Threatened Species Recovery Hub

National **Environmental Science** Programme

Supplementary material

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 'transformed' grassy woodland condition state. Image: Libby Rumpff
Top right: A Eucalyptus camaldulensis *floodplain woodland. Image: Megan Good*
*Bottom left: Obligate-seeder gimlet (*Eucalyptus salubris*) woodland, with a chenopod shrubby understorey. Image: Carl Gosper*
Bottom middle: A 'thicket' woodland condition state. Image: Libby Rumpff
*Bottom right: Obligate-seeder gimlet (*Eucalyptus salubris*) woodland, with a sclerophyll shrubby understorey. Image: Carl Gosper*

Contents

Supplementary material - Part 1

S1.1 Identifying similarities in the structure of STMs

Between the two workshops, 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 woodland condition states (Table 3). The aim was to determine whether there was a consensus model structure for each state, between and across woodland types, and if not, where the differences in transitional pathways occurred. Examining the transitional pathways was the first step in identifying any competing models for woodland dynamics across southern Australia.

We initially included the following woodland types: Floodplain/Riparian woodlands, Temperate Grassy woodlands, Temperate Shrubby woodlands, Subtropical Grassy woodlands, Subtropical Shrubby woodlands, and Obligate seeder woodlands, following the types presented in the Australian Ecosystem Models Framework (Figure 1). We reduced the scope during the workshop to temperate woodlands due to the number of experts available for each woodland type, and to keep the elicitation process manageable during the workshop.

We used the survey data to build Directed Acyclic Graphs (DAG) describing these transitions for each woodland type (Figure 1). Due to similarities between Shrubby and Obligate seeder woodland DAGs, we combined those two woodland types during the workshop. Initial results suggest the DAGs for temperate and subtropical woodlands were also very similar, and this could be explored further at a later stage.

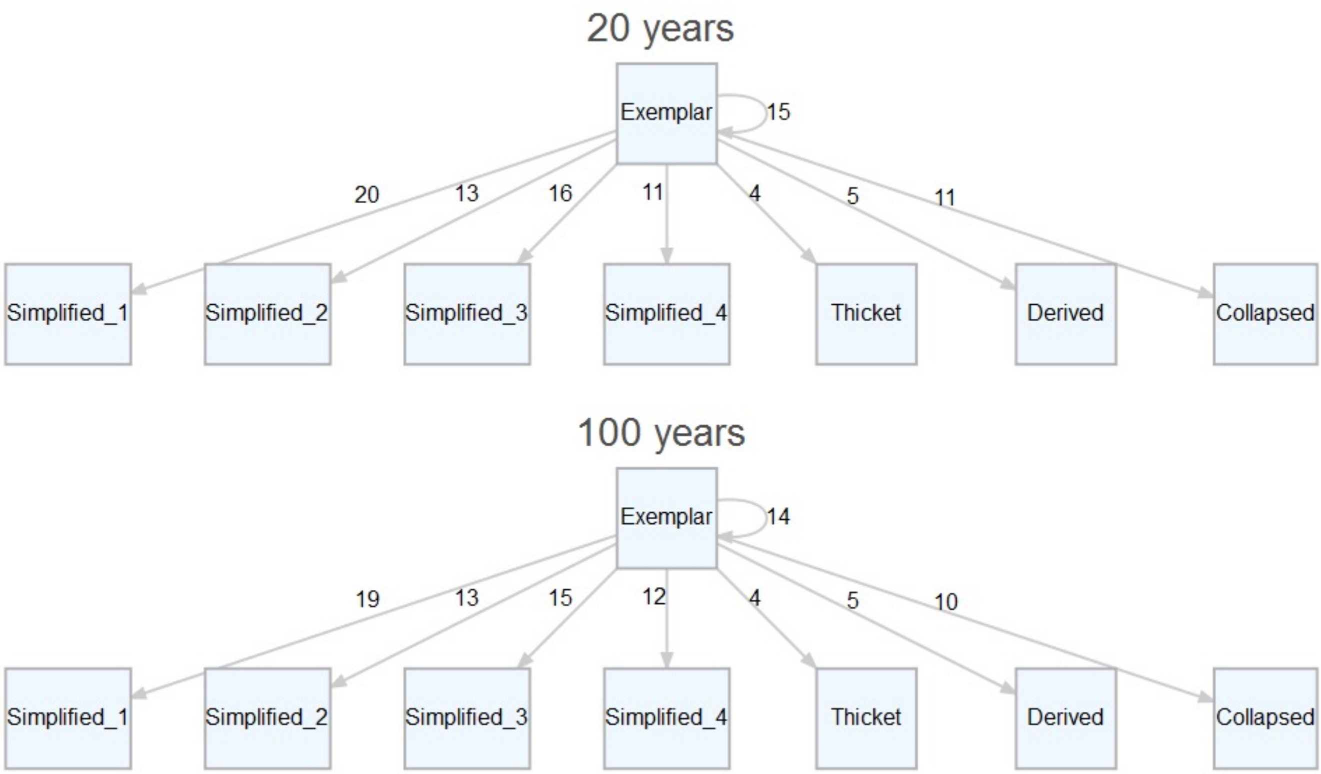


Figure 1. *Example of a Directed Acyclic Graph (DAG) developed during the survey, showing possible direct transitions for the Exemplar state, over 20 and 100 years. This DAG is a collation of findings for the three woodland types - there were 32 responses in total, and the numbers on the edges (or links) indicate the number of responses that indicated the transition was plausible. Preliminary results indicated most changes from Exemplar can happen in 20 years, Exemplar can remain in an Exemplar state, or transition to Simplified 1 or Simplified 3, but is unlikely to go to the Thicket or Derived states. In groups, experts were asked to review and compare the DAGs for each state, for the two time periods, and come up with a consensus model for each state, for each woodland type.*

During the 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. These initial models (DAGS) were then used as the basis for assessing the drivers and likelihood of each transition, for each woodland type (Step 5). Understanding the overarching conceptual models was seen as a necessary first step, to reduce the elicitation burden in Step 5.

Step 5. Unpacking the drivers of transitions

Using the states and transitions that were deemed plausible by the three woodland groups in the workshop, each group was asked to consider each individual transition, for each state, and create a series of plausible cause-and-effect pathways. The cause-and-effect pathways identified drivers that need to occur together or in sequence, in order for the transition to take place (see Figure 2 for an example posed during the workshop). The drivers could be classified as either: environmental drivers (e.g. drought), land-use or management drivers (e.g. grazing, inplanting), or ecological processes (e.g. nutrient cycling). Participants were asked to be as specific as possible regarding the nature and direction of the drivers. For example, instead of just specifying 'drought', participants were asked to write 'increasing drought frequency or duration'.

