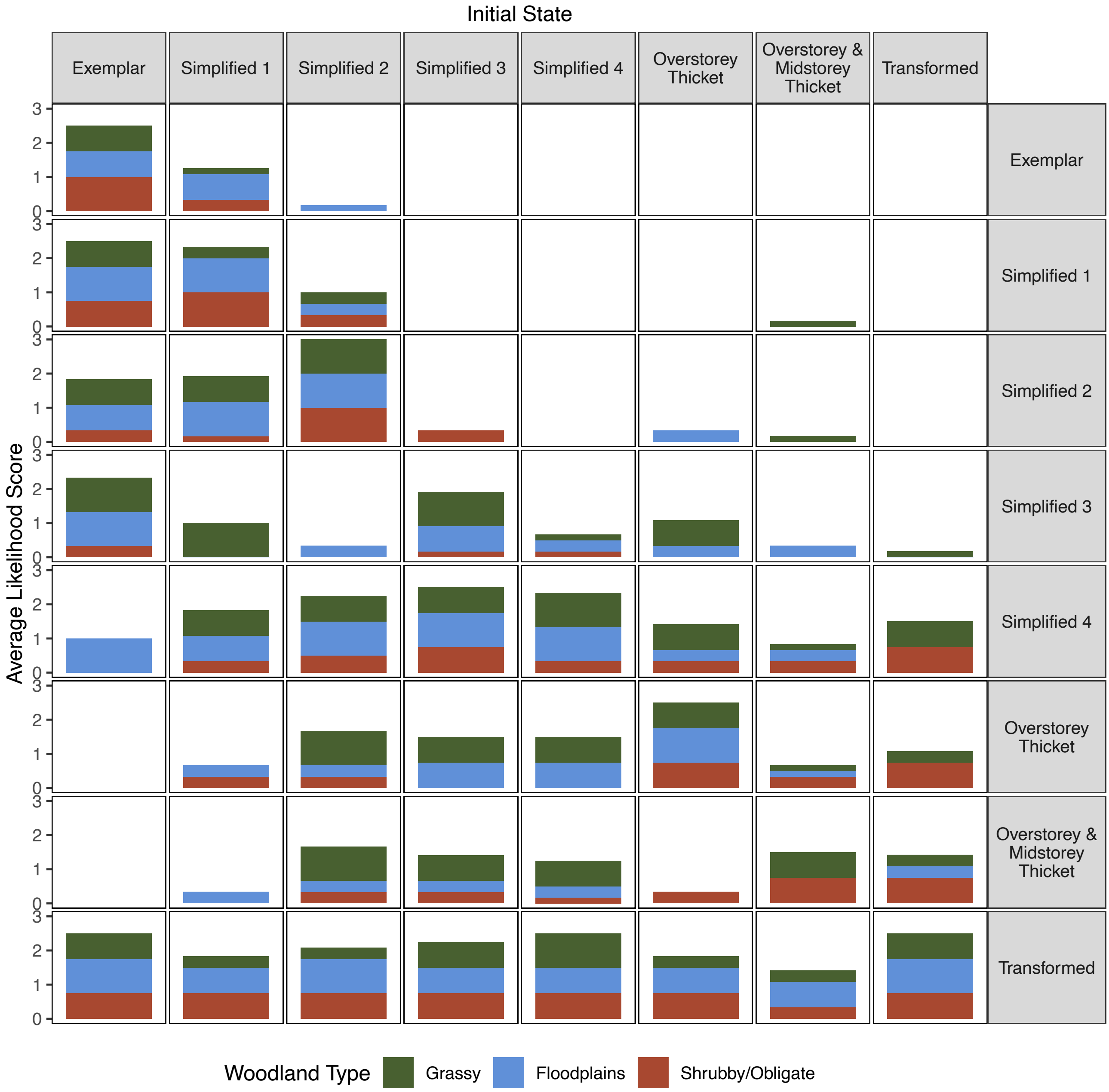


Figure 4. Commonness of transitions between initial states (depicted on the horizontal axis) and final states (depicted on the vertical axis), within a 20-year period. Ex = Exemplar, S1 = Simplfied_1, S2 = Simplified_2, S3 = Simplified_3, S4 = Simplified_4, OSMST = Overstorey and Midstorey Thicket, OST = Overstorey Thicket, Tr = Transformed. The thickness of the bar corresponds to the commonness of the transition. Each likelihood category was assigned a quantitative score, so that the average likelihood for a transition (given all possible causal pathways) could be compared across woodland types. Where a colour is missing from a cell it means that experts thought that transition was not possible.

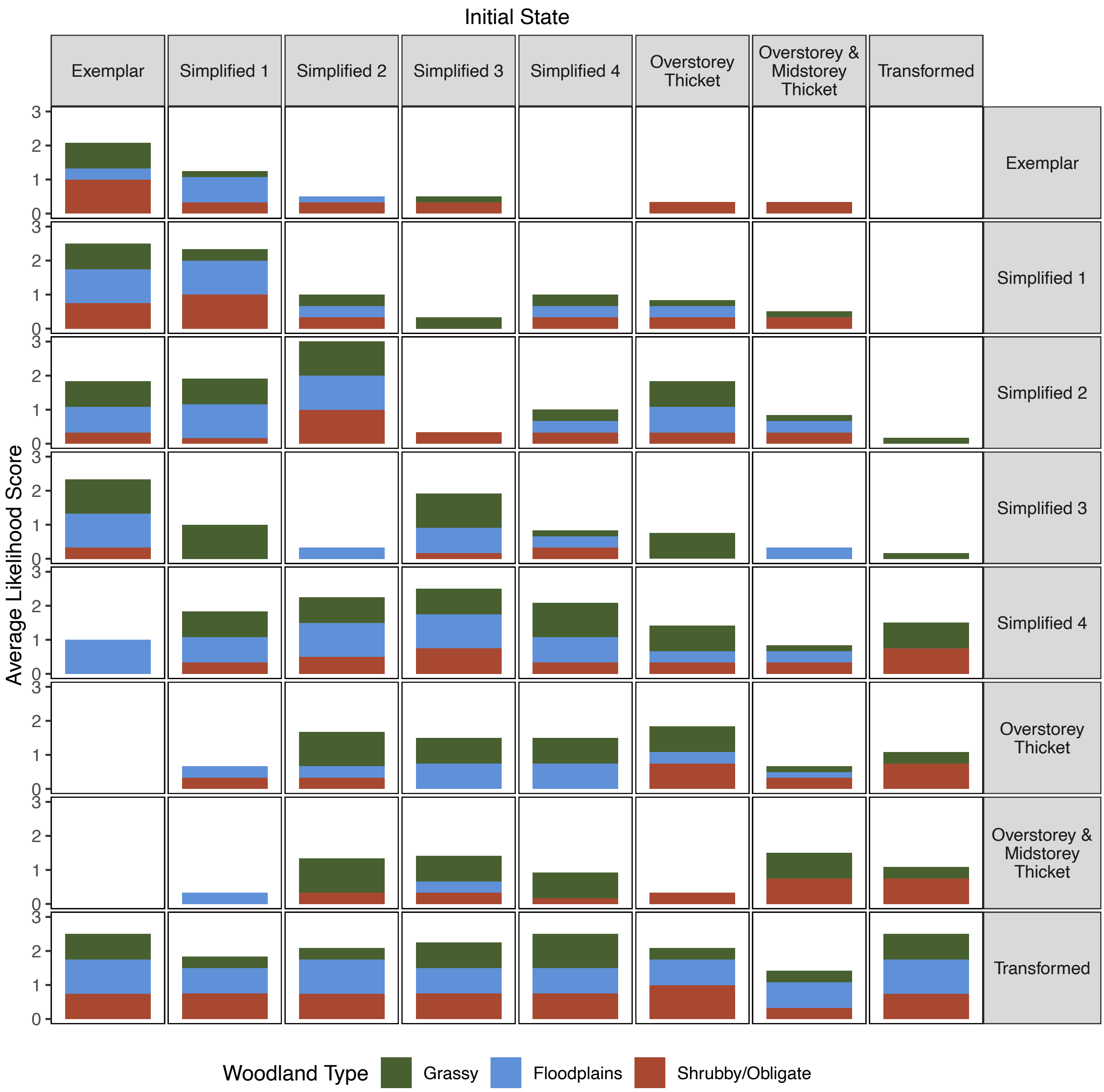


Figure 5. *Commonness of transitions between initial states (depicted on the horizontal axis) and final states (depicted on the vertical axis), within a 100-year period. Ex = Exemplar, S1 = Simplfied_1, S2 = Simplified_2, S3 = Simplified_3, S4 = Simplified_4, OSMST = Overstorey and Midstorey Thicket, OST = Overstorey Thicket, Tr = Transformed. The thickness of the bar corresponds to the commonness of the transition. Each likelihood category was assigned a quantitative score, so that the average likelihood for a transition (given all possible causal pathways) could be compared across woodland types. Where a colour is missing from a cell it means that experts thought that transition was not possible.*

1.3.3 Do the drivers vary? Assessing distinct transitions and common drivers

Overall, experts described 376 causal pathways, across all plausible state-transitions. These included detailed descriptions of environmental conditions and management interventions that drive transitions from one state to another. Figure 7 presents all drivers mentioned by the experts, associated with all plausible state-transitions. Overall, there was a lot of overlap among the three woodland types, with 38 drivers being common to all (Figure 6). Floodplain woodlands had the most unique drivers, whereas shrubby and grassy woodlands only had 2 unique drivers each. At first glance, this highlights that at least the set of threats and drivers is relatively consistent across woodlands.

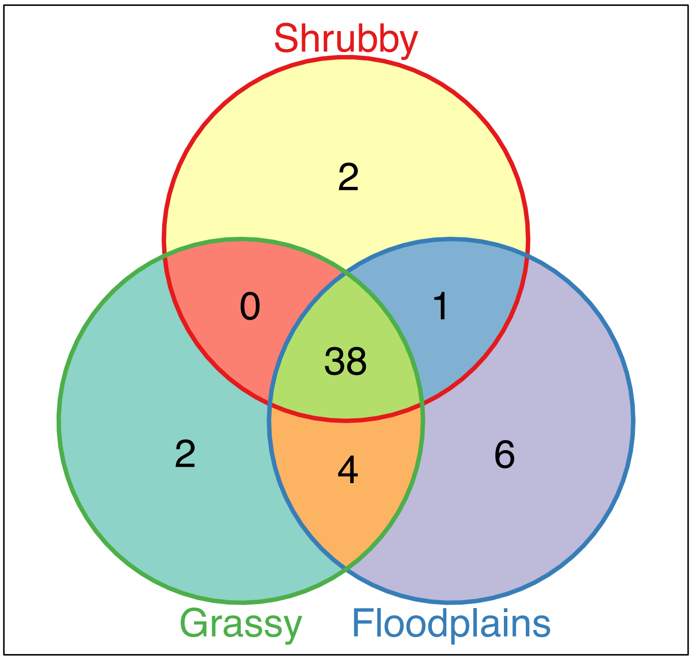


Figure 6. *Shared drivers across all plausible transitions in the three woodland types*

Drivers could lead to positive transitions (towards a more intact state) or negative transitions (towards a more degraded state; these were identified as 'threats'). There were a total of 29 different drivers identified by experts. The types of drivers and threats mentioned in the 'likely' or 'very likely' causal pathways are listed in Figure 7, along with the percentage of chains that each driver or threat was mentioned in, separated into the three woodland types. We focused on 'likely' and 'very likely' causal pathways because we were interested in key threats or drivers rather than threats or drivers that were commonly mentioned across all possible pathways. The three most common positive drivers, across all three woodland types were Revegetation, Grazing management, and Recruitment events, whereas the three most common threats were Vegetation clearing, Soil disturbance and Grazing. Each of these drivers and threats are likely to cause significant changes in the structure, composition and function of woodland ecosystems, so it is unsurprising that they are common features in the causal pathways.

Major disturbance events, via fire and flood, were the drivers that distinguished woodland types from one another. Floodplain woodlands experts mentioned floods often, whereas this driver is not relevant to shrubby and grassy woodlands. Conversely, fire was often cited by grassy and shrubby woodland experts, but never by floodplain experts. These differences are important because they represent areas where woodland types require different management based on their natural disturbance regimes.