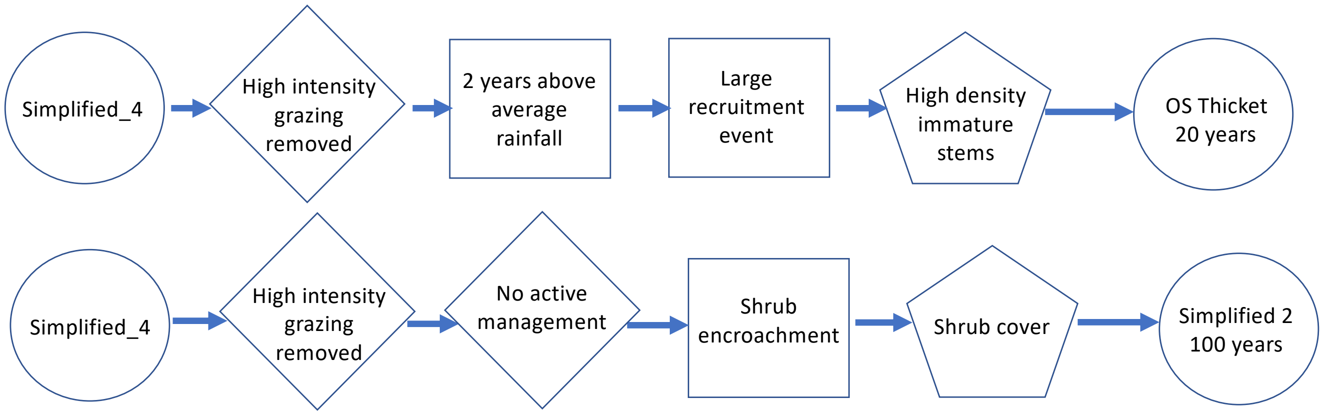


Figure 2. *Two possible causal chains for transitions from the Simplified 4 starting state. These examples are illustrative only, and were provided to experts in the workshop for guidance on the task. Circles indicate starting or final state, diamonds represent land-use or management drivers, rectangles indicate environmental drivers or ecological processes, and pentagons represent the state attributes that indicate whether a transition has taken place.*

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, in Figure 2), 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 qualitiative categories. 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.

S1.2 A preliminary quantification of states

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 (Appendix 3), where experts could draw on their knowledge, or from empirical data if available.

Figure 4 displays all data supplied by experts during this project. It is evident that native understorey richness and cover are variable across woodland types, but generally reduced in Overstorey Thicket, Overstorey and Midstorey Thicket and Transformed states. Commensurately, sapling density is elevated in both Thicket condition states and midstorey density is elevated in the Overstorey and Midstorey Thicket state, but also highly variable across woodland types. Mature tree density is highest in Exemplar, Simplified 1 and Simplified 3 condition states.

We consider 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 (Burgman 2016; Hanea et al 2016; Hemming et al 2017). We expect the quantification in states to be an important potential source of variation between woodland types (as indicated in Figure 3), and across southern Australia. The next iteration of this work (Project 7.2) will involve validation of the states using further expert opinion or against empirical datasets, to explore similarities in woodland types across southern Australia.

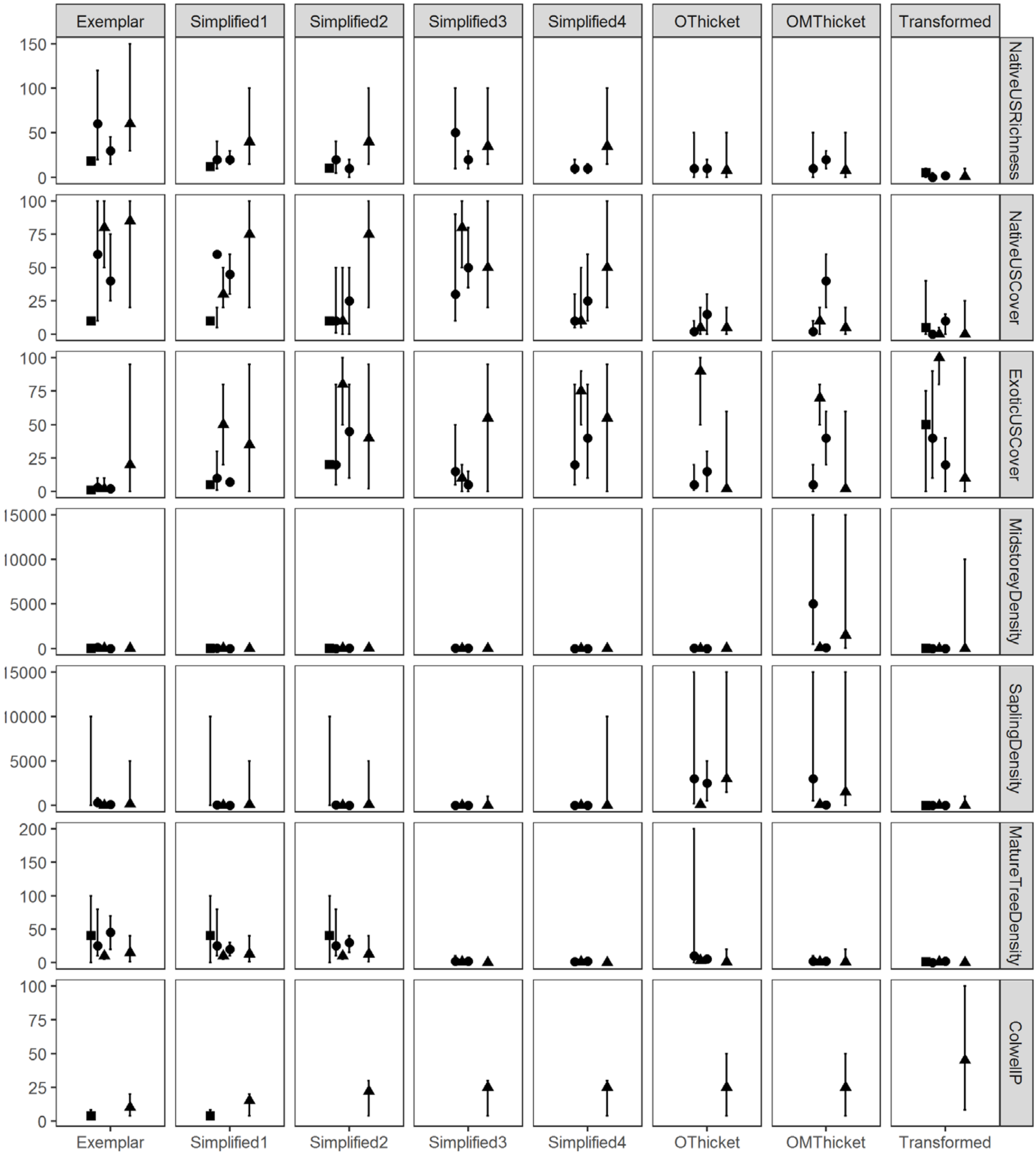


Figure 3. Graph showing expert elicited values of 7 variables across the different woodland condition states. Each point is an expert's estimate, error bars represent the upper and lower plausible values estimated by that expert. Circles represent expert data regarding floodplain/riparian woodlands, triangles grassy woodlands, and squares shrubby/obligate seeder woodlands. 'US' refers to understorey

Several state attributes were difficult to quantify, either because data and/or knowledge was not widely available amongst the experts (e.g. soil P and N), or because the attributes were difficult to define as a useful quantity (e.g. grazing sensitive species). For example, Colwell P was the only soil characteristic that experts felt equipped to quantify, but only 2 experts provided estimates, and not for all states. Preliminary estimates indicate the experts expected Colwell P would be lowest in the Exemplar state, increase though the Simplified states, followed by the Thicket states, and be highest in the Transformed states.

In the workshop, experts specified discrete categories for the attributes that were difficult to quantify, but helped differentiate the states. Experts were asked whether Colwell P, available nitrogen, and pH would be natural or altered in each condition state, and whether grazing sensitive species are present or absent in each state (Table 4). Overall, Table 4 indicates that soil nutrient characteristics are most consistently considered 'altered', and grazing sensitive species 'absent', in the Simplified 2 and Simplified 4 condition states. Though soil condition is likely to be poor in a Transformed state, soil nutrients are not necessarily altered, because these states include salinized areas which may not have been enriched. Again, the Exemplar, Simplified 1 and 3 states are most likely to be considered in good condition in relation to soil nutrients and the presence of grazing sensitive species (though this does not necessarily align with Figure 4 for Colwell P in the Simplified 3 state).

Table 5 *Key terms used in this report with their meanings and any relevant literature.*

Condition State	Colwell P	Available Nitrogen	pH	Grazing Sensitive Species
Exemplar	Natural	Natural	Natural	Present
Simplified 1	Natural	Maybe altered	Natural	May be present
Simplified 2	Altered	Altered	Altered	Absent
Simplified 3	Natural	Natural	Natural	May be present
Simplified 4	Altered	Altered	Altered	Absent
Overstorey Thick-et	May be altered	May be altered	May be altered	Absent
Overstorey and Midstorey Thicket	May be altered	May be altered	May be altered	Absent
Transformed	May be altered	May be altered	May be altered	Absent

S1.2 Practical Management Recommendations

Below, we present summary information for each of the condition states, including:

iv. A description of each condition state,

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

vi. Recommendations for how to:

- o maintain or increase the likelihood of transition to an improved state via positive drivers (decision trees)
- o avoid degradation due to threats (or a negative transition)

Note that the recommendations below assume that certain vegetation condition states are preferable to others, but we recognise this is a value judgement, and depends on the extent and conservation values provided by each state.

Exemplar woodlands

Exemplar vegetation condition is considered uncommon in Shrubby/Obligate Seeder woodlands and very uncommon in Grassy and Floodplain/Riparian woodlands (Table 4). Exemplar condition vegetation is often found in remnants and reserves and is the best vegetation remaining in the landscape, but not necessarily in pre-1788 condition. 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 (Table 3).

How to maintain the Exemplar state

The Exemplar state mostly exists in isolated remnants. Ensuring that these remnants remain in the same state is best achieved by monitoring vegetation and intervening if the understorey diversity declines, or recruits are being heavily browsed (Figure 15). In Floodplain/Riparian woodlands it may be also necessary to control weeds if there is a flood event that is followed by adequate rainfall.

Transitions to watch out for:

These transitions are considered declines in condition from a conservation perspective, and may occur without careful management.

Exemplar to Simplified_1

Vegetation in Exemplar condition can degrade to Simplified 1 condition due to land uses associated with agriculture (i.e. Type 2 transitions). Experts also consider transitions to Simplified 1 very likely due to changes in the fire regime, especially if drought is also involved. Similarly, Exemplar is considered likely to transition to Simplified 1 over long timescales due to fragmentation and associated reductions in geneflow and recruitment.

Simplified 1

The Simplified 1 state is considered uncommon in all woodland types (Table 4). Simplified 1 states are often found in travelling stock reserves, or areas that have not been subject to continuous disturbance. The overstorey is mostly intact; mid/understorey is depleted in both richness and cover; understorey flora is primarily native; and soil nutrient levels are natural, or close to natural (Table 3).

How to restore:

Simplified 1 to Exemplar

The most likely pathway for restoring Simplified 1 vegetation to Exemplar condition is to remove stock and allow for passive regeneration to occur, or, in floodplain and riparian woodlands, by reinstating a natural flood regime. However, it is possible to facilitate this transition by reducing grazing pressure and restoring understorey diversity (Figure 16).

How to stay the same:

It is possible that vegetation will remain in a Simplified 1 state with no intervention, or if low intensity periodic/rotational grazing is retained, and grazing by native or feral herbivores is kept at a low level.

Transitions to watch out for:

Simplified 1 to Simplified 2

Simplified 1 may transition to Simplified 2 states through agricultural interventions (i.e. Type 2 transitions), but this transition may also occur through benign neglect. In Floodplain and Riparian woodlands, this transition can occur via flood events that bring exotic propagules, or altered flood regimes.

Simplified 2

Simplified 2 vegetation is considered common in Grassy woodlands, neither common nor uncommon in Shrubby and Obligate Seeder woodlands, and uncommon in Floodplain/Riparian woodlands (Table 4). It is often seen in road reserves and has a mainly intact overstorey, but the mid/understorey is depleted in richness and can be elevated in cover, exotic annual herbs are present and may be prevalent, and soil processes are altered (Table 3).

How to restore:

Simplified 2 to Simplified 1

None of the pathways from Simplified 2 to Simplified 1 were considered likely but the transition is possible through intensive intervention, including removal of stock, cessation of nutrient additions (i.e. through fertiliser), ecological burning, and through revegetation of the under- and midstorey. In Floodplain and Riparian woodlands reinstating a natural flood regime (or a single flood instance) with follow up weed control can also instigate this transition (Figure 17).