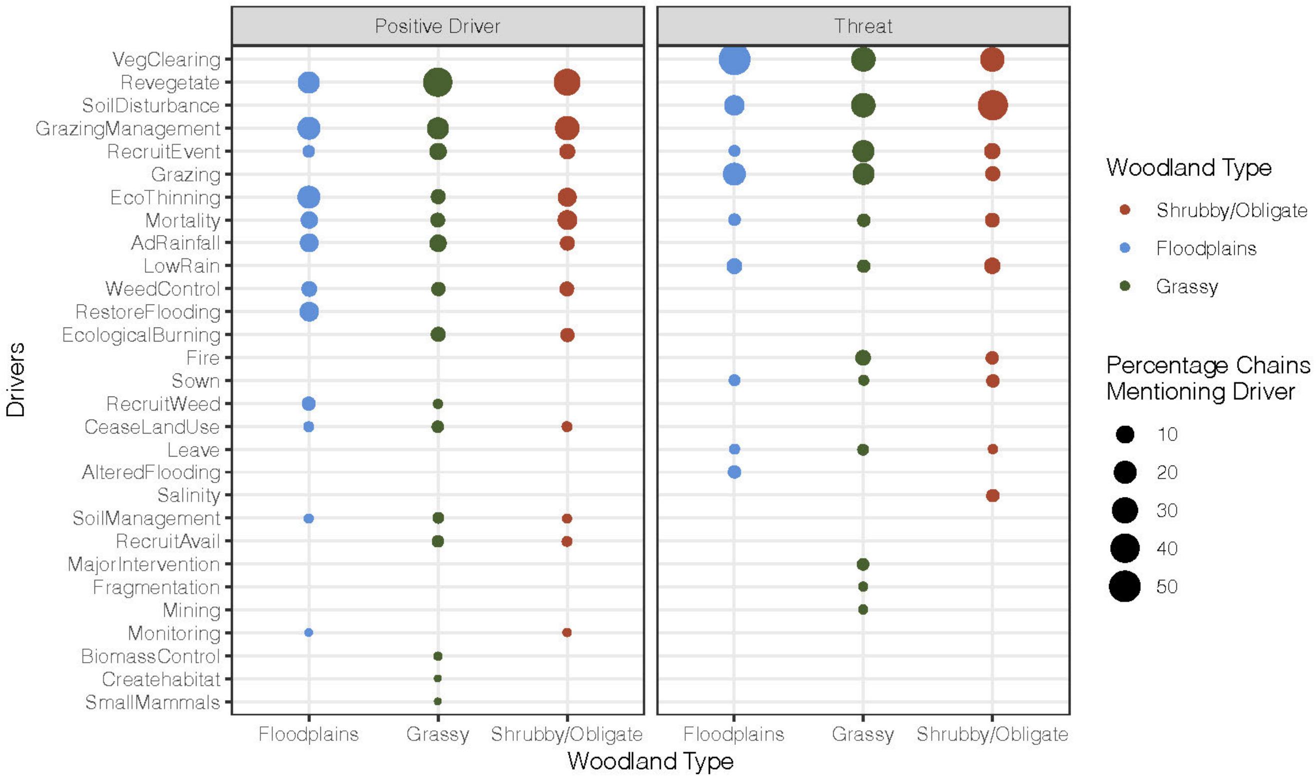
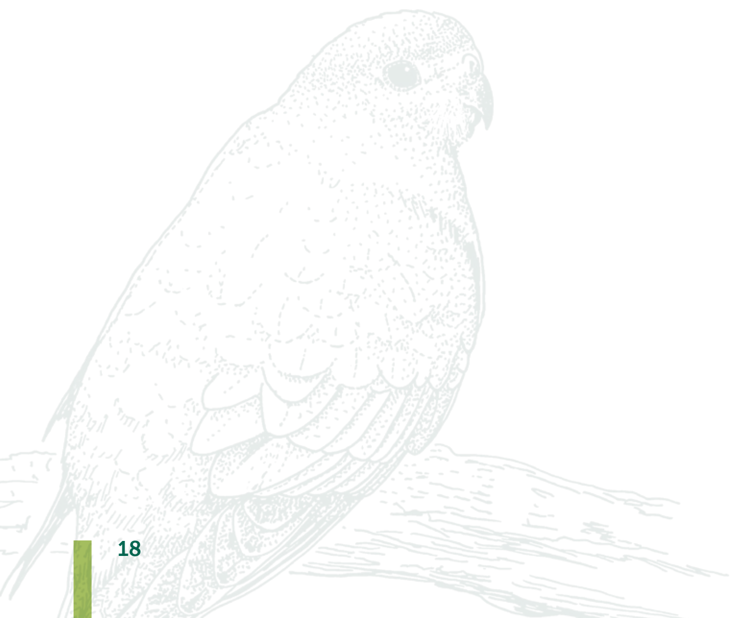


Figure 7. *Drivers mentioned by woodland experts that were associated with different causal pathways that were considered 'likely' or 'very likely'. Drivers were classified as 'positive' if they were assocaited with a pathway leading to an improved condition state. Drivers associated with pathways leading to a more degraded state were considered 'Threats'. The size of the 'bubble' for each driver in each woodland-type represents the percentage of causal pathways that mentioned this driver. Note, we asked experts to be specific about the nature of broad threats, such as climate change (e.g. drought).*

1.4 Practical Management Recommendations

We used the causal pathway data to inform management recommendations. In general, we advocate that differences in the composition, function and structure of woodlands provides useful context for managers, but for the purposes of recovery planning, differences are really only important when they result in changes to management recommendations. As such, this section highlights when management recommendations should be specific to starting state, and woodland type. These recommendations are presented as decision trees, which step users through a series of if/then questions to arrive at suggested management interventions. Full details of each set of recommendations for conditions states can be found in the supplementary material (S1.2), along with relevant decision trees. We have also included these in the Guide (Part 4 of this report).



1.5 Restoration pathways, and transitions to avoid

In order to visualise the possible restoration pathways ('goals') and transitions that may lead to degraded states ('risks'), we calculated the average likelihood of each possible transition from the experts in each woodland group and created two general diagrams (Figure 8). It is clear that most of the restoration pathways were deemed unlikely, whereas transitions to avoid were generally very likely.

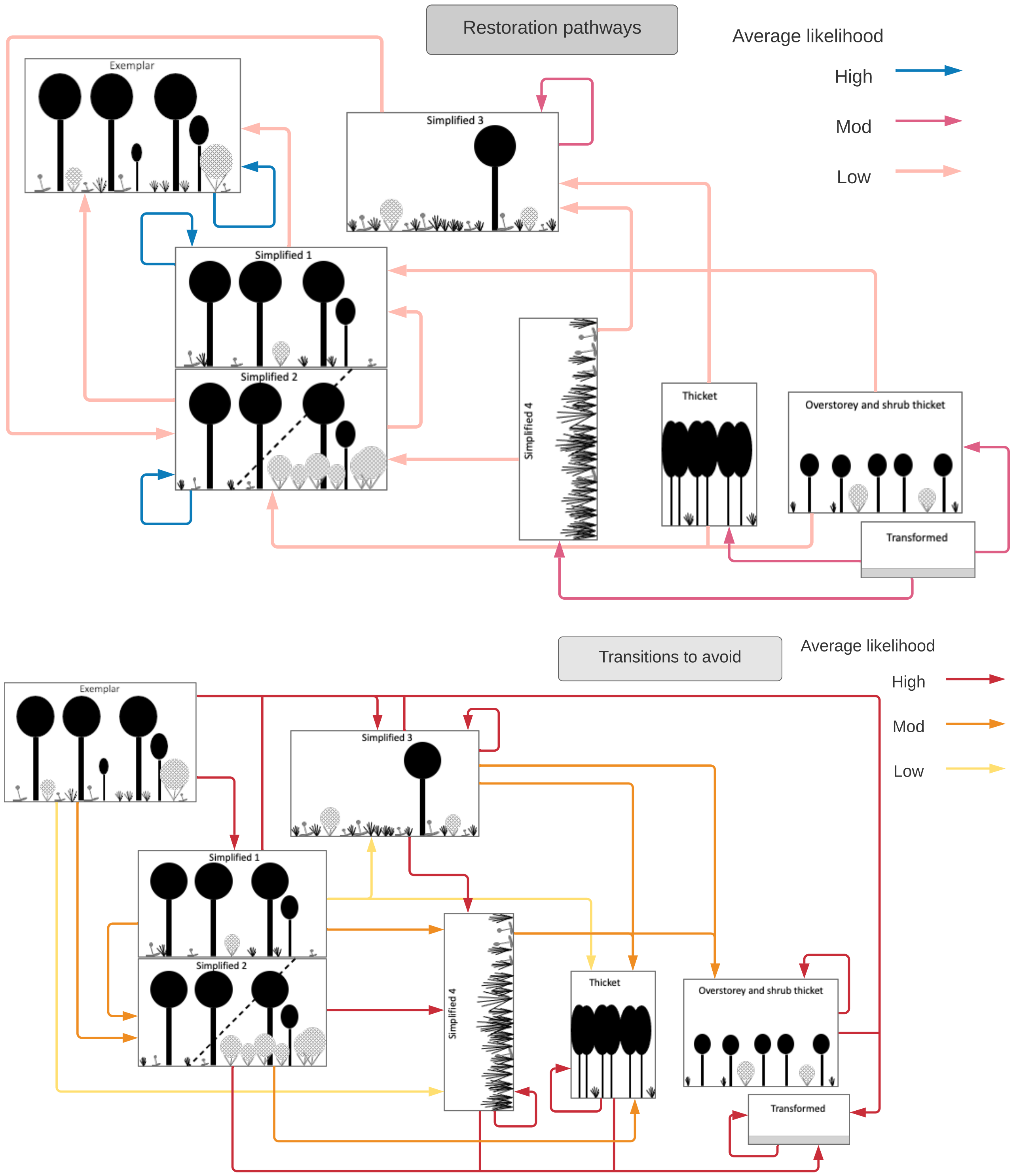


Figure 8. Transition pathways deemed possible by experts. Restoration pathways formed the basis for the decision trees in the Guide and Practical Management Recommendations in Part 4. Transitions to avoid were also noted in the Guide. Colours of arrows relate to the summed likelihood across all woodland types.

1.6 Conclusions

This work seeks to document expert understanding of where we can generalise and transfer understanding from one woodland system to another to aid effective conservation management, without losing critical aspects of what defines each distinct woodland type. We used State Transition Models (STMs) to articulate the different starting and end points for restoration, clarify the key threats impeding recovery, and explore and justify which interventions can be harnessed to best target threats. By providing a basis to transfer understanding from one woodland type to another, the outcomes from this project will inform recovery planning for listed woodlands.

The following are some of the key findings from the project:

- Woodland experts were able to define a series of 8 condition states that were based on measurable vegetation attributes.
- Overall, there was a high level of consensus among experts and among woodland types. Livestock grazing, rainfall and tree clearing were all major drivers of transitions among condition states in all three woodland types. Notable differences in the drivers of change in the woodland types tended to be due to differences in their basic ecology and reliance on resource pulses and disturbance regimes. For example, only floodplain woodlands rely on appropriate flood regimes for tree recruitment, and similarly, fire played a more important role in grassy and shrubby woodland transitions.
- The results from the expert elicitation process were used to create decision trees to advise on the recovery of woodlands in different conditions states, across the different woodland types. These guidelines include important information about how to avoid threats, how to improve degraded states, as well as how to 'stay the same' when woodlands are already in desirable conditions states (see Part 4).

This report shows that there are many overlapping characteristics, threats and drivers, and recommended management interventions for southern Australian woodlands. The decision trees highlighted where specific advice is warranted, based on the expert data. Many of the management recommendations are relevant to all three woodland types, indicating that despite differences in the composition, structure and function of the three woodland types, management advice is likely to be relatively consistent. This provides excellent justification for the development of a generalised STM for southern Australian woodlands, to support multi-community recovery plans.

Experts working through transition pathways in the floodplain woodland group. Image: Libby Rumpff

2. Part Two: Validating the expert model using field data

2.1 Summary

In Project 1.2.5 (Part 1) we developed an expert elicitation protocol to create a general ecosystem model framework for woodlands of southern Australia. Underpinning this framework was a general State Transition Model (STMs), where the states were initially described qualitatively only. In Project 7.2, we focused on validating woodland states with data, for a range of measurable attributes associated with the eight condition states.

We collated woodland datasets that spanned a geographic range (across southern Australia) and the three different woodland types (floodplain, grassy and shrubby woodlands). We asked contributors to assign each field site to one of the eight condition states using the general descriptions developed during the expert elicitation process (Part 1).

Key findings:

- The values for attributes within condition states varied widely among datasets, although there were some consistent trends for some attributes. This is not surprising, especially given the lack of replication across woodland types and geographic space, and the different sampling methods utilised. The findings could indicate that there are either differences in how field ecologists perceive the condition states within their woodland type, or that there is structural and compositional variation in condition states across a large geographic area. More work is required to resolve this knowledge gap, ideally with data collected using a consistent sampling method.
- The Classification and Regression Tree (CART) analyses, for each combinatorial pair of condition states, in each dataset, selected the most best vegetation attributes for distinguishing between condition states. When we compared these results among datasets, some attributes were repeatedly selected (for example measures of shrub abundance was consistently selected in the comparison between Exemplar and Simplified 1, whereas measures of tree density were almost entirely selected in the comparison of Simplified 2 & 4). This shows that even though the absolute values for attributes varied among datasets and contributors, certain attributes are useful for monitoring changes in condition state. The four most selected attributes irrespective of condition state pair were: (1) Tree density; (2) Exotic cover; (3) Native understorey diversity/richness, and; (4) Native understorey cover.
- Using only the variables identified by the CART analyses, we calculated thresholds between pairs of condition states for each variable within individual datasets and found that for some attributes, there was remarkable similarity in the estimated thresholds among different datasets and woodland types. Other variables were found to be inadequate due to the level of uncertainty around the thresholds. While, there were some variables with quite different thresholds when comparing among datasets and woodland types.
- These results highlight the potential for more robust analyses when more datasets become available. Our preliminary findings can already be used to select variables for focused monitoring of transitions following management interventions, or in the detection of degrading trajectories in high quality remnants.

This study demonstrates that assigning condition states based on expert descriptions (from phase one of this project) is likely to be just as reliable using data to assign a condition state to a site. Field ecologists and/or land managers who know an ecological community well, and are familiar with the dynamics of the vegetation, should be able to accurately assign sites or patches of vegetation to a condition state, relative to other sites or patches. From there, the relative change in condition state can be monitored using the vegetation attributes that were most reliably used to distinguish between states in this validation project or using field data from the region being restored. This would allow a more targeted and cost-effective approach to monitoring based on the transition of interest. Our general State and Transition Model is designed in a way that allows (and encourages) ongoing development and refinement as more data becomes available.

By providing a basis to transfer understanding from one woodland type to another, the outcomes from this work will inform recovery planning for listed woodlands. We have synthesised project outcomes in an accompanying guide (Part 4): 'A practical guide for recovery planning using the General Ecosystem Model for Southern Australian Woodlands'.

2.2 Introduction

The overall aim of the 'Woodland Recovery Planning' project was to provide structured advice for how to manage listed woodlands to improve conservation outcomes. Gathering information about how best to manage a newly listed woodland community requires significant resources, and often, relevant research for a specific community isn't available. Yet, much of our knowledge about how to manage woodlands can potentially be transferred from other woodland communities. In this project, we set out to understand where we can generalise and transfer understanding between woodland communities in southern Australia to another to aid effective conservation management.

In Project 1.2.5 (Part 1) we developed an expert elicitation protocol to create a general ecosystem model framework for woodlands of southern Australia. Underpinning this framework was a series of State Transition Models (STMs) for different woodland types, that articulate the different starting and end points for restoration, clarify the key threats impeding recovery, and explore and justify which interventions can be harnessed to best target threats.

The expert elicitation process resulted in the description of a series of eight common woodland condition states that might occur in temperate Australian woodlands, as well as information about possible transitions among condition states, and threats and drivers that might be associated with these transitions. Experts initially described the states qualitatively in relation to compositional, structural and functional attributes. However, when asked to provide estimates of some of the attributes (e.g. tree density or exotic species cover), those experts that responded provided highly variable estimates with large bounds of uncertainty (see Supplementary Material: S2).

In Project 7.2, we attempted to move beyond qualitative descriptions and validate the condition states using existing field data that spanned a large geographic range (across southern Australia) and three different woodland types (floodplain, grassy and shrubby woodlands).

Our aim was to:

i. Explore initial trends in whether there are similarities in structural and compositional attributes for condition states, across datasets from different woodlands;
ii. Develop an analytical framework for assessing which attributes best distinguish condition states, and the thresholds that could be used to evaluate progress toward objectives (i.e. monitor attribute x, until it reaches a threshold that signifies it has transitioned to a different condition state).
iii. Evaluate whether there are targeted monitoring variables that can distinguish between states, irrespective of woodland type or location.
iv. Using field data, investigate if there are clear thresholds between pairs of condition states for different vegetation attributes.

These are the initial steps towards validating the condition states. Eventually, with enough datasets and contributors we would like to be able to confidently provide a list of objective condition measurements that can consistently predict which condition state a woodland is in. However, variation in the structure, composition or function of these conceptual condition states is expected. Of interest is whether, despite this variability, we can detect a consistent set of attributes (and thresholds) that can differentiate between states. We see this as an important step in providing advice within recovery plans that can facilitate targeted and cost-effective monitoring strategies that are focused on a reduced set of attributes, that can be linked back to specific management objectives.

2.3 The approach

After the first phase of this project (Project 1.2.5; Part 1), we set out to gather field data to validate the expert generated condition state and transition framework. Potential contributors were asked to share existing data from one or more of the possible woodland types, and assign each site to a condition state based on the descriptions from Part 1.

A substantial data cleaning exercise was undertaken to enable analysis. Different contributors measured different sets of variables, using different sampling protocols. This meant that we could not run analyses across all datasets, but we did have to set up some rules to enable comparison. First, we assessed the level of missing data from each dataset to determine if it met the minimum requirements for inclusion in the study. For example, it would not be possible to include datasets that do not have any measure of tree density/cover as this is a key attribute that will likely distinguish between condition states. Similarly, missing values for shrub density/cover would also make it difficult to compare results among datasets. Datasets from non-target geographic or climatic regions and/or vegetation types were also excluded.

The analytical framework is as follows (Figure 9):

1. Datasets were grouped according to Source (the contributor) and Woodland type (Floodplain, Shrubby or Grassy).
2. For each Contributor x Woodland type, we explored distributions of each variable using histograms and transformed the data accordingly. All overstorey and understorey variables were presented in boxplots for each dataset to visualise differences between condition states.
3. We then used a Classification and Regression Tree (CART) analysis, to compare pairs of states for each Source x Woodland type and extract the three most important variables for distinguishing between each pair of states. There are up to a possible 28 unique pairs of the 8 condition states for each Source x Woodland type group, but some datasets only contained a subset of the condition states. We then used these top variables to compare among datasets. We looked at the vegetation attributes that were most commonly selected for each pair of states (the top three attributes) to see if there was much overlap among the different datasets/contributors.
4. For each pair of states in each dataset, we then conducted logistic regressions for each of the three variables extracted from the CART analysis. From this analysis we can see the fit of the logistic model and calculate the point at which it is likely a transition between states has occurred (the monitoring threshold), with uncertainty. The results from this section of the analysis is presented as supplementary material (S2.1) due to the volume of output.
5. We then compared among the datasets to investigate whether similar patterns were observed from different woodland types, or if there were large differences between contributors/datasets.

One of the woodland types explored in this project included shrubby and obligate seeder woodlands (Gimlet woodland, pictured). Image: Carl Gosper

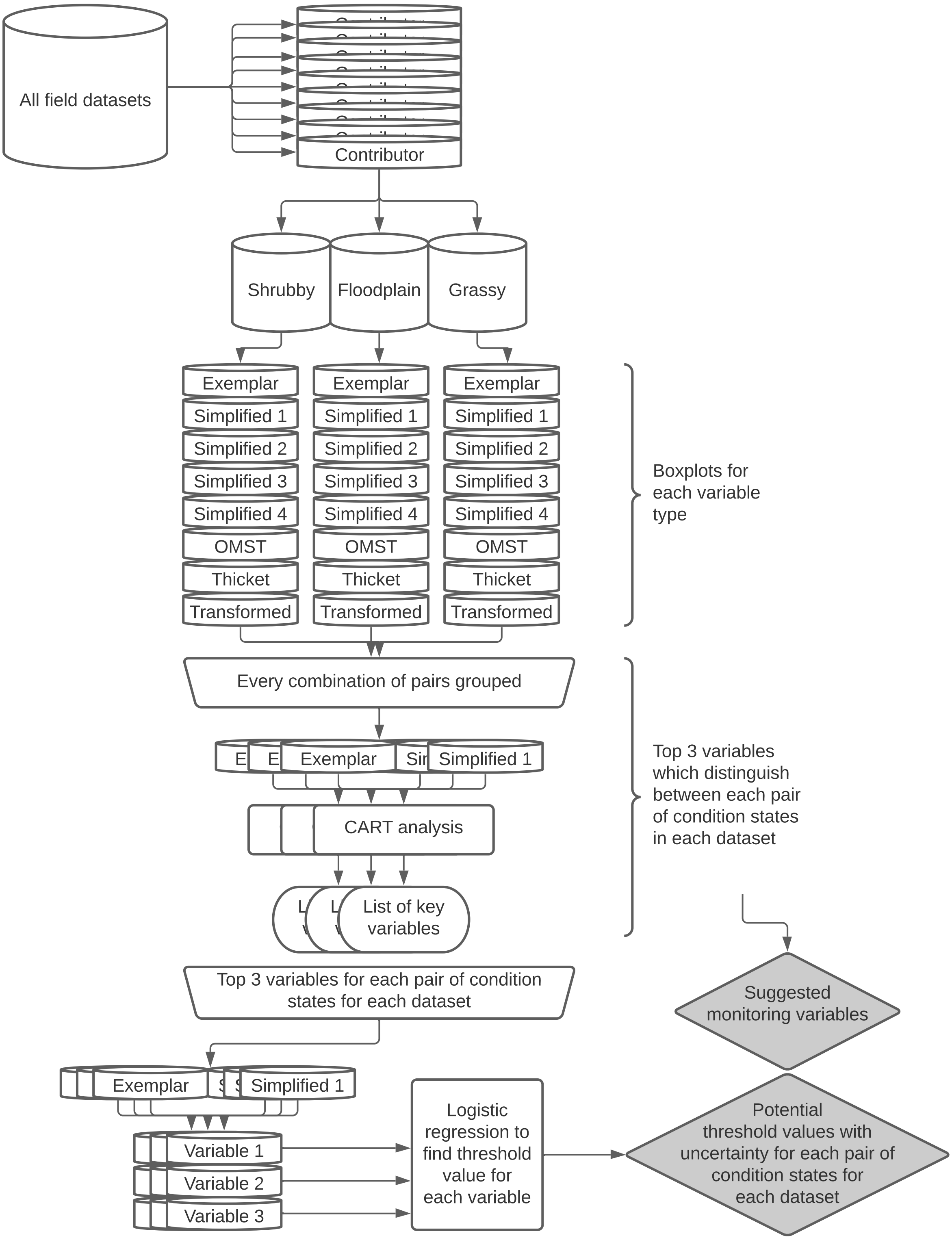


Figure 9. Diagram of the workflow followed for the validation analysis. Grey diamonds represent outputs (results).

2.4 Key Results

2.4.1 The datasets

We were able to collate nine woodland datasets that had a good geographic spread and included the different woodland types and condition states (Table 6). There weren't many condition states represented in the Shrubby dataset, whereas Floodplain and Grassy datasets were relatively well replicated and included sites from all of the condition states. However, some of the condition states were generally poorly represented in the data. For example, the Simplified 3 state only had 27 sites, 20 of which were in Floodplain woodlands. This might indicate that this state doesn't really occur as often in Grassy or Shrubby woodlands. Similarly, Overstorey and midstorey thickets were predominantly recorded in Grassy woodlands (12 out of 14 sites). Transformed sites were not common in the data sets, however this is presumably because field ecologists sampled less in these highly degraded patches.

There was large variation in the types of variables measured among datasets (Figure 10). This is unsurprising, as studies have different aims. The most sampled vegetation attributes were exotic and native understorey cover, shrub cover, richness of native understorey and midstorey and density of trees. Soil variables and diversity were the least sampled attributes (Figure 10). A result of this inconsistency, we were unable to gather a full complement of vegetation attributes and had to analyse each dataset separately.

Overall, as the data was collated it became clear it would be difficult to compare across data sets, especially within the timeframe of the project. To increase our confidence in a comparative analysis requires greater replication across states and woodland types, using the same attributes collected with similar methods, and multiple observers assigning 'condition state' to each site.