How to stay the same:

The Simplified 2 state is likely to remain stable if there is no active management intervention, or if low intensity or rotational grazing is retained, and grazing by native or feral herbivores is moderate to low. If the site is stocked it may be important to reduce the number of stock or remove stock completely in drought conditions.

Transitions to watch out for:

Negative transitions are not common unless there are deliberate mass disturbance interventions such as clearing.

Simplified 3

The Simplified 3 state was considered very uncommon in Grassy and Shrubby and Obligate seeder woodlands and uncommon in Floodplain and Riparian woodlands (Table 4). It may occur in paddocks with scattered trees and low grazing pressure. In Simplified 3 states vegetation is mostly lacking an overstorey, has a depleted midstorey, but a reasonably intact understorey (Table 3).

How to restore:

Simplified 3 to Simplified 1

None of the pathways from Simplified 3 to Simplified 1 are considered likely. However, the transition is thought to be possible either through passive regeneration or active tree planting after low intensity ecological burns, or with fire suppression and grazing at low intensity (Figure 18).

Simplified 3 to Exemplar

None of the transitions between Simplified 3 and Exemplar were considered likely but the transition could be achieved with multiple interventions; by reinstating flood regimes (for floodplain woodlands), managing the weed cover and reinstating cool burns, and where relevant, managing herbivore pressure and either revegetating or allowing for passive regeneration (Figure 19).

How to stay the same:

To ensure that vegetation remains in Simplified 3 condition, managers should monitor to detect dense regrowth, declines in understorey diversity and increases in weed cover. If dense regrowth of woody species occurs, manual ecological thinning is recommended at the seedling stage. If understorey diversity is declining, it may be due to dominance of particular species or increases in weed cover, in which case management via biomass or weed control should be implemented.

Transitions to watch out for:

Simplified 3 to Overstorey Thicket

Vegetation in Simplified 3 condition can transition to Overstorey Thicket condition if revegetation efforts include planting trees at high density (without mortality). Alternatively, dense tree regeneration can occur with the presence of sufficient native propagules, following soil disturbance (i.e. ripping) or after a reduction in grazing pressure, typically with above average rainfall. In the case of Floodplain and Riparian woodlands, dense regeneration may be instigated by a flood event. Where dense regrowth is detected, ecological thinning is recommended at the seedling stage.

Simplified 3 to Overstorey and Midstorey Thicket

As above, vegetation in Simplified 3 condition can transition to Overstorey and Midstorey Thicket condition if revegetation efforts include planting shrubs and trees at high density. As with transitions to Overstorey Thicket state, this transition can also occur with the presence of sufficient native propagules, lowered grazing pressure and above average rainfall. In the case of Floodplain and Riparian woodlands, this may be instigated by a flood, but the transition is uncommon due to absence of the shrub layer (Figure 7). Where dense regrowth is detected, thinning is recommended at the seedling stage.

Simplified 3 to Simplified 4

Vegetation in Simplified 3 condition can transition to Simplified 4 condition due to heavy grazing pressure (either by stock or native and feral herbivores) and resultant degradation of biophysical processes. The transition may also occur due to prolonged drought or, in the case of Floodplain and Riparian woodlands, a flood that brings an abundance of exotic propagules. If grazing by native and feral herbivores is observed to be impeding recruitment and causing declines in understorey condition, culling or removing water points are recommended.

Simplified 4

Simplified 4 is considered common in Grassy woodlands and uncommon in Shrubby and Obligate Seeder and Floodplain and Riparian woodlands (Table 4). Grazed native pastures with no overstorey might fall into this state. It is typified by a depleted or absent overstorey; depleted or absent midstorey; and an understorey that is depleted in native species richness and cover (Table 3).

How to restore:

Simplified 4 to Simplified 2

None of the pathways from Simplified 4 and Simplified 2 are considered likely but it is possible to achieve the transition by removing grazing and revegetating the overstorey and, for Floodplain and Riparian woodlands and Shrubby and Obligate Seeder woodlands, revegetating the midstorey. Alternatively, in the presence of native propagules and sufficient rainfall, removing grazing may be sufficient to allow regeneration (Figure 20).

Simplified 4 to Simplified 1

Pathways between Simplified 4 and Simplified 1 are considered unlikely for all woodland types, but the transition can occur if grazing is removed, weed cover is managed via herbicide or cool burning (if relevant) and the vegetation is allowed to regenerate (if propagules are present) or replanted (Figure 21). If herbivores are acting to prevent understorey regeneration, grazing control (i..e culling, watering point removal) is required.

How to stay the same:

Vegetation is very likely to remain in a Simplified 4 state if existing land-use practices are retained (i.e. retain current level of grazing).

Transitions to watch out for:

Simplified 4 to Overstorey Thicket

As with Simplified 3 vegetation, vegetation in Simplified 4 condition can transition to Overstorey Thicket condition if revegetation efforts include planting trees at high density (without mortality). Alternatively, dense tree regeneration can occur with the presence of sufficient native propagules, following soil disturbance (i.e. ripping) or after a reduction in grazing pressure, typically with above average rainfall. In the case of Floodplain and Riparian woodlands, dense regeration may be instigated by a flood event. Where dense regrowth is detected, thinning is recommended at the seedling stage.

Simplified 4 to Overstorey and Midstorey Thicket

Vegetation in Simplfied 4 condition can transition to Overstorey and Midstorey Thicket condition if revegetation efforts include planting shrubs and trees at high density. As with transitions to Overstorey Thicket state, this transition can also occur with the presence of sufficient native propagules, lowered grazing pressure and above average rainfall. In the case of Floodplain and Riparian woodlands, this may be instigated by a flood, but the transition is uncommon due to absence of the shrub layer (Figure 7). Where dense regrowth is detected, thinning is recommended at the seedling stage.

Thicket

Overstorey Thicket vegetation is considered very uncommon in Shrubby and Obligate seeder woodlands, uncommon in Grassy woodlands and common Floodplain and Riparian woodlands (Table 4). It typically occurs in small isolated patches. Overstorey Thickets often occur in destocked pastures and are typified by an overly dense overstorey; very low understorey species richness, low under/mid storey cover; understorey may be dominated by natives of exotics; and possible compromised soil stability (Table 3).

How to restore:

Overstorey Thicket to Simplified 2

Overstorey Thickets can transition to Simplified 2 via ecological- or self-thinning and either passive regeneration (more common but only effective if native propagules are present) or revegetation of the under- and midstorey (Figure 17).