Table 6. *The number of sites across the nine datasets in each condition state, for each woodland type.*

	Woodland Type			
Condition State	Floodplain	Grassy	Shrubby	Total
Exemplar	19	56	120	195
Simplified 1	61	70	42	173
Simplified 2	123	53	0	176
Simplified 3	20	7	0	27
Simplified 4	33	86	0	119
Overstorey midstorey thicket	2	12	0	14
Thicket	5	29	0	34
Transformed	0	12	30	42
Total	**263**	**325**	**192**	**780**

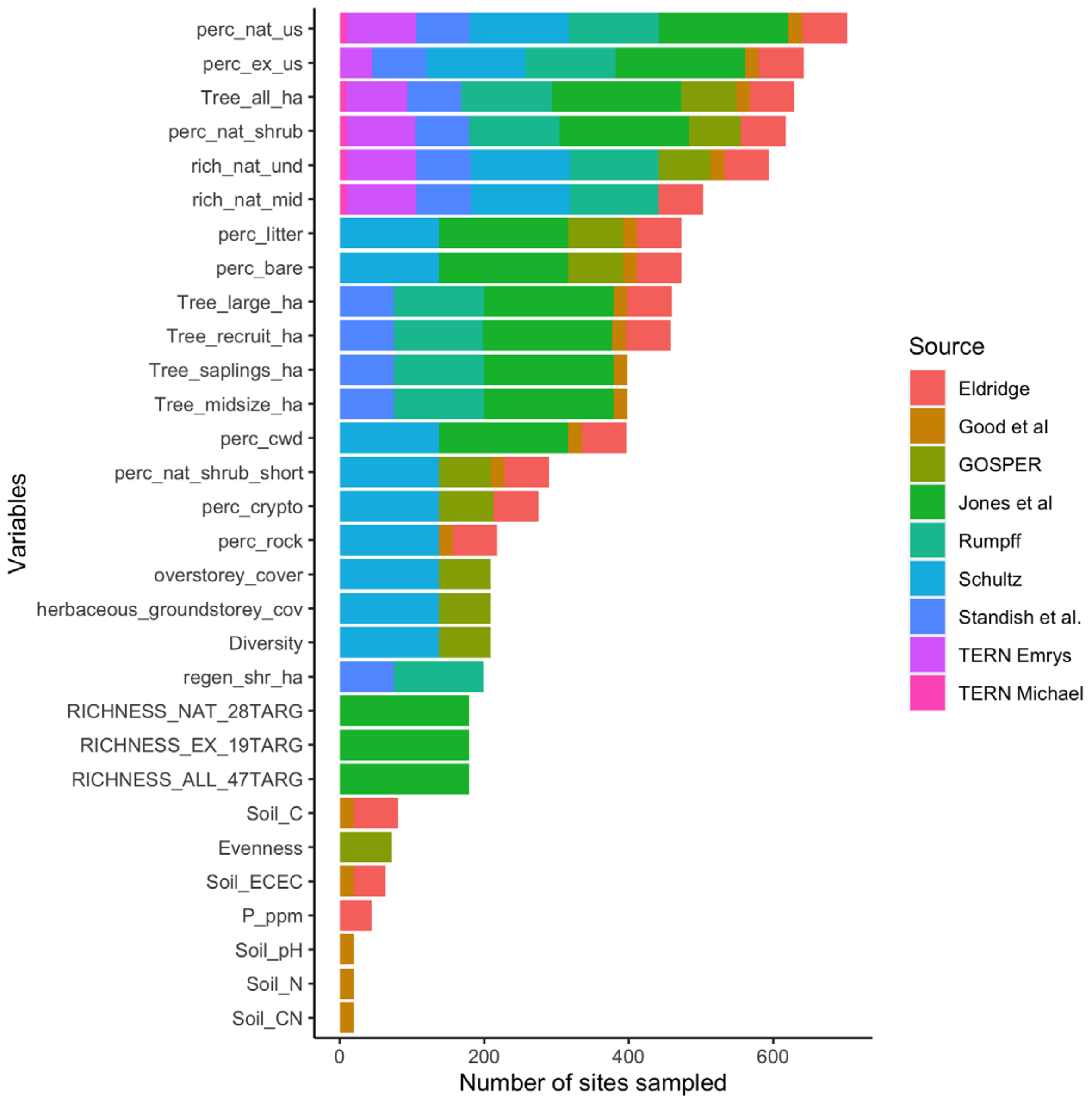


Figure 10. *The range of variables collected across the nine datasets ('Source') and the number of sites sampled for each variable. It is important to note the sampling method did vary for individual variables across datasets.*

2.4.2 Comparing vegetation attributes among condition states

It is difficult to distinguish clear patterns when comparing the range of values for vegetation attributes across datasets and condition states, though there are some notable trends (Figure 11 and 12). These results must be taken with caution, as different sampling methods have been utilised in the collection of data, and only a select group of attributes are presented here (those initially quantified by experts in Part 1):

- Tree density is variable across condition states, with the exception of Thicket states, and the Exemplar state in one Shrubby woodland dataset.
- Native understorey richness, though variable, has higher values in Exemplar, Simplified 1 and Simplified 2 states. Unsurprisingly, lower values are evident in the Thicket and Transformed states.
- Shrubby sites tended to have higher native species cover and richness in the Exemplar state, than Floodplain and Grassy sites. This may have been a function of the way the vegetation attributes were sampled (with some datasets capping cover at 100% and others allowing for layered cover).
- Exotic understorey cover is variable, though tending toward lower values in Thicket, Exemplar and (potentially) Simplified 3 states.
- Native shrub cover has highest values in Exemplar, Simplified 1 and 2 and Overstorey and midstorey thicket states.

It is important to point out that the classification of sites to condition states is subjective, and the variability between datasets may be more a reflection of the perceptions of 'condition state' from the data contributor. However, the condition states were more clearly defined when we examined the patterns within datasets, indicating that the dataset contributors were consistent when assigning their sites to condition states.

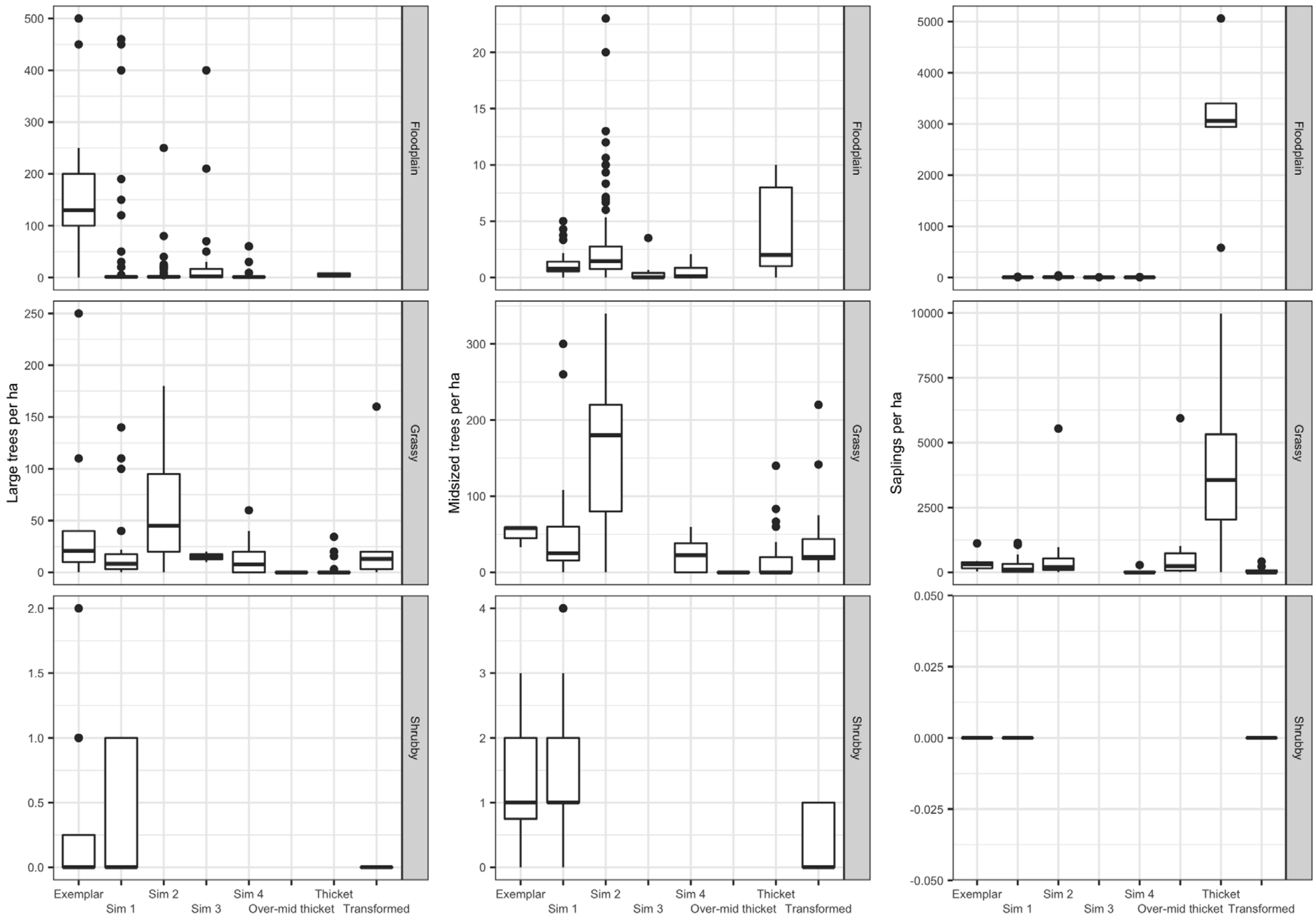


Figure 11. *Boxplots for selected set of overstorey attributes (large trees, midsize trees and sSaplings per hectare), grouped by condition states (to which they were assigned by dataset contributors) and broad woodland type (Floodplain, Grassy and Shrubby). Note: No saplings were recorded in shrubby woodlands.*

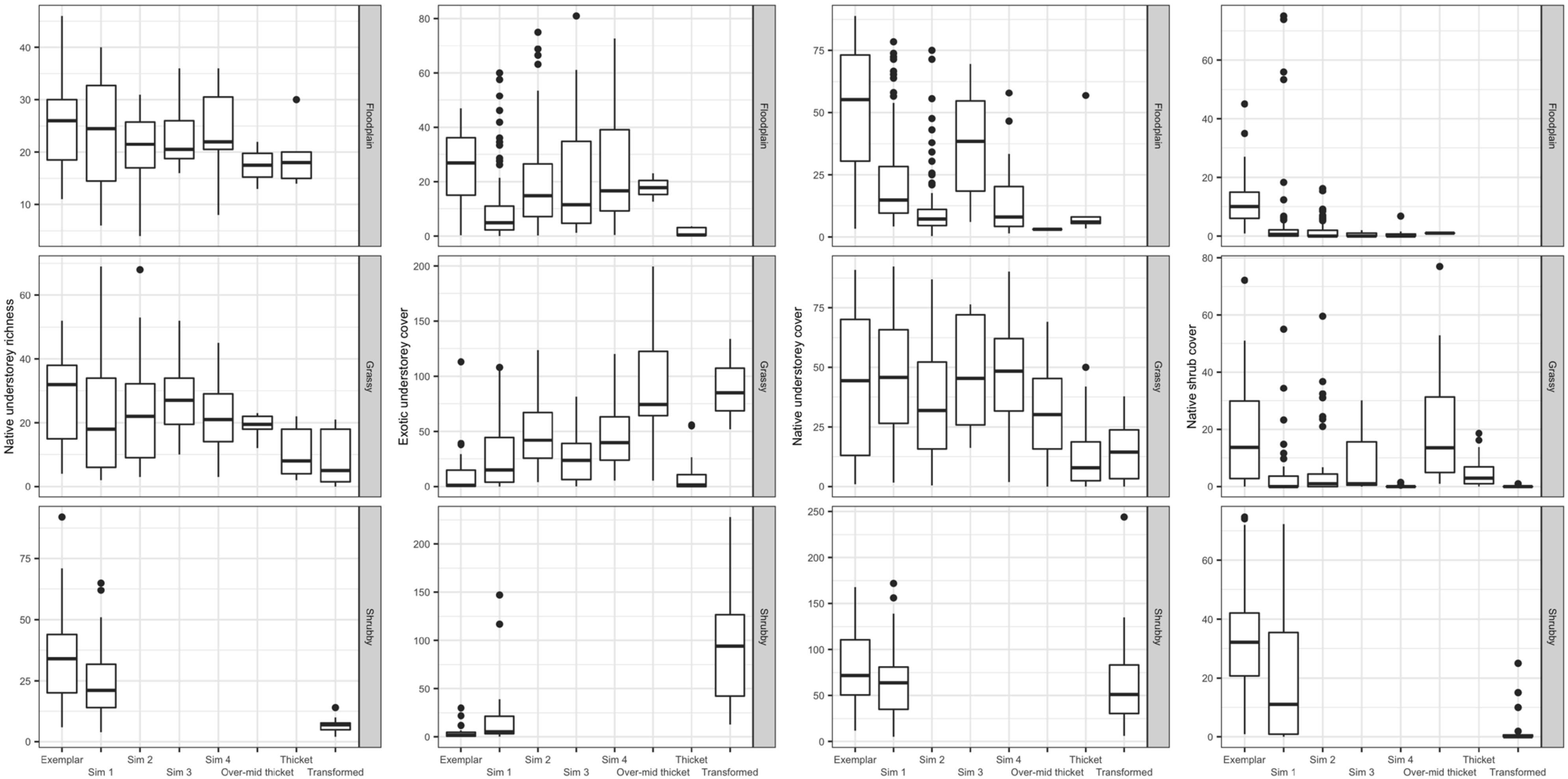


Figure 12. *Boxplots for selected set of understorey attributes (native richness, exotic cover, native cover and shrub cover), grouped by condition states (to which they were assigned by dataset contributors) and broad woodland type (Floodplain, Grassy and Shrubby). These were the attributes chosen by experts from Project 1.2.5 as those that could best distinguish between pairs of condition states.*

2.4.3 Comparing condition states to identify possible monitoring attributes

The classification regression tree analysis examined pairs of condition states (i.e. possible transition states, as represented in the original conceptual model from Part 1; Figure 8) and explored which three attributes were 'best' at differentiating between condition states, given the available data. We could explore this further to examine the first and second ranked attributes, but given the variability across data sets we felt it best not to provide guidance that was too specific at this stage. The analysis was performed on individual data sets, to explore whether there was a similar set of attributes that defined states, irrespective of the variability in the data.

We found that across pairs of states from the different data sets there were generally a suite of attributes that were selected more often as a top three differentiating attribute (Figure 13). For example, the most commonly selected attributes for distinguishing between Exemplar and Simplified 1 were shrub abundance and native understorey richness/diversity (Figure 13). In comparison, for Simplified 1 and 2, native and exotic understorey cover were the most commonly selected attributes. Unsurprisingly, tree density was often selected for pairs of sites that included Thickets. Note we have synthesised these outcomes in the accompanying guide: 'A practical guide for recovery planning using the General Ecosystem Model for Southern Australian Woodlands'.

If we look across all data sets, we see that tree density was the most commonly selected attribute (Figure 14). For floodplain sites, this was followed by ground cover attributes (e.g. litter, bare ground), and then native and exotic understorey cover. For grassy sites, the next most commonly selected attributes were exotic cover and understorey richness/diversity. For shrubby sites, the selected attributes were more evenly spread, but there was less data available to explore trends.

We compared these results with expert judgements from Part 1, where experts indicated which attributes they felt would indicate a transition from one state to another (Figure 15). Tree density was the most commonly selected attribute by experts for each woodland type, which aligns with the data. However, for floodplain sites, experts felt that exotic cover and understorey richness/diversity would be more important differentiating attributes than ground cover attributes. For grassy sites, it was shrub and understorey cover (rather than exotic cover and understorey richness/diversity as per the data), and for shrubby sites, shrub cover and exotic understorey cover. As such, though expert judgements are critical in the absence of data (e.g for shrubby sites), this highlights the importance of validating results with data. These results have shown there is justification for targeting monitoring at a smaller suite of attributes to assess progress toward objectives using a state-transition framework.

It is important to point out, the CART outputs are contingent on the variables that were available for each dataset. So, just because there one attribute is often selected from different CARTs might also be a function of that attribute having more data available between datasets. For example, soil variables did not get selected often, but this is not necessarily a reflection of 'importance' of the attribute, rather that only two datasets recorded soil attributes.

Careful management of woodlands can have benefits for native flora, especially understorey species.
Images: Megan Good and Libby Rumpff

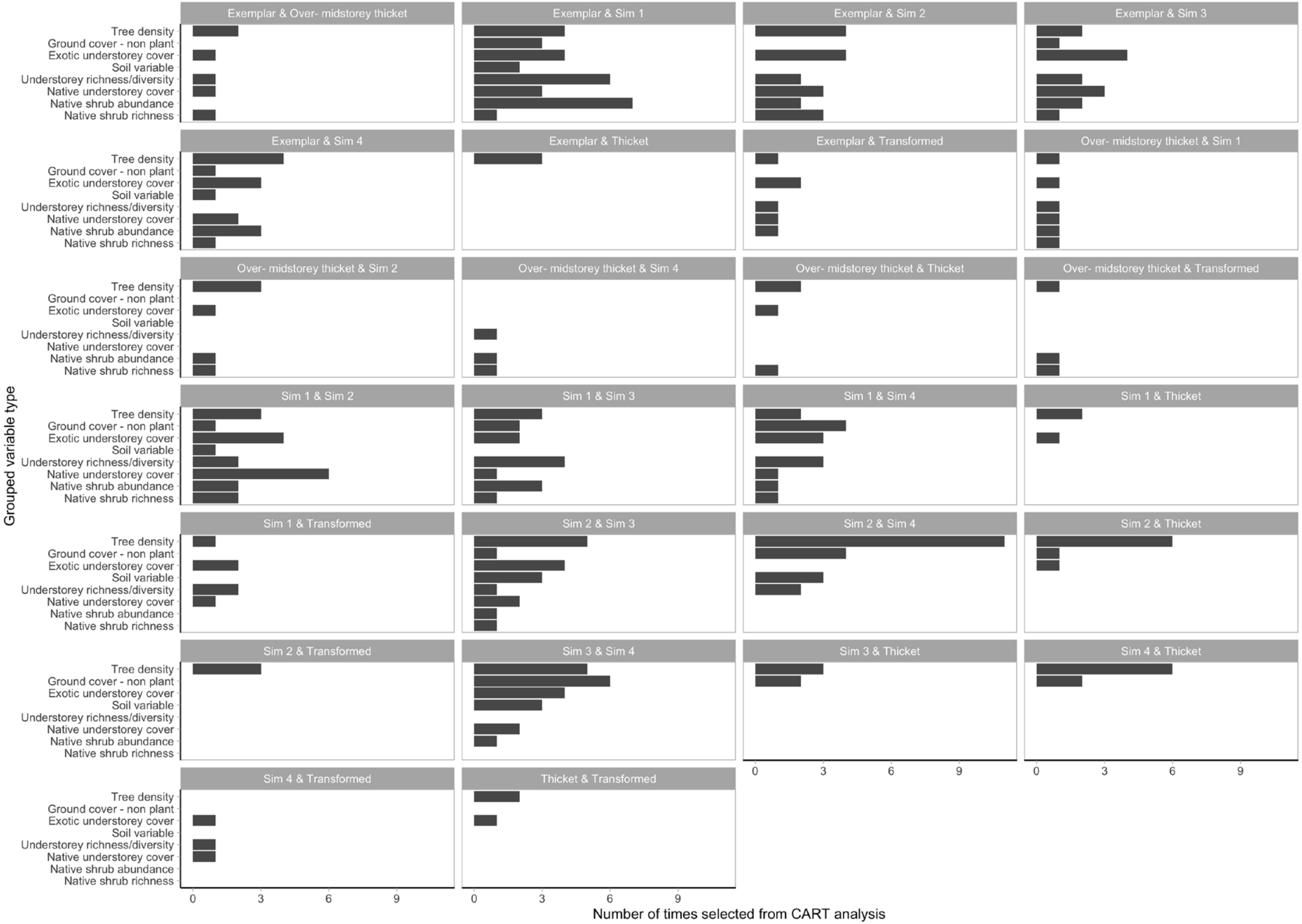


Figure 13. *The top three attributes selected in the CART analysis, for each pair of transition states represented in the original state and transition model (Project 1.2.5). Attributes had to be grouped into broader categories (e.g. 'tree density' encompasses a range of stem density classes), to account for variation in the attributes sampled across data set.*

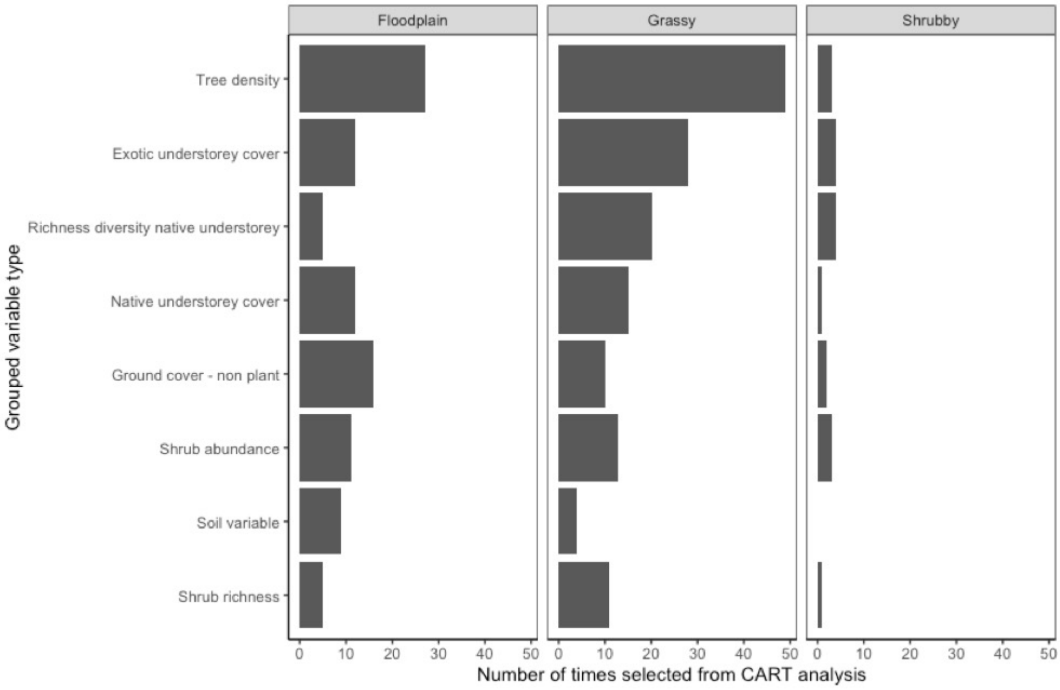


Figure 14. *The number of times each attribute was selected in the CART analysis (i.e. top 3 attributes) for each woodland type. Attributes are grouped into broader categories.*

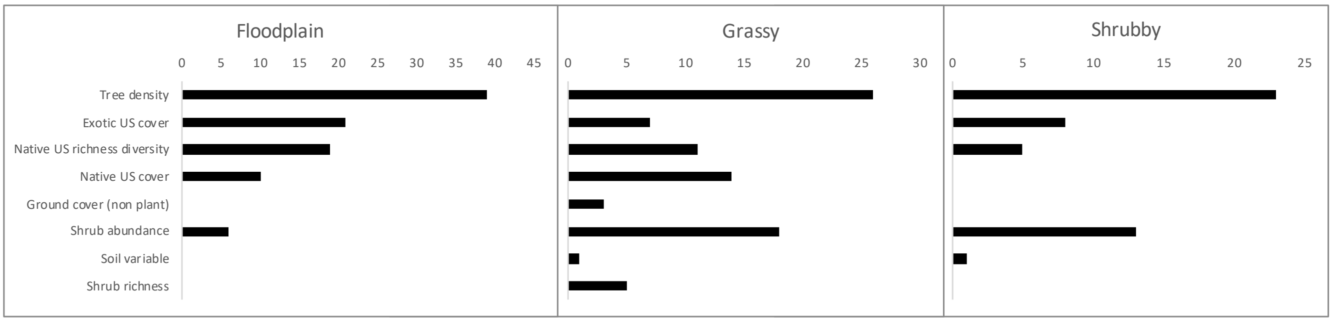


Figure 15. *The percentage of expert derived causal pathways (i.e. state-transition pathways) that mentioned each attribute, for each woodland type (Part 1). These are only for causal pathways that were considered 'likely' or 'very likely'. Attributes are grouped into broader categories.*

2.4.4 Comparing pairs of condition states to explore thresholds

We extracted the top three attributes selected by the CART analysis (above) to calculate the point at which it is likely a transition between states has occurred along with an estimate of the uncertainty around this threshold (95% confidence interval). We excluded from this analysis any thresholds where the confidence interval spanned the whole range of the attribute variable and we also removed any thresholds where the range of the lower or upper confidence interval was lower or greater than the highest value for the attribute. This reduced the total number of threshold analyses from 265 to 147.