Overstorey Thicket to Simplified_1

None of the pathways between Overstorey Thicket and Simplified 1 condition are considered likely but the transition is possible by a combination of the ecological- or self-thinning and planting as described in Figure K in conjunction with weed control (Figure 18). Note that grassy woodlands are depicted separately here because they are not expected to have a significant midstorey and therefore do not require midstorey regeneration or revegetation.

How to stay the same:

Without active intervention vegetation is very likely to remain in the overstorey thicket state.

Transitions to watch out for:

Without active intervention no transitions are likely.

Overstorey and midstorey thicket

Overstorey and Midstorey Thicket vegetation is considered common in Grassy woodlands, and very uncommon in Shrubby, and Obligate seeder and Floodplain and Riparian woodlands. It often occurs as a result of dense planting or in response to release from grazing and increased rainfall or flood. It is distributed patchily in the landscape. It is typified by having 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; and a low native understorey richness.

How to restore:

Overstorey/Midstorey Thicket to Simplified 2

None of the pathways between Overstorey and Midstorey Thicket and Simplified 2 condition were considered likely. However, ecological- and self-thinning of the mid- and overstorey vegetation and revegetation of the understorey can facilitate this transition (Figure 24)

Overstorey/Midstorey Thicket to Simplified 1

None of the pathways between Overstorey and Midstorey Thicket and Simplified 1 condition were considered likely. However, the transition is possible through ecological- or self-thinning of mid- and overstorey and revegetation (as above) combined with weed control (Figure 25)

How to stay the same:

Without active intervention vegetation is very likely to remain in the overstorey thicket state.

Transitions to watch out for:

Without active intervention no transitions are likely.

Transformed

Transformed vegetation is considered very common in all woodland types (Table 4), and is typified by very low to no vegetation cover in the mid and understorey; overstorey absent or low, dead or dying, an absence of recruitment, saline, acidic, or highly nitrified soil (Table 3). Any transitions from this state are favourable so in this case we have highlighted the transitions that are most likely to be successful.

How to restore:

Transformed to Simplified 4

In this case all specified pathways between Transformed at Simplified 4 were considered likely (Figure 26). If soil nutrients are not substantially elevated, adequate grazing and cessation of current landuse along with either passive regeneration (if propagules are present) or revegetation can result in a transition from the Transformed to Simplified 4 state. Herbivore control may be required. If soil nutrients are elevated, crash-grazing may be necessary to remove some of the nutrients.

Transformed to Overstorey Thicket or Overstorey/Midstorey Thicket

The most likely pathway for Transformed vegetation to transition to Overstorey Thicket condition is by ceasing current landuse and revegetating with overstorey species (at high density). This transition may also occur if sufficient seed propagules are available, and with a flood (in the case of Floodplain woodlands). To transition to Overstorey and Midstorey Thicket condition, regeneration (or replanting at high density) of the midstorey is necessary (Figure 27).

Transformed (saline or acidic soils) to Novel Ecosystem

In cases where sites have become saline or highly acidic it may be impossible to restore any approximation of woodland vegetation in 100 years or longer. In this case, replanting with any (preferably native) species that are able to tolerate these conditions is recommended to attempt restoration of some ecosystem function.

Supplementary material - Part 2

S 2.1 Threshold values along with 95% confidence intervals for each of the top-3 variables selected in the CART analysis, for each pair of condition states in each woodland type from each dataset.

Vegetation Attribute Thresholds - Exemplar & Simplified 1

			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
Soil_C	Soil variable	3.48	1.75	7.78
perc_cwd	Ground cover - non plant	0.80	0.35	5.00
TERN Emrys - Floodplain				
perc_nat_shrub	Native shrub abundance	7.20	0.89	26.47
Eldridge - Grassy				
perc_nat_shrub	Native shrub abundance	5.45	1.26	10.91
P_ppm	Soil variable	344.84	252.28	411.35
rich_nat_und	Understorey richness/diversity	25.30	13.77	39.00
Rumpff - Grassy				
perc_nat_shrub	Native shrub abundance	7.90	2.77	20.59
Schultz - Grassy				
rich_nat_und	Understorey richness/diversity	39.85	29.25	47.12
perc_ex_us	Exotic understorey cover	1.79	0.00	8.91
TERN Emrys - Grassy				
rich_nat_und	Understorey richness/diversity	42.07	28.06	69.00
Standish et al. - Shrubby				
perc_ex_us	Exotic understorey cover	5.69	0.00	18.47
perc_nat_shrub	Native shrub abundance	10.88	2.92	32.80
perc_nat_us	Native understorey cover	95.29	19.71	164.85
TERN Emrys - Shrubby				
perc_ex_us	Exotic understorey cover	2.49	0.22	2.71
TERN Michael - Shrubby				
rich_nat_mid	Native shrub richness	19.50	12.51	35.98
rich_nat_und	Understorey richness/diversity	19.60	13.23	20.50

Vegetation Attribute Thresholds - Exemplar & Simplified 2

			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
rich_nat_mid	Native shrub richness	0.70	0.04	1.48
Tree_all_ha	Tree density	41.07	0.00	172.41
TERN Emrys - Floodplain				
perc_nat_us	Native understorey cover	8.17	2.67	21.44
rich_nat_mid	Native shrub richness	10.33	7.30	13.19
Eldridge - Grassy				
perc_ex_us	Exotic understorey cover	21.37	11.43	36.56
rich_nat_und	Understorey richness/diversity	32.00	25.14	39.00
Tree_large_ha	Tree density	28.01	1.96	51.91
Rumpff - Grassy				
perc_ex_us	Exotic understorey cover	32.27	0.08	47.52
perc_nat_us	Native understorey cover	67.63	37.82	77.78
Tree_midsize_ha	Tree density	30.48	0.00	74.58
Schultz - Grassy				
perc_ex_us	Exotic understorey cover	10.93	1.42	20.72
overstorey_cover	Tree density	8.30	3.52	12.78
herbaceous_groundstorey_cov	Native understorey cover	17.82	11.02	30.29
TERN Emrys - Grassy				
rich_nat_und	Understorey richness/diversity	47.80	30.83	68.00
rich_nat_mid	Native shrub richness	5.18	3.00	8.43