For the 147 recorded thresholds, we can explore the confidence we might have for some of these attributes to differentiate between states, in relation to the variability of the threshold values across datasets, and the uncertainty associated with the thresholds (Supplementary Material: S2.1). Some of the threshold estimates were remarkably similar to one another, even across woodland types. For example, native shrub cover was the most often chosen variable to distinguish between Exemplar and Simplified 1 states (in the CART analysis), and the threshold between these states were 7.2% (TERN – floodplain), 5.45% (Eldridge – Grassy), 7.9% (Rumpff – Grassy) and 10.88% (Standish – Shrubby; see Supplementary Material S2.1). Two of these examples (Eldridge and Rumpff) are shown in Figure 16. Other comparisons between datasets for Simplified 2 & 4 and for Simplified 1 &2 can be found in Figure 16. The former shows that midsize trees per hectare is a reliable attribute within datasets (with small confidence intervals around the threshold estimate), but that there might be large variability in the actual threshold values between woodland types; grassy woodlands have a threshold of 32 midsized trees per hectare whereas floodplains have a much lower threshold of 0.04 midsized trees per hectare when comparing Simplified 2 & 4 condition states. This difference might be a function of the different ecology of these woodland types, with floodplain woodlands tending to have more episodic recruitment. The final pair of threshold plots demonstrates differences in the fit of the logistic relationship, with the Jones – Floodplain woodland plot showing a good fit with a clear threshold whereas there is much more error and uncertainty around the Rumpff – Grassy woodland plot.

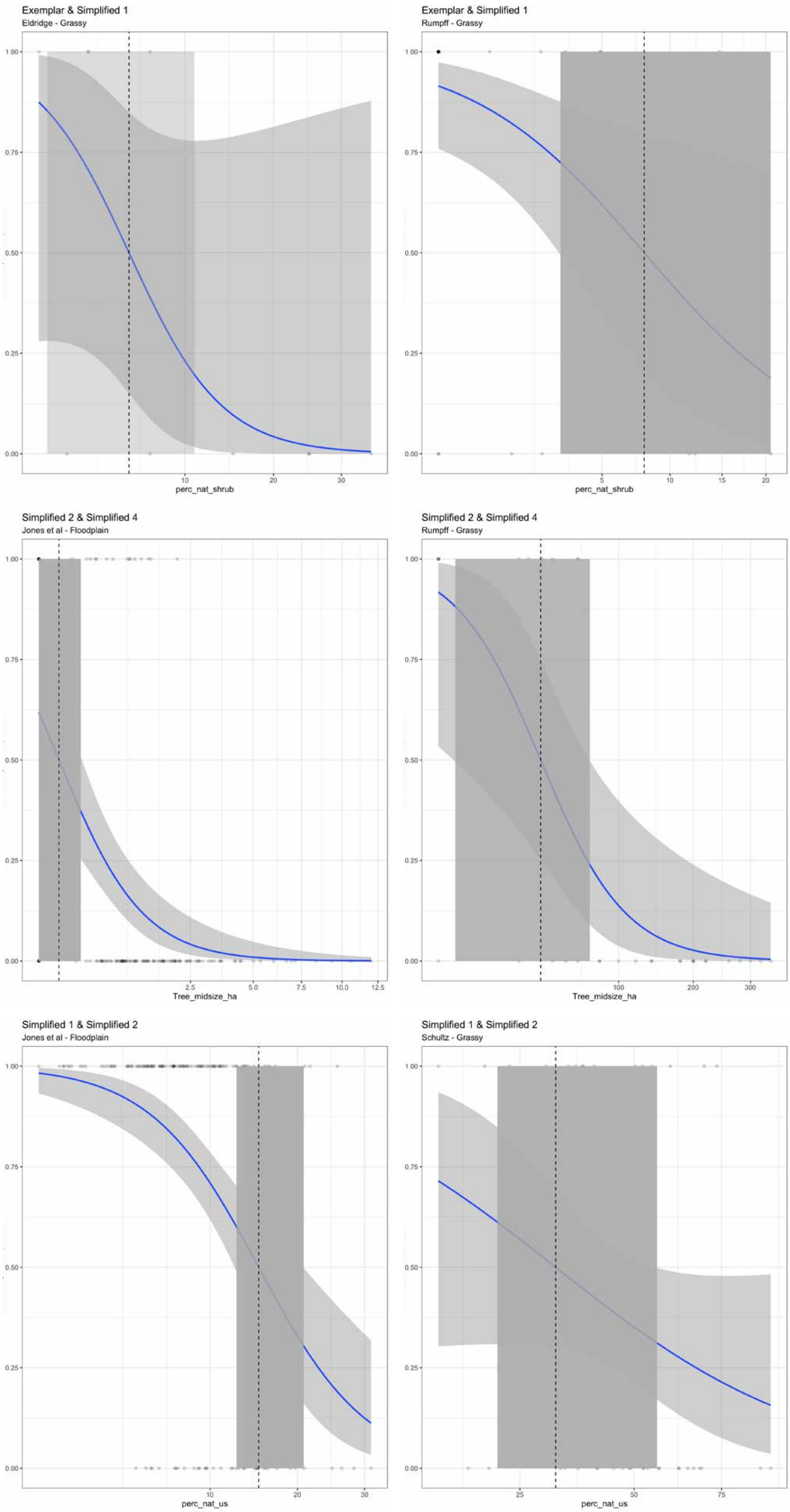


Figure 16. *Examples of logistic regressions with expected thresholds between condition states (dotted lines) with 95% confidence intervals around the threshold (shaded area around threshold). These are examples from different datasets but for the equivalent pairs of condition states and for the most commonly selected attribute (as per Figure 14).*

2.5 Discussion

This study was a preliminary investigation into how condition states vary across different woodland types in southern Australia. Given data limitations, it is not yet possible to make general conclusions without more targeted data collection and analyses. However, using field data to investigate how field ecologists perceive the different condition states described in the expert elicited model was an effective way to explore vegetation attributes associated with different condition states. The values for attributes varied among datasets, but the ability of field ecologists to compare among condition states in known sites was fairly consistent.

This study demonstrates that assigning condition states based on expert descriptions (from phase one of this project) is likely to be just as reliable as using data to assign a condition state to a site. Field ecologists and/or land managers who know an ecological community well, and are familiar with the dynamics of the vegetation, should be able to accurately assign sites or patches of vegetation to a condition state, relative to other sites or patches. From there, the relative change in condition state can be monitored using the vegetation attributes that were most reliably used to distinguish between states in this validation project. This would allow targeted monitoring based on the transition of interest, which is likely to be a more cost-effective approach to monitoring. Our general state and transition model framework is designed in a way that allows (and encourages) ongoing development and refinement as more data becomes available.

2.5.1 Were there any key differences between the datasets/contributors and why might this be the case?

Variability among datasets is difficult to interpret since there are at least three possible explanations for any differences between datasets; 1) the contributor themselves had a slightly different interpretation of the condition states; 2) the range of condition states and variables within those states is fundamentally different among different woodland communities; 3) large variability in the climate of the regions and overall productivity results in large variability in the range of vegetation attributes (for example the maximum understorey cover in a lower rainfall region is likely to be a lot lower than in a more mesic area). There are several other sources of variability that are likely, including the timing of data collection in relation to drought years. These are all factors that would need to be considered when attempting to do an overall analysis of the datasets. However, since our analyses were carried out on individual data sets, these considerations are less important for now.

Within individual datasets, differences between condition states in terms of the absolute value of attributes was clearer, indicating either relative consistency in variation between condition states within a region/vegetation type, or that the application of the condition states to known field sites was consistent for a single observer.

2.5.2 Can we distinguish between states?

Despite variability in the data, we found there are some combinations of condition states that are easier to distinguish from one another. For example, a Thicket site is quite easy to distinguish from any other state because the defining feature is the high density of trees which is a consistent and easily measured attribute that doesn't vary much among seasons and through time. Exemplar and Simplified 1 sites are more likely to have higher levels of native species richness and cover, and lower weed cover (in general). In contrast, it is more difficult to consistently distinguish between some of the Simplified sites because herbaceous vegetation (exotic and native cover) is much more dynamic and difficult to measure/observe in a consistent way.

We were able to highlight a suite of attributes that could be used to distinguish between states and could be used to support monitoring toward specific objectives using the STM framework. The threshold analysis for each of the selected attributes demonstrated that for a number of attributes measured by different dataset contributors, the actual threshold numbers were similar across systems and woodland types. Our preliminary findings can already be used to select variables for focused monitoring of transitions following management interventions, or in the detection of degrading trajectories in high quality remnants. We are confident we have developed a robust method for identifying and measuring transitions between pairs of condition states, and additional data (preferably with states assigned by multiple observers) should provide further clarity on any patterns that are emerging, and potentially enable us to explore other drivers of variability, beyond woodland type (e.g. cumulative rainfall, time etc).

2.5.3 What next?

A number of other woodland ecologists offered to contribute to the study, but it was difficult for many to find the time required to assign each of their sites to a condition state. However, this project is simply a starting point, as we have developed a data repository and framework that allows automated analysis of data. Replication of datasets would improve our ability to draw conclusions about the management thresholds and monitoring attributes. Currently, we analyse each dataset separately, so that we can utilise all the measured attributes, rather than only using the attributes that have been measured by all contributors. With the addition of more datasets, the overlap between variables will increase and we will be able to run analyses including several contributors which will be a much more powerful analysis.

Eventually, with enough datasets and contributors we would like to be able to confidently provide a list of objective condition measurements that can consistently predict which condition state a woodland is in. For example, using the data available, we have developed a preliminary predictive model (Bayesian Network) to demonstrate how data can be used to estimate the probability of being in any particular state (Figure 17). In this model, the continuous vegetation attributes are discretised into different categories (e.g. Very Low to High). Based on the values at a site, a user can select the relevant categories for each attribute and evaluate the probability of a site being in a particular condition state. This would allow for data to be analysed without experts having to assign sites to states.

Finally, this study does highlight the importance of consistent vegetation monitoring protocols to enable comparisons among different vegetation communities, across space and time. Therefore, we suggest that the next phase of this project could involve targeted and consistent monitoring to further develop and test the original model and findings.

A state-transition model framework can help with the development of targeted monitoring strategies. Image: Megan Good

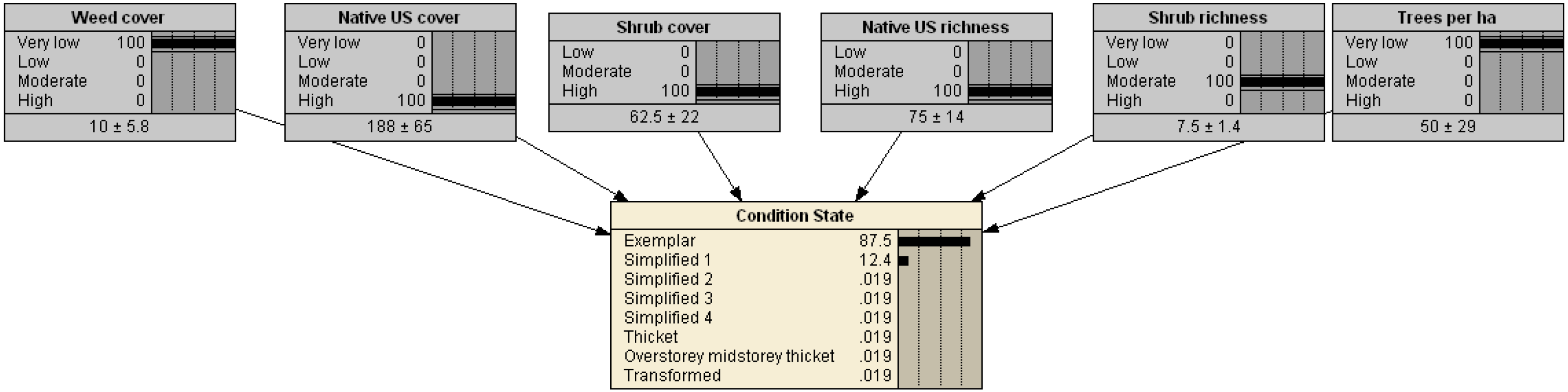


Figure 17. *Example of a predictive model (Bayes Net) which can utilise the available data (quantitative data which is discretised into node 'states') to provide a basis for predicting the probability of being in a condition state at a site.*

3. Part Three: How do we integrate fauna into our model?

3.1 Summary

We invited woodland fauna experts to participate in a survey and virtual workshop to elicit feedback and ideas for how to increase the relevance of our vegetation focused Woodland Ecosystem Model. The feedback we received indicated there was overlap in the types of threats, management interventions, and attributes that are important for woodland fauna and flora. However, there were some key differences which highlighted the importance of integrating different perspectives into the woodland ecosystem model. Fauna experts placed a bigger emphasis on the structural complexity of the vegetation layers, the presence or absence of hollows and logs, and the complexity of the non-plant groundcover (e.g. open patches in ground layer to accommodate ground dwelling species).