Vegetation Attribute Thresholds - Exemplar & Simplified 3				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
perc_nat_shrub	Native shrub abundance	2.21	0.72	2.88
perc_ex_us	Exotic understorey cover	44.04	30.08	80.95
perc_nat_us	Native understorey cover	54.81	24.42	68.46
Eldridge - Grassy				
perc_ex_us	Exotic understorey cover	27.80	21.97	29.36
perc_nat_us	Native understorey cover	72.03	70.21	78.47
Schultz - Grassy				
overstorey_cover	Tree density	1.32	1.00	6.12
perc_ex_us	Exotic understorey cover	13.86	5.74	37.99
herbaceous_groundstorey_cov	Native understorey cover	36.52	19.00	47.10

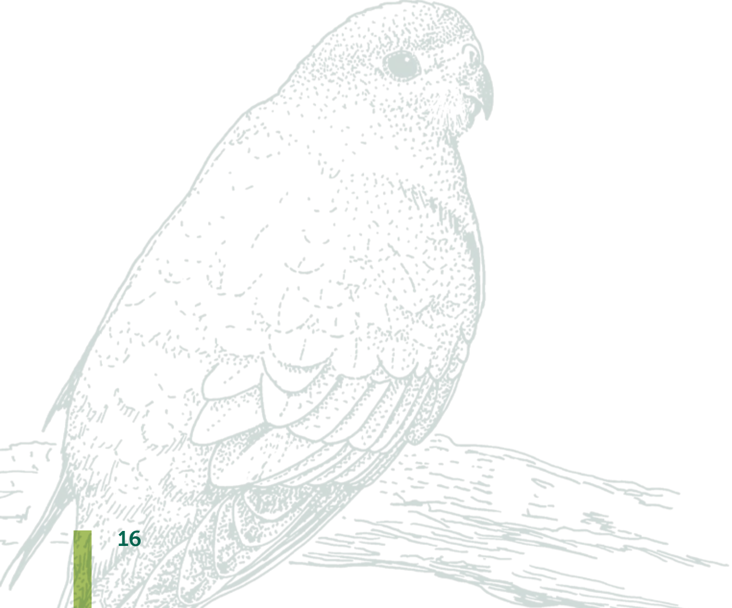
Vegetation Attribute Thresholds - Exemplar & Simplified 4

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Eldridge - Floodplain				
perc_ex_us	Exotic understorey cover	51.21	35.56	58.88
perc_nat_us	Native understorey cover	48.06	43.65	72.64
rich_nat_mid	Native shrub richness	0.47	0.00	1.36
Rumpff - Grassy				
Tree_all_ha	Tree density	301.58	63.36	1,441.27
Tree_saplings_ha	Tree density	110.05	6.46	583.06
perc_nat_shrub	Native shrub abundance	0.86	0.00	2.41
Schultz - Grassy				
perc_ex_us	Exotic understorey cover	6.59	3.00	9.55
perc_litter	Ground cover - non plant	14.17	9.81	22.50

Vegetation Attribute Thresholds - Exemplar & Overstorey midstorey thicket

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Rumpff - Grassy				
rich_nat_und	Understorey richness/diversity	13.31	4.00	19.11

Vegetation Attribute Thresholds - Exemplar & Transformed				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
perc_ex_us	Exotic understorey cover	47.42	0.00	77.30
Tree_all_ha	Tree density	486.73	95.98	2,340.00
perc_nat_us	Native understorey cover	32.58	7.63	90.00
Standish et al. - Shrubby				
rich_nat_und	Understorey richness/diversity	10.31	8.74	13.52
perc_ex_us	Exotic understorey cover	20.71	10.56	35.11
perc_nat_shrub	Native shrub abundance	8.23	3.27	17.81



Vegetation Attribute Thresholds - Simplified 1 & Simplified 2				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
rich_nat_und	Understorey richness/diversity	19.54	19.32	33.28
Tree_all_ha	Tree density	35.70	4.72	292.54
Jones et al - Floodplain				
perc_nat_us	Native understorey cover	15.13	12.66	20.84
perc_ex_us	Exotic understorey cover	3.92	1.86	5.83
RICHNESS_NAT_28TARG	Understorey richness/diversity	11.27	10.26	13.11
TERN Emrys - Floodplain				
perc_nat_us	Native understorey cover	6.60	2.67	21.29
Tree_all_ha	Tree density	55.74	47.53	75.04
perc_nat_shrub	Native shrub abundance	5.00	0.83	15.44
Eldridge - Grassy				
perc_ex_us	Exotic understorey cover	15.45	12.96	32.38
perc_nat_us	Native understorey cover	83.81	67.57	85.27
Rumpff - Grassy				
rich_nat_mid	Native shrub richness	4.68	1.85	9.69
perc_ex_us	Exotic understorey cover	65.48	47.52	96.99
Tree_large_ha	Tree density	35.21	19.50	66.45
Schultz - Grassy				
perc_ex_us	Exotic understorey cover	19.59	10.57	36.83
perc_nat_us	Native understorey cover	31.92	21.07	56.09
herbaceous_groundstorey_cov	Native understorey cover	25.13	13.16	81.30
TERN Emrys - Grassy				
rich_nat_mid	Native shrub richness	8.14	3.00	18.00

Vegetation Attribute Thresholds - Simplified 1 & Simplified 3

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Eldridge - Floodplain				
rich_nat_und	Understorey richness/diversity	21.85	14.00	35.58
perc_ex_us	Exotic understorey cover	53.86	31.01	56.32
perc_nat_shrub	Native shrub abundance	0.66	0.04	2.00
Jones et al - Floodplain				
Tree_midsize_ha	Tree density	0.00	0.00	0.21
perc_bare	Ground cover - non plant	22.39	17.16	28.61
Eldridge - Grassy				
rich_nat_und	Understorey richness/diversity	31.91	24.82	32.96
Schultz - Grassy				
perc_litter	Ground cover - non plant	0.27	0.25	7.63
rich_nat_und	Understorey richness/diversity	19.15	12.00	27.03

Vegetation Attribute Thresholds - Simplified 1 & Simplified 4

			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
perc_ex_us	Exotic understorey cover	59.16	34.37	72.73
perc_nat_us	Native understorey cover	40.00	27.27	57.36
perc_litter	Ground cover - non plant	2.56	1.36	13.74
Jones et al - Floodplain				
RICHNESS_NAT_28TARG	Understorey richness/diversity	8.15	7.04	9.03
perc_ex_us	Exotic understorey cover	10.55	7.97	14.97
perc_bare	Ground cover - non plant	17.40	12.88	26.08
Rumpff - Grassy				
Tree_all_ha	Tree density	11.49	0.00	95.16
rich_nat_und	Understorey richness/diversity	16.09	9.77	23.00
Schultz - Grassy				
perc_ex_us	Exotic understorey cover	8.98	4.42	13.76
perc_litter	Ground cover - non plant	13.39	9.84	18.61