As a group, the decision was to update the existing models and The Guide (Part 4) to incorporate the key threats and habitat attributes required for fauna in each condition state. However, it was noted that a process for building STMs that integrate faunal objectives and indicators is required, because including habitat attributes alone could perpetuate the risk of a 'silent forests' approach to restoration. This will be a challenge, as most STMs focused on site-scale processes, but landscape context and landscape scale processes are critical for fauna conservation. Last, there is a need to incorporate reintroduction and protection of fauna as an action to support restoration of processes to drive transitions to functioning, self-sustaining states (i.e. the 'Exemplar' state).

3.2 Introduction

Planning for implementation of ecological restoration actions at a landscape scale is critical to ensure the conservation of fauna, but also to support the ecological processes that are required to achieve functioning, self-sustaining ecosystems (McAlpine et al 2016). Acting at a landscape scale is challenging, largely due to the funding and operational (e.g. access) constraints limiting action at larger scales, particularly in fragmented agricultural landscapes (Vesk and McNally 2006). In addition, chronic short-term funding perpetuates the implementation of short-term actions and site-scale restoration goals, where success is (potentially) more demonstrable. These reasons (and others) have contributed to a disconnect between fauna conservation and vegetation restoration efforts.

A vegetation focused approach to conservation can have perverse outcomes for fauna. A focus on restoring vegetation (or habitat) extent and condition is often associated with an assumption that there will be flow-on positive consequences for fauna communities, akin to the Field of Dreams hypotheses for restoration (Palmer et al. 1997). Yet this is a risky assumption. For instance, the protection of existing habitat via reserve systems or through laws that restrict vegetation clearing have largely failed to protect the most endangered Australian mammals (Woinarski et al. 2015). In addition, there is potential for some common restoration actions to negatively affect fauna (e.g. weed control and invertebrates), though there is little research available that explores these potential impacts (but see Lindenmayer et al, 2017).

Unsurprisingly, the development of state and transition models to support restoration management decisions has also generally been largely focused on site-scale actions to support vegetation condition (Bestelmeyer et al 2017). Fauna are sometimes considered, but often indirectly via the use of key habitat features that are thought to influence fauna assemblages (such as the abundance of tree hollows, midstorey complexity, litter depth, course woody debris), reflecting the implicit assumption that habitat begets fauna. For example, Croft et al (2016) demonstrated the potential negative consequences of frequent fires on fauna habitat in open forests and woodlands of northern NSW. Yet the state and transition model framework may be useful for understanding the dynamics, habitat requirements and threats to fauna assemblages, especially when fauna responds to changes in their habitat in a non-linear way. For example, Letnic et al (2004) found that small mammals respond differently to post fire succession than reptile assemblages, via complex interactions with predator numbers, the presence or absence of food resources, the timing and amount of rainfall, cattle grazing and fire regime (amongst other factors). Similarly, Radford et al (2014) identified distinct mammal communities in the Kimberley region of Northern Australia and the processes governing these assemblages were a complex interaction between predators and the consistency of resources within sites. These examples demonstrate that the factors contributing to fauna composition are a complex mix of site and landscape scale processes and that these factors can influence fauna in a non-linear way.

One problem with the site-scale focus of STMs is that many fauna groups are influenced by multiscale factors that cannot be measured or managed at the site scale. For example, the presence of introduced predators remains the most threatening process for most endangered mammals (Woinarski et al. 2015) and yet, in the absence of predator proof fences or effective landscape scale predator eradication, any attempts to restore a faunal community within a site will be largely ineffective or, at best, inefficient. Overgrazing by macropods and degradation by feral ungulates is also a threat that is best managed at a landscape scale, to maximise restoration efforts within a site. However, spatially explicit STMs which incorporate multi-scale processes are possible and have been attempted in the rangelands of North America (Bestelmeyer et al. 2011) and this approach could be used to better incorporate these landscape scale threats for ecosystems.

The complexity of the interactions between vegetation, soil, climate, and fauna cannot be overstated. However, the importance of attempting to accommodate this complexity into an ecosystem model is vital to capture our understanding (and uncertainty) of system dynamics and management response, in order to support decision-making (Vesk and McNally 2006). Fauna are often considered to be passengers in ecosystems, but many ecosystem processes are dependent on fauna. The role of invertebrates and soil organisms in the carbon cycle of an ecosystem is well established, and recent studies have demonstrated the importance of digging mammals for soil fertility, seed germination and overall woodland condition (Davies et al 2019, Valentine et al 2018). Clearly, development of restoration models requires the inclusion of habitat attributes, the target faunal assemblages, and better attempts to reconcile site and landscape scale threats and drivers.

3.3 The approach

This project is based on a site-based State and Transition model that was initially focused on vegetation condition (Part 1). Expert elicitation as well as field data from vegetation surveys were used as a basis for a Guide that supports conservation planning of eucalypt woodlands across Southern Australia (Part 4). The focus on vegetation data meant that there was a risk that the model could represent an incomplete suite of management recommendations that do not positively impact woodland fauna, or worse, may have unintended negative consequences for fauna. For this reason, we consulted a team of woodland fauna experts to ask: is our model suitable for a range of fauna groups? And if not, how does the model, and/or the model development process, need to be altered?

We invited 10 woodland fauna experts to participate in a 1-day virtual workshop in order to elicit feedback about how we could best integrate fauna-specific habitat attributes, threats and management opportunities into our vegetation focused general ecosystem model for woodlands of southern Australia. To support discussions, we first sent out a survey (see supplementary 3. 1) to help participants gain familiarity with the existing models, and to obtain information that would help structure the workshop. All the invited participants responded to the survey, and of those, 8 answered all of the questions. The 1-day workshop was attended by 8 fauna experts with at least one expert representing each of the main fauna groups: birds; mammals; reptiles and amphibians; invertebrates; and macropods.

3.3.1 The survey:

The survey asked for the following information:

1. Habitat attributes that are relevant to the fauna group of interest, for each condition state (participants could opt to do this for up to four fauna groups, depending on their areas of expertise)
2. Specific fauna species or functional groups (i.e. faunal indicators) associated with each condition state;
3. The potential threats and management interventions that might be specific to each condition state; and
4. General feedback about how applicable the experts felt the model was for their fauna groups of interest, and also any other broader issues that need to be addressed to better accommodate fauna into the model.

3.3.2 The workshop:

We presented the survey results to the participants and goals for the project: to attempt to integrate the fauna habitat attributes, threats and management interventions into our general model. We discussed:

1. whether the condition states made sense for fauna, and the key issues with adapting site-based models;
2. the habitat attributes, threats and management levers driving transitions for fauna, and how these compared to those from the initial process with vegetation experts; and
3. the process of updating our decision trees in order to better accommodate fauna (see Supplementary material S3.3).

3.4 Results and discussion

3.4.1 Habitat attributes

There was some overlap in the key habitat attributes suggested by the fauna experts as key indicators of condition states (Figure 18). The habitat characteristics that were most often mentioned, across all condition states, were attributes relating to the health, structural complexity and density of the overstorey, closely followed by mentions of coarse woody debris, groundstorey type or cover and tree hollows. Habitat attributes relating to the groundstorey were most often mentioned by invertebrate and reptile experts, while bird and aboreal mammal experts mostly mentioned overstorey and midstorey attributes. Tree hollows were consistently mentioned by all fauna group experts. For comparison, the most common attributes identified by plant ecologists that could be used to distinguish between condition states, across woodland types, include tree density, exotic understorey cover, and diversity/richness and cover of the native understorey (Figure 15).

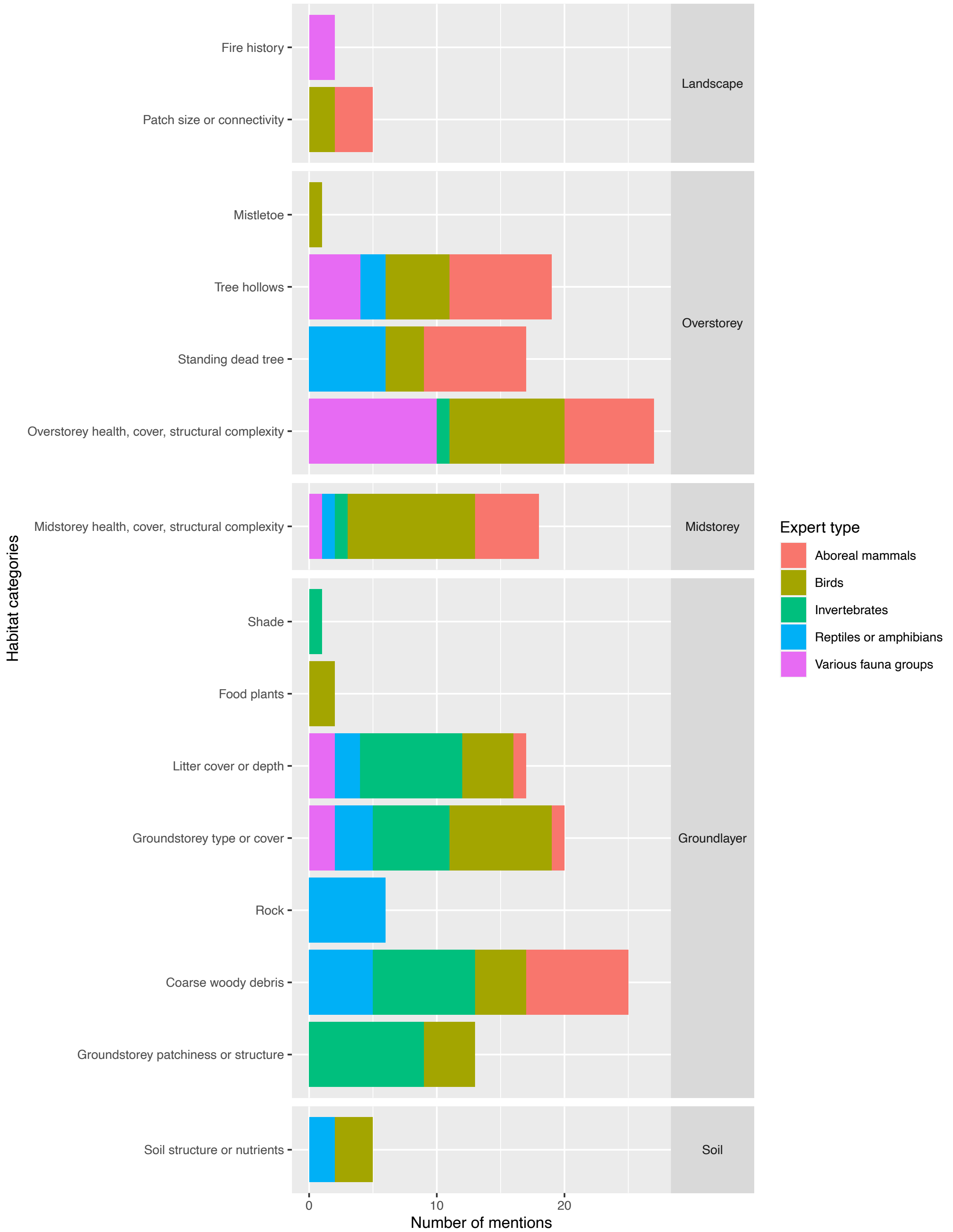


Figure 18. *Total number of times each habitat attribute was mentioned by fauna experts across all condition states.*

3.4.2 Threats and management opportunities

All experts across fauna groups mentioned (inappropriate) fire regimes as a key threat to fauna, and whilst reinstating appropriate fire regimes was a commonly mentioned management intervention, it was not the most mentioned intervention (Figure 19). Any threats which degraded or removed the key habitat attributes were very often mentioned by experts. These include vegetation clearing, removal of coarse woody debris, tree mortality, drought, and fragmentation. Grazing management (stock, feral animals and macropods) was by far the most mentioned category of management intervention. Managing coarse woody debris, revegetation and increasing connectivity were also frequently mentioned.