Vegetation Attribute Thresholds - Overstorey midstorey thicket & Simplified 1

			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
rich_nat_und	Understorey richness/diversity	14.61	9.25	17.97

Vegetation Attribute Thresholds - Simplified 1 & Thicket

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Rumpff - Grassy				
Tree_all_ha	Tree density	1,857.31	1,156.87	3,079.63
Tree_saplings_ha	Tree density	898.00	518.11	1,536.74
perc_ex_us	Exotic understorey cover	15.96	7.63	26.32

Vegetation Attribute Thresholds - Simplified 1 & Transformed

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Rumpff - Grassy				
perc_nat_us	Native understorey cover	9.52	0.00	19.96
perc_ex_us	Exotic understorey cover	86.07	67.33	134.00
Standish et al. - Shrubby				
perc_ex_us	Exotic understorey cover	36.24	21.24	56.03
Tree_all_ha	Tree density	0.95	0.50	1.42
rich_nat_und	Understorey richness/diversity	9.56	7.96	12.08

Vegetation Attribute Thresholds - Simplified 2 & Simplified 3

Vegetation Attribute Variable	Attribute Category	Threshold Value	95% CI Lower	95% CI Upper
Jones et al - Floodplain				
perc_nat_us	Native understorey cover	23.58	18.17	28.54
Eldridge - Grassy				
Soil_ECEC	Soil variable	3.04	2.46	3.15

Vegetation Attribute Thresholds - Simplified 2 & Simplified 4				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
perc_litter	Ground cover - non plant	5.23	1.62	12.21
Soil_C	Soil variable	5.30	4.67	5.54
Jones et al - Floodplain				
Tree_midsize_ha	Tree density	0.04	0.00	0.19
Tree_all_ha	Tree density	2.38	1.05	3.45
Eldridge - Grassy				
rich_nat_und	Understorey richness/diversity	34.73	32.84	35.36
perc_bare	Ground cover - non plant	47.72	42.23	51.18
Rumpff - Grassy				
Tree_midsize_ha	Tree density	32.21	0.87	70.60
Tree_all_ha	Tree density	165.85	28.56	349.85
Tree_recruit_ha	Tree density	1.42	0.00	30.57
Schultz - Grassy				
perc_litter	Ground cover - non plant	14.97	9.43	33.25
Diversity	Understorey richness/diversity	67.63	59.98	77.00

Vegetation Attribute Thresholds - Overstorey midstorey thicket & Simplified 2				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
TERN Emrys - Floodplain				
Tree_all_ha	Tree density	36.23	35.97	54.46
Rumpff - Grassy				
perc_nat_shrub	Native shrub abundance	3.13	1.78	10.37

Vegetation Attribute Thresholds - Simplified 2 & Thicket				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
perc_ex_us	Exotic understorey cover	37.83	20.27	51.48
Tree_all_ha	Tree density	2,332.88	1,374.68	3,935.71
Tree_saplings_ha	Tree density	1,038.96	518.11	1,848.56

Vegetation Attribute Thresholds - Simplified 2 & Transformed				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
Tree_large_ha	Tree density	14.01	0.00	37.38
Tree_all_ha	Tree density	207.81	16.06	456.95
Tree_midsize_ha	Tree density	40.73	0.22	91.58

Vegetation Attribute Thresholds - Simplified 3 & Simplified 4				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Eldridge - Floodplain				
perc_ex_us	Exotic understorey cover	64.53	43.80	70.97
Good et al - Floodplain				
perc_bare	Ground cover - non plant	49.46	48.21	49.91
perc_litter	Ground cover - non plant	8.17	6.76	10.14
Soil_C	Soil variable	1.18	0.98	1.42
Soil_N	Soil variable	0.11	0.10	0.14
Soil_pH	Soil variable	6.99	6.74	7.10
Jones et al - Floodplain				
perc_nat_us	Native understorey cover	16.24	11.22	28.54
perc_ex_us	Exotic understorey cover	5.30	1.23	10.19
Schultz - Grassy				
perc_crypto	Ground cover - non plant	6.74	1.95	8.00
perc_litter	Ground cover - non plant	40.77	18.03	45.00

Vegetation Attribute Thresholds - Overstorey midstorey thicket & Simplified 4				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
perc_nat_shrub	Native shrub abundance	1.35	0.20	2.42
rich_nat_und	Understorey richness/diversity	14.41	3.00	20.82

Vegetation Attribute Thresholds - Simplified 4 & Thicket				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
Tree_all_ha	Tree density	517.18	80.12	9,344.66
Tree_saplings_ha	Tree density	224.26	14.39	1,536.74
Tree_recruit_ha	Tree density	28.23	0.00	92.61

Vegetation Attribute Thresholds - Overstorey midstorey thicket & Thicket				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
rich_nat_mid	Native shrub richness	11.76	10.79	13.52
perc_ex_us	Exotic understorey cover	41.02	21.61	76.75
Tree_all_ha	Tree density	1,436.07	157.03	3,079.63
Tree_saplings_ha	Tree density	680.03	39.98	1,439.19

Vegetation Attribute Thresholds - Simplified 4 & Transformed				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
rich_nat_und	Understorey richness/diversity	10.55	5.05	12.40
perc_ex_us	Exotic understorey cover	65.92	26.89	134.00
perc_nat_us	Native understorey cover	26.52	6.37	85.69

Vegetation Attribute Thresholds - Thicket & Transformed				
			95% CI	
Vegetation Attribute Variable	Attribute Category	Threshold Value	Lower	Upper
Rumpff - Grassy				
perc_ex_us	Exotic understorey cover	54.26	53.68	60.31
Tree_all_ha	Tree density	804.24	205.10	2,695.08
Tree_saplings_ha	Tree density	327.48	57.57	1,165.75

Supplementary material - Part 3

S 3.1: Screenshots of parts one and two of the survey where participants were asked to suggest habitat attributes and indicator groups or species of fauna (part one) and then in part two, threats and management interventions relevant to each condition state.

	Possible habitat indicators	Possible indicator species or groups	Comments / faunal group
Exemplar			
Simplified 1			
Simplified 2			
Simplified 3			
Simplified 4			
Overstorey and midstorey thicket			
Thicket			
Transformed			

In this section, suggest some threats or management interventions (positive drivers) which might be relevant for fauna in each condition state. For example a common threat facing Exemplar sites is clearing and weed invasions (from a vegetation perspective). But perhaps firewood collection might pose a bigger threat to certain fauna groups. You can leave fields blank and don't be afraid of repetition.

	Possible threats (leading to degradation)	Possible management interventions to maintain or restore
Exemplar		
Simplified 1		
Simplified 2		
Simplified 3		
Simplified 4		
Overstorey and midstorey thicket		
Thicket		
Transformed		

S3.2 All indicator species mentioned by fauna experts in the survey.

All indicator species and groups								
Fauna_group	Exemplar	Simplified 1	Simplified 2	Simplified 3	Simplified 4	OMST	Thicket	Transformed
birds	Cuckoos, Treecreepers, Robins, Robins, flycatchers, treecreepers, nightjars, finches, owls, Hooded robin, Diamond firetail, Painted honeyeater, Bush-stone curlew, Brown treecreeper, Grey crowned babbler, Regent honeyeater, woodswallows, babblers, varied sittella, more than 3 species of honeyeater, woodland bird community index (Fraser 2019), functional groups listed in conservation action plan for woodland birds, pouncers, predators, bark gleaners, nectar sippers, hooded robin, varied sittella, brown treecreeper, diamond firetail, heathwren, tawny crowned honeyeater, beautiful firetail, bassian thrush, diverse and abundant hollow dependant birds (owls, parrots), diverse bird community (including declining woodland birds)	painted button quail, grey crowned babbler, red browed finch, restless flycatcher, leaden flycatcher, noisy miner, Robins, mistletoe bird, treecreepers, cuckoos, whistlers, more than 3 species of thornbills, babblers, varied sittella, woodswallows, Presence of 'degraded' woodland species (fraser et al), red capped robin, jacky winter, brown treecreeper, restless flycatcher, diverse and abundant hollow dependant birds (owls, parrots), diverse bird community (including declining woodland birds)	honeyeaters, kookaburra, noisy miner, Parrots, all species, mistletoe bird, Pardalotes, honeyeaters, noisy miner, thornbills, Presence of 'degraded' woodland species (fraser et al), striated pardalote, weebill, larger honeyeaters, noisy miner	red rumped parrot, painted button quail, crested pigeon, Australian magpie, Magpie lark, White winged Chough, Corella, Sulphur crested cockatoo, noisy miner, Presence of 'degraded' woodland species (fraser et al), songlark, southern whiteface, Australian magpie	Absence of birds, Australian magpie, other trash birds, starlings, mynas, sparrows, feral pigeon, Presence of 'degraded' woodland species (fraser et al), Australian magpie	new holland honeyeater, thornbills, Superb fairy-wren, white browed scrub wren, noisy miner, white browed babbler, white fronted chat	thornbills, treecreepers, Superb fairy-wren, whistlers, white browed scrub wren, thornbills, common blackbird, noisy miner, pardalotes, thornbills, honeyeaters	Absence of birds, Australian magpie, other trash birds, starlings, mynas, sparrows, Presence of 'degraded' woodland species (fraser et al), Australian magpie
Reptiles or amphibians	geckos, monitors, legless lizards, blind snakes, Aprasia, whip snakes	geckos, dragons, legless lizards, blind snakes, Aprasia, Suta suta, Parasuta dwyerii	dragons, legless lizards, Aprasia, Suta suta, Parasuta dwyerii	common skink species, common snake species	common skink species, common snake species			Boulenger skink, pest species, Eastern brown snake

aboreal mammals	feral pigeon, brush tailed phascogale, koala, agile antechinus, gliders, microbats, presence of large owls (indicates food source of aboreal mammals)	gliders, koala, microbats, ringtail possum, common brush tail possum	ringtail possum, common brush tail possum	ringtail possum, common brush tail possum	all aboreal mammals absent	ringtail possum	ringtail possum	all aboreal mammals absent
invertebrates	habitat specialist species covering a range of niches, specialist species with ecological dependencies and narrow trophic specialist, diverse litter fauna, species sensitive to dessication, short range endemic spider groups, native millipedes, land snails, rich and mostly native invertebrate fauna	habitat specialist species with ecological dependencies, narrow trophic specialist species, diverse litter fauna, species sensitive to dessication, short range endemic spider groups, native millipedes, land snails, lacking specied specialised on native vegetation	habitat specialist species covering a range of niches, specialist species with ecological dependencies and narrow trophic specialist, lacking specied specialised on native vegetation, exotic generalist species, species associated with weeds, diverse litter fauna, species sensitive to dessication, native millipedes, short range endemic spider groups, land snails	specialists to open habitats	specialists to open habitats, generalist species associated with exotic groundcover and variable abiotic conditions, exotic species associated with exotic groundcover and variable abiotic conditions	habitat generalists, species associated with exotic ground cover, exotic species, some habitat specialists, absence of dessication sensitive species	habitat generalists with broad physiological tolerance and low sensitivity to dessication, broad trophic niche groups, exotic species, relatively diverse leaf litter fauna	habitat generalists with broad physiological tolerance and low sensitivity to dessication, broad trophic niche groups, exotic species
mammals	mammals (bats, possums)	mammals (bats, possums)						
various	abundance and diversity of animal species with important ecological function (nectarivores, frugivores, seed dispersers, burrowers etc)		abundance of miners (and reciprocally reduced abundance and diversity of woodland birds), abundance of suite of invertebrates that contribute to dieback	hollow dependant animals	proportion of non-native animals across taxonomic groups, low diversity of most animal groups, no hollow-dependent animals, high proportion of non-native animals	poor representation of successional breadth in animal assemblages, low diversity of most animal groups, some hollow-dependent animals	non-diverse bird community (few declining woodland birds), low abundance and diversity of animal species with important ecological function (nectarivores, frugivores, seed dispersers, burrowers etc), low diversity of most animal groups, no hollow dependent animals	low diversity of most animal groups, no hollow dependent animals, high proportion of non-native animals

S3.3: The agenda for the virtual fauna expert workshop.

Agenda

Time	Item
9:30am	Acknowledgement of Country Introductions Outline and aims for the day Housekeeping – breaks, format of discussions, other
9:50	Background to project: How did we get to this point?
10:15	The states - Do these states make sense for fauna? What needs to change? - Group discussion
10:45	*Break*
11:00	Threats and Drivers - Results from fauna survey – what's different? - Task: Updating a decision tree(s) for the woodlands guide
12:45	*Lunch*
1:15	- What we heard from you about how this works for fauna - Task: Is the approach we used broken, or how would you alter it to accommodate multiple values? Groups - Report back
2:45	Next steps
3pm	*Finish*

Further information:

http://www.nespthreatenedspecies.edu.au

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Threatened Species Recovery Hub

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