In Figure 7 (Part 1), we highlight the most common threats driving the transitions between vegetation condition states. Not surprisingly, there is some overlap, as threats such as vegetation clearing, mortality, grazing and low rainfall can all lead to a loss or decline in vegetation condition or habitat. Fire was a more prominent threat to fauna, but this again is unsurprising given the direct (e.g., mortality) and indirect (e.g. temporary loss of habitat features, predation) consequences of fire on fauna (Letnic et al 2004, Davis et al 2016). In addition, it is the removal of specific habitat attributes (CWD, rocks, hollows) that is problematic for fauna, but less so for vegetation condition. The other key difference was the importance of threats which act at the landscape scale (e.g. fragmentation), which again, affect both persistence of fauna and vegetation condition over time. However, the impacts on fauna are greater in the short-term due to disruptions to dispersal and movement, particularly for mobile fauna with large range size. Revegetation and grazing management were also key actions for managing vegetation condition, but ecological thinning, and weed control were far more commonly mentioned actions for vegetation condition. Some work on vertebrates has shown that control of weedy shrubs and ecological thinning likely have neutral affects on vertebrates (Gonsalves et al 2018, Lindenmeyer et al 2017). Yet, there are potential negative consequences of both weed control and thinning on certain faunal groups, and more research is required in this area, especially for invertebrate species who would be likely most affected by changes to the ground layer.

A fence-line shows the effect of grazing pressure on groundcover during a drought. Boulders and rocks are important habitat for woodland fauna. Image: Megan Good

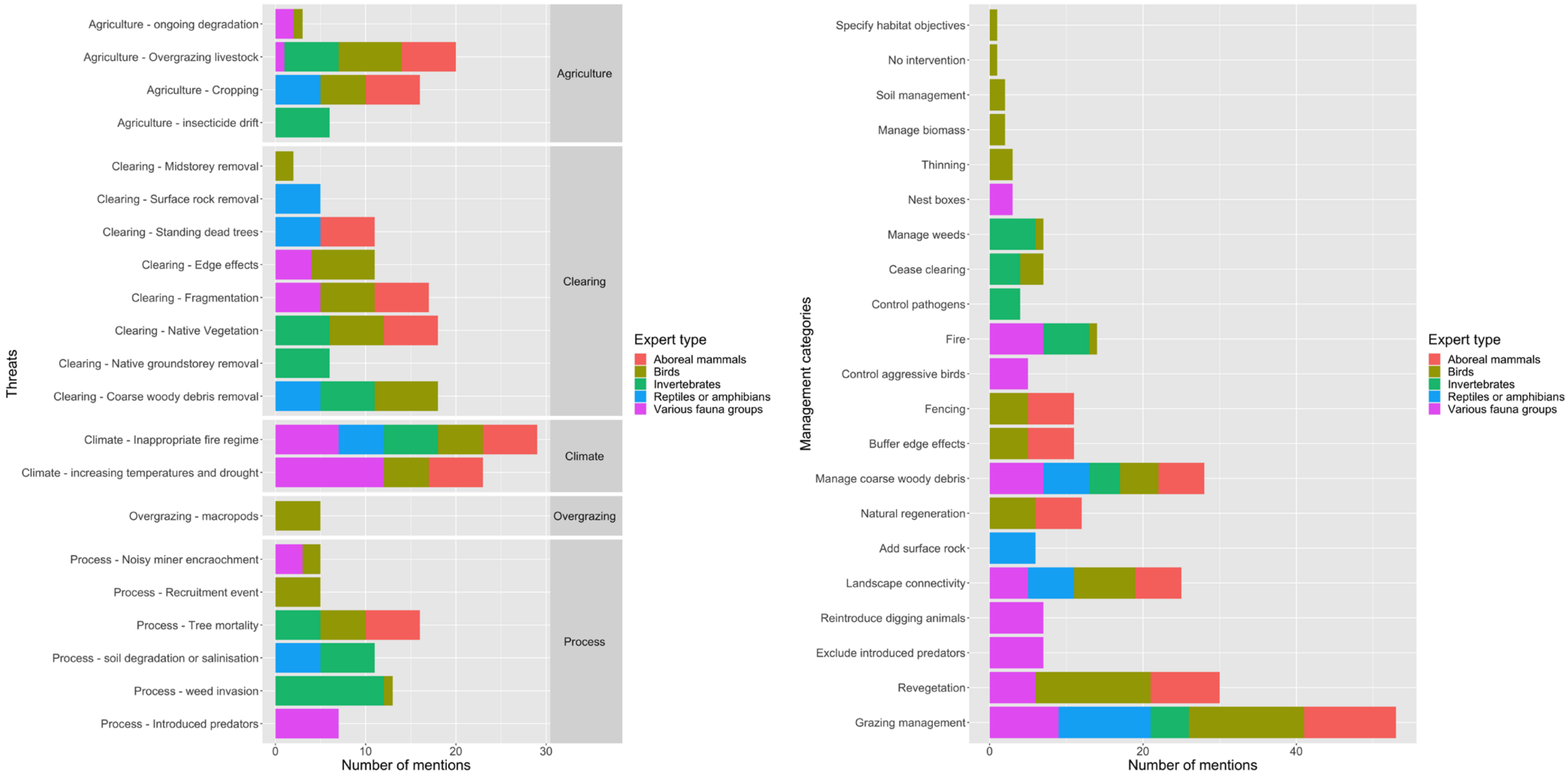


Figure 19. *All threats and management interventions mentioned in the survey by fauna experts, categorised for ease of comparison. Expert types are in different colours.*

3.4.3 Indicator fauna species or groups

Experts listed many groups and species which might be associated with each condition state. At this stage we have simply made a table of all the responses for this section (Supplementary Material S3.2), but we also discussed using some published lists and resources to identify which groups of species might be useful for indicating which 'faunal' condition state a site is in. This is an area for future work, and could be further developed to align with the targeted monitoring variables approach highlighted in Part 2.

3.4.4 Integration of information into the guide

We opted to include two additional fact sheets in the Guide (Part 4) which we have included as an additional step in the conservation planning process: 'Step 5: Assess fauna habitat attributes and landscape processes'. We decided on this approach because we felt that the incorporation of fauna habitat attributes could be included in any condition state. For example, even a Transformed site could be improved – from a fauna habitat perspective – with the addition of coarse woody debris and rock piles. We also included the landscape processes fact sheet to highlight the factors which might influence success at the site scale – however this is an area that requires more thought as we develop the model further.

3.4.5 Next steps

There is a clear need to consider landscape composition to prioritise where to act, which is likely driven primarily by resource availability, and operational constraints. However, the point was made in the workshop that it is critical to consider management of landscape scale processes/threats, because they both help determine what actions are appropriate at the patch scale, but also have an impact on effectiveness of those actions. This is true for both management of fauna and vegetation over time, but clearly landscape scale threats and actions are critical for managing fauna in the short-term.

During the workshop we discussed some of the results from the survey, but our discussion turned to how to progress development of models to support both management of vegetation condition and fauna. More work is required to ensure that specification of management objectives incorporate the key role of fauna in a functioning woodland ecosystem. Next steps include:

1. incorporate landscape scale processes, (connectivity, patch size, edge effects, distance to source populations, minimum habitat size requirements) into a site-scale model. STM's are recognised as a useful tool, so more work is required to adapt them to incorporate landscape context, which is clearly important for the management of fauna.
2. ensuring that monitoring includes targeted fauna monitoring to objectively assess the success of restoration projects.
3. identifying groups of fauna species (using existing work where available) which may be useful indicators of woodland condition.

An example of a woodland bird – The Grey-crowned Babbler – favours woodland habitat with an open shrub layer and plenty of course woody debris and leaf litter. Image: Mark Gillow, CC BY 2.0.

4. Part Four: A practical guide for conservation planning using the General Ecosystem Model for Southern Australian Woodlands

4.1 Introduction

We synthesised the information gathered throughout the project (Parts 1-3) into a Guide to support conservation planning of eucalypt woodlands of southern Australia. The link to the Guide is provided at the end of this section, but we provide a brief overview of the process here.

The Guide is structured as a series of interactive fact sheets aimed at policy makers and on-ground managers to provide:

- An understanding of the key threats, management interventions, and key monitoring variables for each woodland condition state,
- decision trees for each positive state-transition, to guide management decisions based on site-scale conditions, and
- information on habitat attributes and landscape processes that influence fauna, to help identify opportunities to enhance site-scale restoration for faunal communities.

4.2 The Guide

This guide is an attempt to bring together the expert knowledge and field data to create an interactive and practical framework to streamline the process of building conservation plans for woodlands, including advice on management and targeted monitoring.

4.2.1 Who is the target audience for this guide?

There are expected to be two types of users of this guide: (1) those responsible for writing and researching the specific Conservation Advice and Recovery Plans for existing and new listed woodland communities and/or; (2) those responsible for designing and implementing regional restoration or management projects for eucalypt woodlands in southern Australia.

4.2.2 How should the guide be used?

The guide can be used to assist with conservation planning (e.g.Recovery Plans or Conservation Advice) for listed ecological communities, and/or it can be used to set management objectives and create a management and monitoring program for on-ground restoration. We have focused the guide on a general state-and-transition model for woodland condition. As such there is detail on the specific risks and opportunities related to the eight condition states. The steps in using the guide to help develop conservation plans for listed woodland communities are as follows:

Step 1: Choose a woodland type that most aligns with your focal woodland community.

Step 2: Set landscape goals by first considering the type and proportion of condition states present in the landscape.

Step 3: Identify the restoration pathways and transition risks that are most likely for each of the condition states in the landscape.

Step 4: For each condition state, use the relevant fact sheet to create a detailed plan. The fact sheets include information on key threats, decision trees for different restoration pathways, and monitoring variables that will indicate the direction of change through time.

Step 5: For each condition state, consider the habitat attributes and landscape processes that influence fauna, and identify opportunities to enhance site-scale restoration for faunal communities.

Step 6: Monitoring programs are critical for evaluating the effectiveness of management interventions and should be conducted in a consistent, objective way, which may require additional resources. Uncertainty about management intervention effectiveness is often high and trialling different actions via adaptive management may be necessary.

The Guide can be found here (KATE Please provide hyperlink to the guide)

5. Conclusion

The initial trigger for this work was to explore the potential for developing a multi-community plan for the eucalypt woodlands of southern Australia, underpinned by an expert-elicited general model. We believed that broader ecosystem management models that clearly describe existing information and indicate the generality or specificity among the full suite of ecosystems can be useful, or indeed critical, for guiding future management.

This report shows that there are many overlapping characteristics, threats and drivers, and recommended management interventions for southern Australian eucalypt woodlands. Despite differences in the composition, structure and function of the three woodland types, management advice is likely to be relatively consistent across multiple communities. This provides excellent justification for the development of a generalised STM for southern Australian woodlands, to support multi-community recovery plans. In addition, though we restricted this project to explore similarities and differences in eucalypt woodlands of southern Australia, but we believe there is good justification to explore non-eucalypt woodlands, and those from northern Australia.

Our intent was that the specific information and approach from this report (the Guide, Part 4) will be used by those responsible for developing woodland conservation plans, and/or designing and implementing regional restoration or management projects. However, more broadly, in this project we have developed and demonstrated i) a robust and transparent process for eliciting general models to support recovery planning, and ii) a structured analytical framework for assessing which monitoring attributes best distinguish condition states, and the thresholds that could be used to evaluate progress toward conservation (condition state) objectives, and; iii) a framework for developing a Guide to support conservation planning of ecological communities, underpinned by STMs and decision trees to guide management. Given that resource and time constraints are considerable impediments to the development and implementation of conservation plans, we believe our approach may provide a more structured and cost-efficient approach that enables development of multi-community plans.

6. Ethics statement

This project was led by researchers at the University of Melbourne. It was funded by the Australian Federal Government' National Environmental Science Program's Threatened Species Recovery Hub. This project was conducted under human ethics approval from the University of Melbourne (Project 12032).

7. Acknowledgments

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Further information:

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